GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

THERMAL ENGINEERING-I

3RD SEMESTER

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Course outcomes

At the end of the course students will be able to:

CO	Statement
C3T4.1	Apply knowledge of basic thermodynamic properties and terminologies to analyze a thermodynamic system.
C3T4.2	Apply the laws of thermodynamic and their significance in the field of energy conversation and utilization.
C3T4.3	Analyze I.C engine and Gas power cycles workdone and efficiencies and their modern updation in engineering.

Chapter-1

Thermodynamic concept & Terminology

INTRODUCTION:

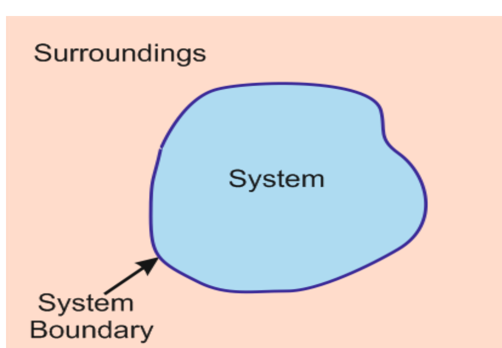
- Thermodynamics is the science that deals with heat and work and those properties of substance that bear a relation to heat and work.
- Thermodynamics is the study of the patterns of energy change. Most of this course will be concerned with understanding the patterns of energy change.
- More specifically, thermodynamics deals with (a) energy conversion and (b) the direction of change.

  Basis of thermodynamics is experimental observation. In that sense it is an empirical science. The principles of thermodynamics are summarized in the form of four laws known as zeroth, first, second, and the third laws of thermodynamics.
- Thermodynamics comes from two greek words Thermi & Dynamic. Thermi means heat & dynamic means power or work by motion.

Macroscopic and Microscopic Approaches:

- Microscopic approach uses the statistical considerations and probability theory, where we deal with "average" for all particles under consideration. This is the approach used in the disciplines known as kinetic theory and statistical mechanics.
- In the macroscopic point of view, of classical thermodynamics, one is concerned with the time-averaged influence of many molecules that can be perceived by the senses and measured by the instruments. The pressure exerted by a gas is an example of this. It results from the change in momentum of the molecules, as they collide with the wall. Here we are not concerned with the actions of individual molecules but with the time-averaged force on a given area that can be measured by a pressure gage.
- From the macroscopic point of view, we are always concerned with volumes that are very large compared to molecular dimensions, and therefore a system contains many molecules, and this is called continuum. The concept of continuum loses validity when the mean free path of molecules approaches the order of typical system dimensions.

Thermodynamic systems:



A Thermodynamic system is defined as the fixed mass or fixed region in space upon which our study is focused. A specified region in a space upon which attention is focused for thermodynamic analysis is known as a system.

We introduce boundaries in our study called the system and surroundings. The boundaries are set up in a way most conducive to understanding the energetics of what we're studying. Defining the system and surroundings is arbitrary, but it becomes important when we consider the exchange of energy between the system and surroundings.

Surroundings: Everything external to the system is called Surrounding.

Boundary: It is a real or imaginary surface which separates system from the surroundings. A boundary can be fixed or movable. A boundary has no thickness, no mass and no volume.

Two types of exchange can occur between system and surroundings:

(1) energy exchange (heat, work, friction, radiation, etc.) and,

(2) matter exchange (movement of molecules across the boundary of the system and surroundings).

Based on the types of exchange which take place or don't take place, we will define three types of systems:

- **isolated systems**: no exchange of matter or energy.
- **closed systems**: no exchange of matter but some exchange of energy.
- **open systems**: exchange of both matter and energy.

Thermodynamic Property :

In thermodynamics a property is any characteristic of a system that is associated with the energy and can be quantitatively evaluated.

- The property of a system should have a definite value when the system is in a particular state.
- Thermodynamic property is a point function.
- Properties like volume of a system that depend on the mass of a system are called extensive properties.
- Properties like pressure or temperature which do not depend on the system mass are called intensive properties.
- The ratio of extensive property to the mass of the system are called specific properties and therefore become intensive properties.
- Substance can be found in three states of physical aggregation namely, solid, liquid and vapor which are called its phases.
- If the system consists of mixture of different phases, the phases are separated from each other by phase boundary.
- The thermodynamic properties change abruptly at the phase boundary, even though the intensive properties like temperature and pressure are identical.

Pressure (p):

A fluid exerts on a surface element dS of a wall a force of pressure perpendicular to dS, directed outwards with a norm equal to p dS, where by definition p is the pressure of the fluid.

The force of pressure, which is a force, a vector quantity the SI unit of which is the Newton, should not be confused with the pressure, a scalar quantity whose **SI unit is the Pascal(N/M^2)**. At thermodynamic equilibrium, the system must specifically be at mechanical equilibrium.

Temperature (T):

Temperature is a measure of the average kinetic energy of the atoms or molecules in the system. The unit of measurement in the International System of Units (SI) is the kelvin. Kelvin is, therefore, the unit used by scientists. It is frequent to see it referenced as a **Kelvin degree**.

The basic units (SI Units)

- Mass----kg.
- Mole----The mole is the amount of substance that contains as many atoms (or molecules) as there are atoms in 0.012 kg of carbon-12.
- Length—m.
- Time: second (s)
- SI unit of temperature is Kelvin (abbreviated as K). The Kelvin is defined as the fraction of 1/273.16 of the thermodynamic temperature of the triple point of water. The relation between Kelvin and Celsius temperature is K = C + 273.15 (The triple point of water is at 0.01 C).
- Force: 1 N = 1 kg m/s,
- Pressure, 1 Pa = 1 N/m^2 , 1 bar = 10^5 Pa, 1 atm. = 101.325 KPa.= 760 mm of HG
  In thermodynamics we are concerned with absolute pressure.
  Gauge pressure = absolute pressure – atmospheric pressure.
  Ordinary vacuum gauge pressure = atmospheric pressure – absolute pressure.

Volume (V):

The volume of a thermodynamic system typically refers to the volume of the working fluid, such as, for example, the fluid within a piston. Changes to this volume may be made through an application of work, or may be used to produce work. **SI unit of volume is M^3.**

Internal Energy :

• The molecule as a whole can move in x, y and z directions with respective components of velocities and hence possesses kinetic energy.

• There can be rotation of molecule about its center of mass and than the kinetic energy associated with rotation is called rotational energy.

• In addition the bond length undergoes change and the energy associated with it is called vibrational energy.

• The electron move around the nucleus and they possess a certain energy that is called electron energy.

• The microscopic modes of energy are due to the internal structure of the matter and hence sum of all microscopic modes of energy is called the internal energy.

Bulk kinetic energy (KE) and potential energy (PE) are considered separately and the other energy of control mass as a single property (U).

The total energy possessed by the body is given by:

E = KE + PE + U

Intensive & Extensive properties:

- An intensive property is one that does not depend on the mass of the substance or system.
- Temperature (T), pressure (P) and density (r) are examples of intensive properties.

Intensive Property Examples;

The properties of matter that do not depend on the size or quantity of matter in any way are referred to as an intensive property of matter. Temperatures, density, color, melting and boiling point, etc., all are intensive property as they will not change with a change in size or quantity of matter. The density of 1 liter of water or 100 liters of water will remain the same as it is an intensive property.

- An extensive property of a system depends on the system size or the amount of matter in the system.

If the value of the property of a system is equal to the sum of the values for the parts of the system then such a property is called extensive property. Volume, energy, and mass are examples of extensive properties.

Extensive Property Examples;

There are properties such as length, mass, volume, weight, etc. that depend on the quantity or size of the matter, these properties are called an extensive property of matter and their value changes if the size or quantity of matter changes. Suppose we have two boxes made up of the same material, one has a capacity of four litres while the other has a capacity of ten litres. The box with ten litres capacity will have more amount of matter as compared to that of a four-liter box.

Extensive property	Symbol	SI units	Intensive property	Symbol	SI units
Volume	*V*	m^3 *or L*	*Specific volume*	*v*	*m3/kg or L/kg*
Internal energy	*U*	*J*	*Specific internal energy*	*u*	*J/kg*
Entropy	*S*	*J/K*	*Specific entropy*	*s*	*J/(kg·K)*
Enthalpy	*H*	*J*	*Specific enthalpy*	*h*	*J/kg*
Gibbs free energy	*G*	*J*	*Specific Gibbs free energy*	*g*	*J/kg*
Heat capacity at constant volume	C_V	*J/K*	*Specific heat capacity at constant volume*	c_v	*J/(kg·K)*
Heat capacity at constant pressure	C_P	*J/K*	*Specific heat capacity at constant pressure*	c_p	*J/(kg·K)*

Specific properties derived from extensive properties

Thermodynamic process:

A process is path followed by a system in reaching a given final state of equilibrium state starting from a specified initial state.

An actual process occurs only when the equilibrium state does not exist.

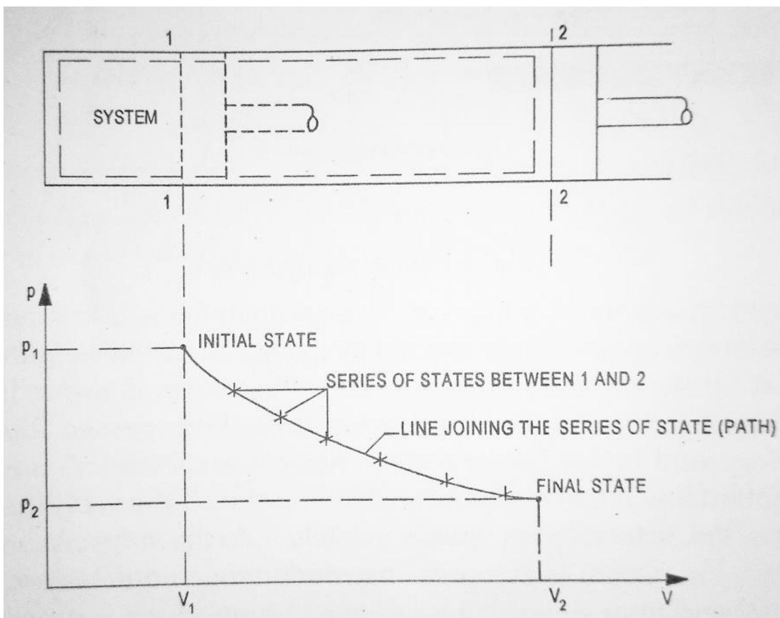
An ideal process can be defined in which the deviation from thermodynamic equilibrium is infinitesimal. All the states the system passes through during a quasi-equilibrium process may be considered equilibrium states.

For non-equilibrium processes, we are limited to a description of the system before the process occurs and after the equilibrium is restored.

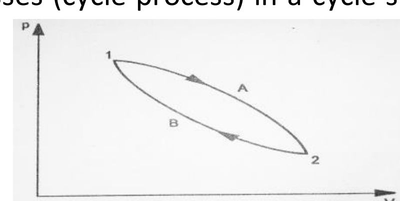
- A process is said to be reversible if both the system and its surroundings can be restored to their respective initial states by reversing the direction of the process.

- **reversible:** if the process happens slow enough to be reversed.
  irreversible: if the process cannot be reversed (like most processes).
- **isobaric**: process done at constant pressure
- **isochoric:** process done at constant volume
- **isothermal:** process done at constant temperature
- **adiabatic**: process where heat transfer is zero.(q=0)
- **cyclic:** process where initial state = final state

Thermodynamic State: A system is said to be exist in a definite state if all the properties of the system (*pressure, temperature, volume etc,*) have fixed values. If any one of the property changes, the system changes to another state.
Example: At 1 atm pressure and 10 degree centigrade water is in solid state (mixed state)
At 1 atm pressure and 110 degree centigrade it is vapour state.
Thermodynamic Path: The series of states passed through by the system during a change from one equilibrium state to another. Change of state of a system is the consequence of any operation in which properties will change. The series of states through which system passes during a change of state is called the path of the process.



Thermodynamic Cycle: Thermodynamics cycle is a process in which initial and final conditions are same. A thermodynamic cycle is defined as a series of process such that the system returns to its initial state. Thus the series of processes (cycle process) in a cycle starts and ends at the same state of a system.



(Figure illustrate the cycle comprising two processes A and B.)

Path function:

A Path function is a function whose value depends on the path followed by the thermodynamic process irrespective of the initial and final states of the process.

An example of path function is work done in a thermodynamic process.

- Work done in a thermodynamic process is dependent on the path followed by the process.
- A path function is an inexact or imperfect differential.

Point function:

A Point function (also known as state function) is a function whose value depends on the final and initial states of the thermodynamic process, irrespective of the path followed by the process.

- Example of point functions are density, enthalpy, internal energy, entropy etc.
- A point function is a property of the system or we can say all the properties of the system are point functions.
- Point functions are exact or perfect differential.

Note: Since a point function is only dependent on the initial or final state of the system, hence in a cyclic process value of a thermodynamic function is zero, or change in thermodynamic property is zero.

Difference between point function and path function:

Sr. no.	**Point Function**	**Path Function**
1	Its values are based on the state of the system (i.e. pressure, volume, temperature etc.)	Its values are based on how that particular thermodynamic state is achieved.
2	No matter by which process the state is obtained, its values will always remain the same.	Different processes to obtain a particular state will give us different values.

3	Only initial and final states of the process are sufficient	We need to know exact path followed by the process
4	Its values are independent of the path followed	Its values are dependent on the path followed
5	It is an exact or perfect differential	It is an inexact or imperfect differential.
6	Its cyclic integral is always zero	Its cyclic integral may or may not be zero
7	It is property of the system	It is not the property of the system
8	Its examples are density, enthalpy, internal energy, entropy etc	Its examples are Heat, work etc.

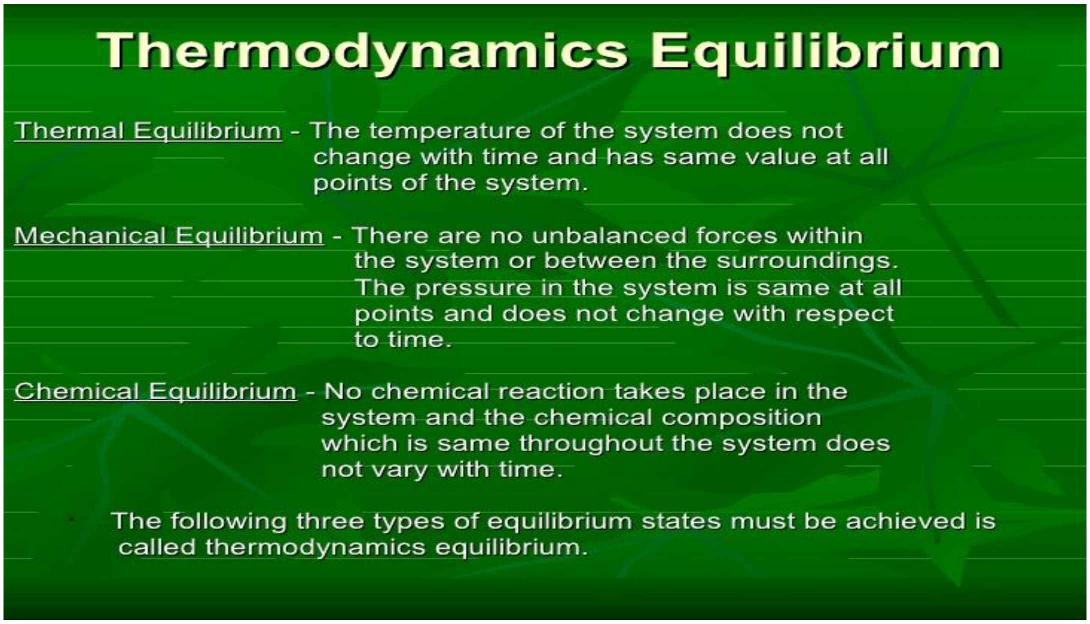
Thermodynamic equilibrium:

The system is said to be thermodynamic equilibrium when there is no spontaneous change in any macroscopic property is observed, as the system is isolated from its surroundings is known as thermodynamic Equilibrium.

When the property of a system is defined, it is understood that the system is in equilibrium.

• If a system is in thermal equilibrium, the temperature will be same throughout the system.

• If a system is in mechanical equilibrium, there is no tendency for the pressure to change. In a single phase system, if the concentration is uniform and there is no tendency for mass transfer or diffusion, the system is said to be in chemical equilibrium.



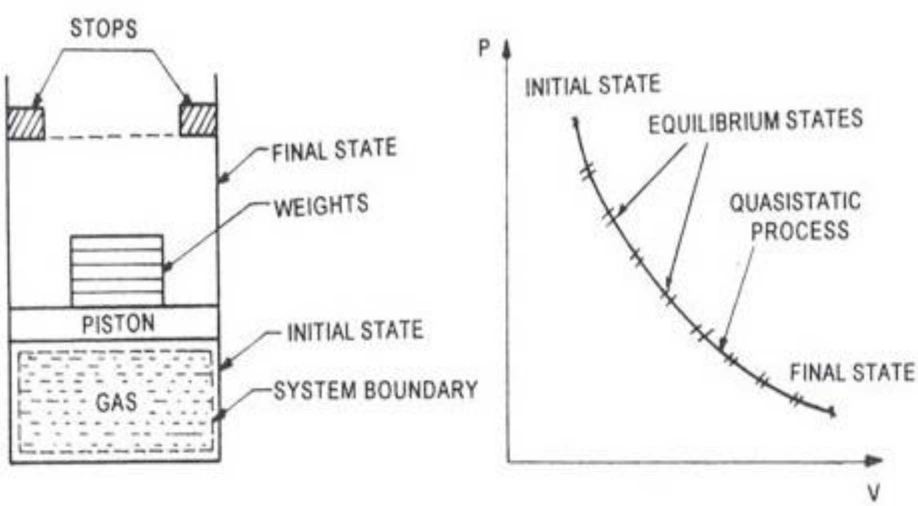
Quasi-static process:

When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times: Quasi-static or Quasi-equilibrium process

• The process proceeds slow enough to allow the system to the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts.

Engineers are interested in quasi-static processes because – they are easy to analyse – work-producing devices deliver maximum work when they operate on quasi-static processes

• Quasi-static processes serve as standards to which actual processes can be compared.



(Fig. Quasi-static process)

- The quasi-static or quasi-equilibrium process is also known as reversible process. A process which can be reversed in direction and the system retraces the same equilibrium states is known as reversible process.

Energy:

Energy possesses the ability to produce a dynamic, vital effect. Energy exists in various forms. e.g. mechanical, thermal, electrical etc. One form of energy can transform to other by suitable arrangements.

SOURCES OF ENERGY:

The various sources of energy are:

- Fuels- I. Solids-Coal,Coke, Anthracite etc.
  2. Liquids-Petroleum and its derivates
  3. Gases-Natural gas, blast furnace gas etc
- Energy stored in water
- Nuclear energy
- Wind energy
- Solar energy
- Tidal energy
- Geothermal energy
- Thermoelectric power

Power:

Any Physical unit of energy when divided by a unit of time automatically becomes a unit of power. Power can be defined as rate of flow of energy and can state that a power plant is a unit built for production and delivery of flow of mechanical and electrical energy. With the advancement of technology the power consumption is rising steadily.

This necessitates that in addition to the existing source of power such as coal, water, petroleum etc. other source of energy should be searched out and new and more efficient ways of producing energy should be decided.

Work:

The work is said to be done by a force when it acts on a body moving in the direction of force.

Whenever a system interacts with its surroundings, it can exchange energy in two wayswork and heat.

In mechanics, work is defined as the product of the force and the displacement in the direction of the force.

Work done when a volume is increased or decreased Consider a gas in a container with a movable piston on top. If the gas expands, the piston moves out and work is done by the system on the surroundings.

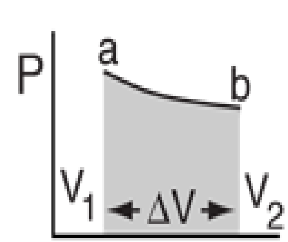
To calculate the work done in moving the piston,

- we know that the**, force = pressure x area** and then,
  work = pressure x area timex distance or, **work = pressure x change in volume**.
  So, $W = \int p\, dV$
- The differential work done (dW) associated with a differential displacement (dl) is given by
  $dW = F\,.dl$
- For a piston cylinder assembly, $dW = F\, dl = PA\, (dl) = P\, dV$
- If the gas is allowed to expand reversibly from the initial pressure P to final pressure P, then the work done is given by $W = \int p\, dV$

The integral represents the area under the curve on a pressure versus volume diagram. Therefore the work depends on the path followed and work is a path function and hence not a property of the system.
• The above expression does not represent work in the case of an irreversible process.
• The thermodynamic definition of work is *" Work is said to be done by a system on the surrounding if the sole effect external to the system could be reduced to the raising of a mass through a distance".*

The integral expression gives the exact area under the curve which is equal to the work.

$$W = \int_{V_1}^{V_2} P\,dV$$



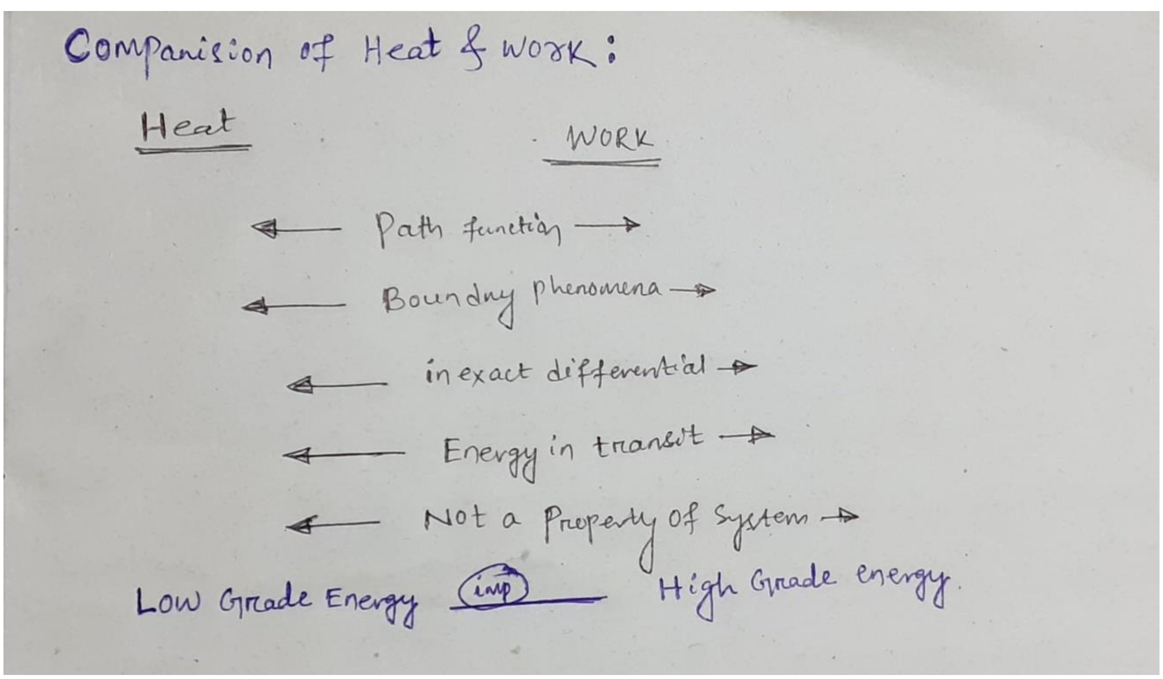
Heat:

Heat is the mode of energy transfer which takes place by virtue of temperature difference. The direction of spontaneous heat transfer is always from higher temperature to lower temperature. The mode of heat transfer may be in conduction, convection and radiation.

Heat like work, is energy in transit and it can be identified only at the boundary of the system.

- Heat is not stored in the body but energy is stored in the body.
- Heat, like work is not aproperty of the systemand hence it is not an exact differential.
- Thus heat is also a path function and notpoint function.

Comparision of heat and work:



Comparision of Heat & work:

Heat ← → WORK

← Path function →

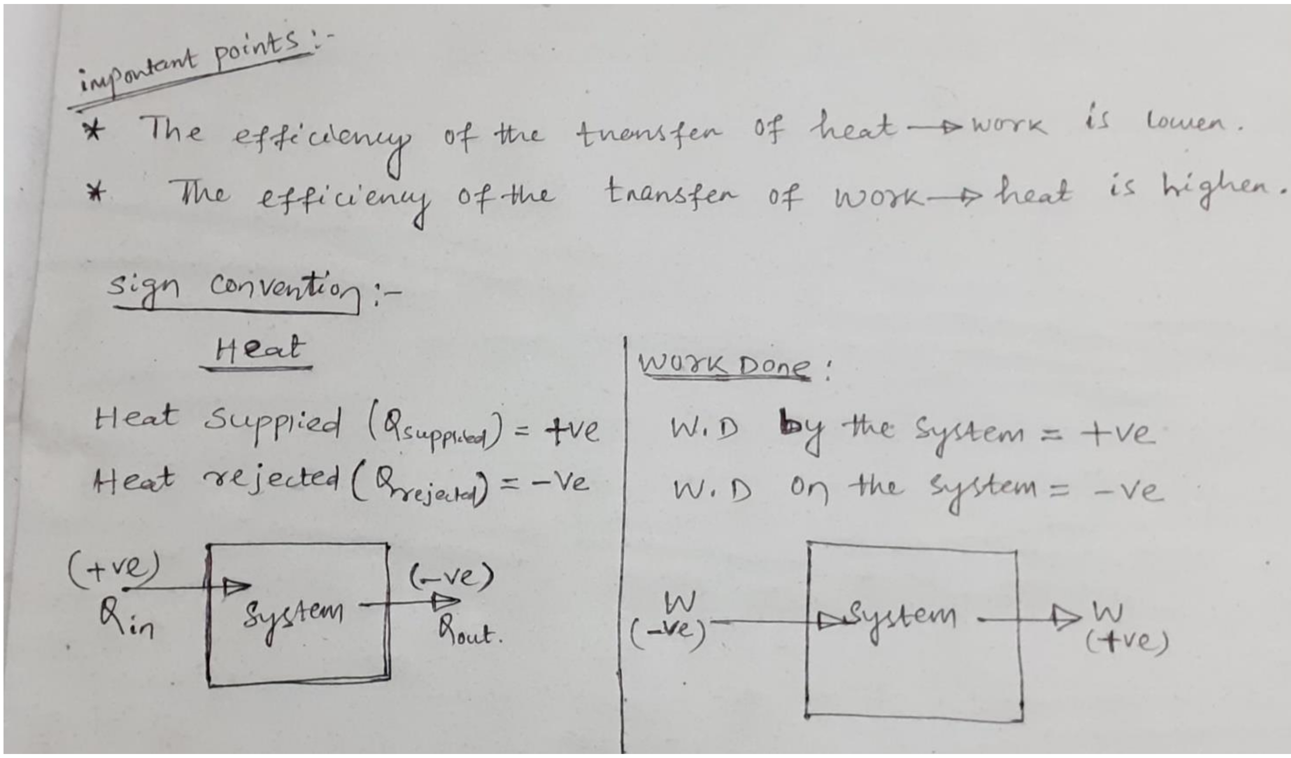
← Boundry phenomena →

← inexact differential →

← Energy in transit →

← Not a Property of System →

Low Grade Energy (imp) High Grade energy.



important points :-

* The efficiency of the transfer of heat → work is lower.
* The efficiency of the transfer of work → heat is higher.

sign convention :-

Heat

Heat supplied ($Q_{supplied}$) = +ve

Heat rejected ($Q_{rejected}$) = −ve

Work Done :

W.D by the system = +ve

W.D on the system = −ve

Mechanical equivalent of Heat:

There is a simple relation between mechanical work done on a system and heat generated in it. **James Prescott Joule** first experimentally found that the heat produced in a system is directly proportional to the mechanical work done on it.

He also calculated the constant of proportionality through a unique experiment, which we will also describe in this article. The constant is popularly known as **Mechanical Equivalent of Heat**. After the name of **James Prescott Joule**, the constant is also often known as **Joule's Mechanical Equivalent of Heat** or simply **Joule's Constant**. We denote it with the capital English letter J.

If W is the work done on a system and Q is the quantity of heat produced due to this work, then

$$W \propto Q$$
$$\Rightarrow W = JQ$$
$$\Rightarrow J = \frac{W}{Q}$$

After, this experiment, by putting all known values of

$$J = 4.186 \ \ kJ/kcal$$

Here, in this experiment, the potential energy of the falling mass is converted into the kinetic energy and finally to the heat energy.

Displacement work:

Consider a piston cylinder arrangement as given in the Figure 2.4. If the pressure of the fluid is greater than that of the surroundings, there will be an unbalanced force on the face of the piston. Hence, the piston will move towards right.

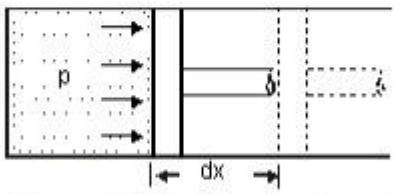


Figure 2.4 Displacement work

Force acting on the piston =Pressure x Area

= p.A

Work done =Force x distance

= pA x dx

= p.dV

Where, dV =change in volume.

This work is known as displacement work or pdV work corresponding to the elemental displacement dx . To obtain the total work done in a process, this elemental work must be added from the initial state to the final state.

Chapter-2

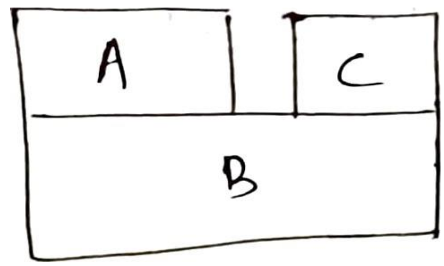
Laws of thermodynamics

The Zeroth Law of Thermodynamics:

The Zeroth law was first formulated and labeled by R.H. Fowler in 1931.
The Zeroth law of thermodynamics states that if two bodies are individually in equilibrium with a separate third body, then the first two bodies are also in thermal equilibrium with each other.
If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.

- This obvious fact cannot be concluded from the other laws of thermodynamics, and it serves as a basis of temperature measurement.
- By replacing the third body with a thermometer, the zeroth law can be restated two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.

$T_A = T_B$, Also
$T_B = T_C$,
Therefore, $T_A = T_B = T_C$



(Thermal equilibrium of three bodies)

First law of Thermodynamics:

- The first law of thermodynamics is the thermodynamic expression of the conservation of energy.
- This law most simply stated by saying that "energy can not be created or destroyed" or that "the energy of the universe is constant".
- This law can be stated for a system (control mass) undergoing a cycle or for a change of state of a system. Stated for a system undergoing a cycle, the cyclic integral of the work is proportional to the cyclic integral of the heat.
- The important thing to remember is that the first law states that the energy is conserved always.

Mathematically stated,
for a control mass undergoing a cyclic process such as in Joule's experiment and for consistent set of units ,

$$\oint dQ \text{ from system} = \oint dW \text{ on system}$$
$$\text{Or, } \oint dQ \text{ from system} - \oint dW \text{ on system} = 0$$

Limitations of first law of thermodynamics:

1. Heat is a path function;
 Suppose a system is taken from state 1 to state 2 by the path 1-a-2 and is restored to the initial state by the path 2-b-1, then the system has undergone a cyclic process 1-a-2-b-1.
 If the system is restored to the initial state by path 2-c-1, then the system has undergone the cyclic change 1-a-2-c-1.

Let us apply the first law of thermodynamics to the cyclic processes 1-a-2- b-1 and 1-a-2-c-1 to obtain

$$\int_{1\text{-}a\text{-}2}dQ + \int_{2\text{-}b\text{-}1}dQ - \int_{1\text{-}a\text{-}2}dW - \int_{2\text{-}b\text{-}1}dW = 0 \quad \int_{1\text{-}a\text{-}2}dQ + \int_{2\text{-}c\text{-}1}dQ - \int_{1\text{-}a\text{-}2}dW - \int_{2\text{-}c\text{-}1}dW = 0$$

Subtracting, we get

$$\int_{2b1}dQ - \int_{2c1}dQ - \left(\int_{2b1}dW - \int_{2c1}dW \right) = 0$$

We know that the work is a path function and hence the term in the bracket is non-zero.

Hence we find $\int_{2b1}dQ = \int_{2c1}dQ$

That is heat is also a path function.

2. Energy is a property of the system:;

   By rearranging we can have $\int_{2b1}(dQ - dW) = \int_{2c1}(dQ - dW)$

   It shows that the integral is the same for the paths 2-b-1 and 2-c-1, connecting the states 2 and state 1. That is, the quantity $\int (dQ - dW)$ does not depend on the path followed by a system, but depends only on the initial and the final states of the system.

   That is **$\int (dQ - dW)$ is an exact differential of a property.**

   This property is called energy (E). It is given by $dE = dQ - dW$ $E = KE + PE + U$

   where U is the internal energy.

   Therefore, $dE = d(KE) + d(PE) + dU = dQ - dW$

   Quite often in many situations the KE or PE changes are negligible.

   $$dU = dQ - dW$$

   An isolated system does not exchange energy with the surroundings in the form of work as well as heat.

   Hence $dQ = 0$ and $dW = 0$.

   Then the first law of thermodynamics reduces to $dE = 0$ **or** $E_2 = E_1$ that is energy of an isolated system remains constant.

Perpetual Motion Machine of the first kind :

PMM-I is an imaginary device which delivers work continuously without absorbing energy from the surroundings is called a Perpetual Motion machine of the first kind.

Since the device has to deliver work continuously, it has to operate on a cycle.

If such a device does not absorb energy from its surroundings $\oint dQ = 0$.

From the first law, it can be observed that $\oint dW = 0$, if $\oint dQ = 0$.

Therefore such a device is impossible from first law of thermodynamics.

Control-Volume Analysis:

Control volume is a volume in space of special interest for particular analysis.

The surface of the control volume is referred as a control surface and is a closed surface.The surface is defined with relative to a coordinate system that may be fixed, moving or rotating.

Mass, heat and work can cross the control surface and mass and properties can change with time within the control volume.

Examples: turbines, compressors, nozzle, diffuser, pumps, heat exchanger, reactors, a thrustproducing device, and combinations of these.

Steady flow process;

A flow process is the one in which a fluid enters the system and then leaves if after a work interaction.

The mass flow rate and energy flow rate across the system boundary are constant.

Important terms

Flow work – whenever a certain amount of mass enters a system, an amount of work is required to push the mass into the system and out of it to maintain the continuity of flow.

i.e. Flow work = PV

Control Volume

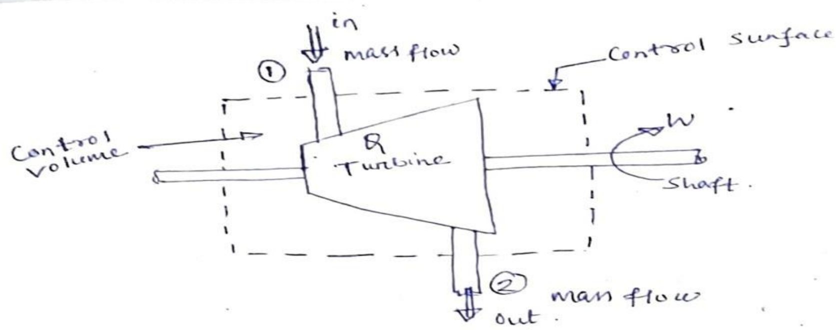
For computation of mass and energy notes during a flow process, it is convenient to focus attention upon a certain fixed region in space called control volume.

Control surface

The boundary line defining the control volume is called control surface.

Stored energy of a system in a flow process:

During a steady state flow, there is neither any accumulation of mass nor energy.



- The broken line represents the surface of the control volume which is known as control surface.

- Most of the engineering devices are open systems such as Turbines, Pumps, Compressor, Nozzle, Diffuser, etc.

Steady Flow Systems: -

→ Steady flow means that the rates of flow of mass and energy across the control surface are constant.

→ There is no accumulation of mass or energy within the control volume and the properties at any location within the control volume are steady with time.

Let us assume;

h = Specific enthalpy ⟶ Heat content of the system.

u = Specific internal energy.

$P.v$ = flow work

C = Velocity

Z = Datum head

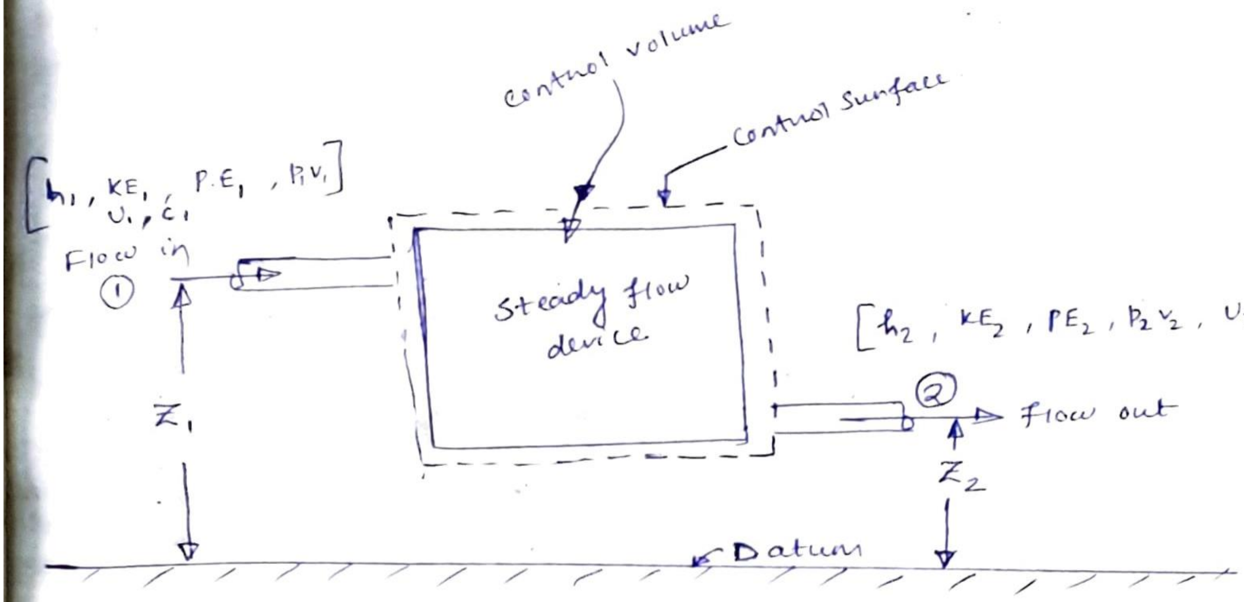
K.E = Specific kinetic energy

P.E = Specific potential energy

Q = heat transfer

W = work transfer

$$\boxed{h = u + P.v}$$



(fig: steady flow process)

Apply energy conservation principle ;

$$[U_1 + P_1V_1 + K.E_1 + PE_1 + Q] = [U_2 + P_2V_2 + KE_2 + PE_2 + W]$$

$$\Rightarrow \boxed{h_1 + KE_1 + PE_1 + Q = h_2 + KE_2 + PE_2 + W}$$

$$\Rightarrow \boxed{h_1 + \frac{c_1^2}{2} + gZ_1 + Q = h_2 + \frac{c_2^2}{2} + gZ_2 + W}$$

putting Q & W per mass rate.

$$h_1 + \frac{c_1^2}{2} + gZ_1 + \frac{dQ}{dM} = h_2 + \frac{c_2^2}{2} + gZ_2 + \frac{dW}{dm}$$

we know, $q = \frac{\dot{Q}}{\dot{m}}$ and $W_{cv} = \frac{\dot{W}}{\dot{m}}$

Control surface work

$$\boxed{h_1 + \frac{c_1^2}{2} + gZ_1 + q = h_2 + \frac{c_2^2}{2} + gZ_2 + W_{cv}} \quad \text{--- (1)}$$

S.F.E.E for unit mass transfer ($\sim/\dot{m}$).

If we consider total mass transfer ;

$$\boxed{\dot{m}\left[h_1 + \frac{c_1^2}{2} + gZ_1\right] + \dot{Q} = \dot{m}\left[h_2 + \frac{c_2^2}{2} + gZ_2\right] + \dot{W}_{cv}} \quad \text{--- (2)}$$

S.F.E.E for unit time.

③ Turbine :-

It is a work producing device in which energy transferred from working fluid to the rotor.

In the case of turbine, expansion of the working fluid is takes place.

i.e work is done by the system.

Assumption:-

i) Neglecting kinetic energy changes.

ii) " potential energy changes.

iii) Neglecting heat.

$$h_1 + \cancel{KE_1} + \cancel{PE_1} + \cancel{Q} = h_2 + \cancel{KE_2} + \cancel{PE_2} + W$$

$$\boxed{W_T = h_1 - h_2}$$

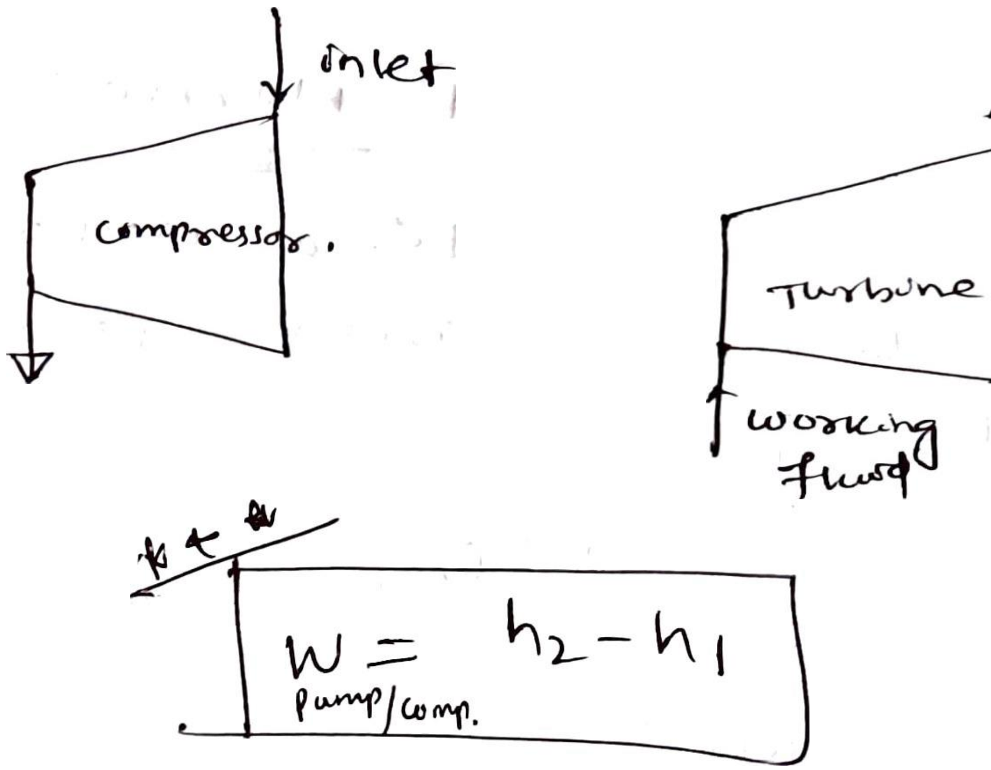
④ Compressor and pump :-

Both are work absorbing device, in which energy is transferred from rotor to working fluid. ⑤

⇒ Compressor, is generally used to handle the gasseous phase of the working fluid.

⇒ Pump, is generally used to handle the ~~~~ liquid phase of the working fluid.

- Pump is generally used to increase the pressure of working liquid.
- Compressor is used for increasing the pressure and temperature of gaseous working substance.



- A compressor compresses air or a gas by harnessing external work fed from a prime mover. The increase in the gas pressure is accompanied by the temperature rise.
- A steam turbine receives a superheated, high pressure steam that experiences its. Enthalpy drop as the steam passes over the turbine blades.

This enthalpy drop is converted into the kinetic energy of rotation of the blades mounted on the turbine drum.

The turbine is well insulated which gives rise to the maximum work output. The turbine is well insulated. $Q = 0$

Steam velocity at the turbine input = the steam velocity at the output.

Second law of Thermodynamics:

Limitation of first law;

There are two basic limitations of the first law of thermodynamics

- First law does not differentiate between heat and work. It assumes complete inter-convertibility of the two. Though work being a high grade energy can be fully converted into heat but heat cannot be completely converted to work.
- It does not permit us to know the direction of energy transfer. We cannot ascertain whether heat will flow from a higher temperature body to a lower temperature body vice versa.

Thermal Reservoir;

A thermal reservoir is a heat source or heat sink that remains at a constant temperature, regardless of energy interaction.

Otherwise a thermal energy reservoir (TER) is a large system body of infinite heat capacity which is capable of absorbing or rejecting a finite amount of heat without any changes in its thermodynamic co-ordinates.

The high temperature reservoir (T_H) that supplies heat is a **source**.

Sink – Low temperature reservoir (T_L) to which heat is rejected.

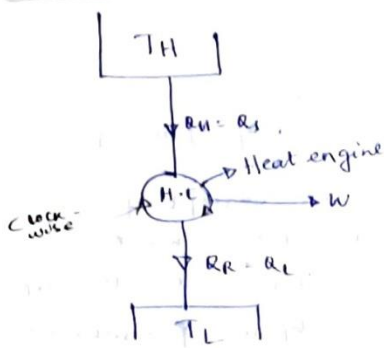
Example; Ocean water and atmospheric air are two good examples.

Statement of second law of the thermodynamics:

1. Kelvin Planck statement
2. Clausius statement

Kelvin-planck's Statement!-

"It is impossible to construct a device which operating on a cycle produces work continuously while interacting with single thermal reservoir".



$$\eta = \frac{o/p}{i/p} = \frac{W_{net}}{Q_s} = \frac{Q_{net}}{Q_s} = 1 - \frac{Q_R}{Q_s}$$

$$\boxed{\eta = 1 - \frac{Q_R}{Q_s}}$$

Thermodynamic temp. scale or Kelvin temp. scale

i.e $Q \propto T$.

$$\frac{Q_R}{Q_s} = \frac{T_R}{T_s} = \frac{T_L}{T_H}$$

$$\boxed{\eta = 1 - \frac{T_L}{T_H}}$$

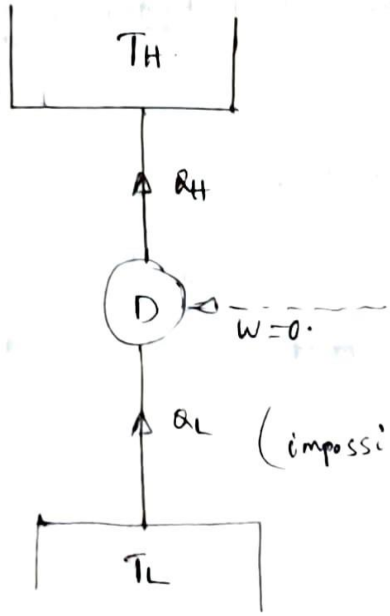
Note:- Kelvin planck' provides the concept of work producing device i.e Heat engine.

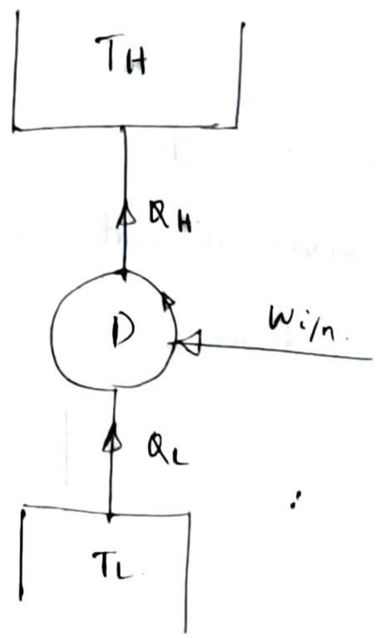
Heat engine :-

A heat engine may be defined as a device, which operates in a thermodynamic cycle, converts heat energy into useful work and rejects the remaining heat to sink.

* Heat engine is a work producing device. [+ W_{net}.]

Clausius Statement :- "It is impossible to construct a device which operating in a cycle transfer heat from low temp. to high temp. without consuming any other form of energy".





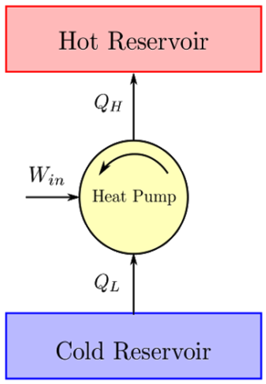
Heat pump:

A heat pump is a reversed heat engine. It receives heat from a low temperature reservoir source and rejects it to high temperature reservoir (since) for which an external work which is supplied to the pump.

Refrigerator:

A refrigerator is similar to a heat pump. It operates as a reversed heat engine. Its duty is to extract heat as much as possible from the cold body and deliver the same to high temperature body.

Coefficient of performance (COP)/ Energy performance ratio (EPR):



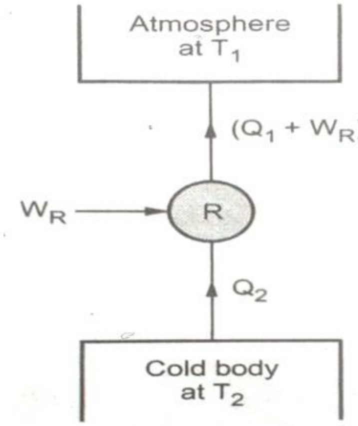


Figure: Refrigerator

Fig. (heat pump and refrigerator)

$$\text{COP} = \frac{\textbf{Desired effect}}{\textbf{Work input}}$$

$$(\text{COP})_{\text{HP}} = \frac{Q_H}{W}$$

$$= Q_H/(Q_H - Q_L) \quad = T_1/(T_1 - T_2)$$

$$(c.o.p)_R = \frac{D.E}{w_{in}} =$$

$$\boxed{(c.o.p)_R = \frac{T_L}{TH - Tu}}$$

Comparision of performance of Heat engine, Heat pump and Refrigerator:-

$$\eta_{H.E} = 1 - \frac{T_L}{T_H} = \frac{T_H - T_L}{T_H} \quad \text{---} (1)$$

$$(Cop)_{Hp.} = \frac{T_H}{T_H - T_L} = \frac{1}{\eta_{H.E}} \quad \text{---} (2)$$

Also; $(Cop)_{Hp} = 1 + (Cop)_R$

$$\therefore \boxed{(Cop)_{HP} = 1 + (Cop)_R = \frac{1}{\eta_{H.E}}}$$

imp

⇒ only applicable for same temp. limit for all.

Numerical on efficiency of H.E , COP of heat pump and refrigerator:

Numericals :-

① What will be the efficiency of heat engine operating with a hot reservoir of furnace gases at 1700°c and cooling water available is at 15°c.

Ans :- ____

② A domestic food refrigerator maintains a temperature of −10°c. The ambient air temperature is 40°c. If heat removed from the freezer is at the rate of 2.5 KJ/s, determine the least power necessary to ~~pump~~ this.

③ If the efficiency of Reversible heat engine is 40 %. Then what will be the c.o.p of heat pump and Refrigerator.

Chapter-3

Properties processes of perfect gas:

Introduction:

Gases:

• In contrast, changing the pressure or temperature of a gas will have an easily observable effect on the volume of that gas. For an **ideal gas** (no intermolecular interactions and no molecular volume) n appropriate equation of state would be: V(T,P,n) = (nRT)/P.

• There are many equations of state describing **real gases**. These equations take in consideration molecular volume and interactions. The most well-known such equations is probably the Van der Waals equation.

Ideal and real gases:

- An ideal gas is one which follows the ideal gas equation of state, namely

  $\mathbf{PV = m.R.T = n\,.R_U\,.T}$

  Where, R= gas constant or characteristics gas constant

  n = No. of moles

  $\mathbf{R_U}$= universal gas constant

The universal gas constant ($\mathbf{R_U}$) has a value of 8.314 J/mol K or kJ/kmol K and is related to the specific gas constant by the relation

$$\mathbf{R_U = (R\,/M)}$$

- The ideal gas equation of state can be derived from the kinetic theory of gases where the following assumptions are made:

1. The molecules are independent of each other. In other words, there are no attractive forces between the molecules.

2. The molecules do not occupy any volume. That is the volume occupied by the molecules is quite negligible compared to the volume available for motion of the molecules.

The internal energy of an ideal gas is a function of temperature only and is independent of pressure and volume.

That is, $u= u(T)$ $(\partial u/\partial P)_T =0$, $(\partial u /\partial v)_T = 0$

Difference between Real gas & Ideal gas Ideal gas :

Sl. no	Real gas	Ideal gas
1	No gas follows all conditions of gas law under certain conditions of pressure & temperature but it approaches the ideal gas behavior. Hence it is called real gas.	A gas which obeys all the laws of gas under all conditions of temperature & pressure.
2	The relations derived from ideal gas may be applied to real gases under certain condition.	Ideal gas law is simple & hence simple relations are derived from it.
3	In certain condition real gas no more remain in gaseous phase but changes its state. So real gases under certain condition behaves like ideal gas.	O2, N2, H2 may be treated as ideal gas because ordinarily these are difficult to liquefy.

Ideal gas equation :-

The ideal gas equation is given as

$$\boxed{PV = mRT} \quad \text{—— (1)}$$

m = mass of the gas (kg).

R = characteristic gas constant in KJ/kg-K

or,

$$\boxed{PV = n.\bar{R}.T} \quad \text{—— (2)}$$

n = number of kilomoles of the gas.

$\bar{R}$ = universal gas constant.

= 8.314 KJ/K mol K

} important.

Note

* Value of R changes from gas to gas.

$\boxed{\text{For air, } R = 0.287 \text{ KJ/kg K (or) } 287 \text{ J/kg K}}$

⇒ Characteristic gas constant :- (R)

when the equation deals with mass ; this is used. It's value changes from gas to gas.

⇒ For air, $R = 0.287$ kJ/kg-K
$= 287$ J/kg-K

⇒ Universal gas constant ($\bar{R}$) :-

- When the equation deals with moles, it is in use.
- The value of $\bar{R}$ is same for all the gasses.

$$\bar{R} = 8.314 \ \text{KJ/kg-mol-K}$$
$$= 8314 \ \text{J/kg-mol-K}$$

* We know for ideal gas, $PV = mRT$

$$\frac{PV}{T} = mR = \text{constant}$$ (as mass is always conserved).

$$\therefore \quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \text{Constant}$$ (for closed system).

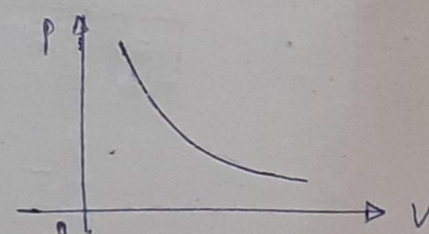
→ [Robert Boyle - 1662]

Boyle's law :- It states that, "the pressure exerted by a gas is inversely proportional to the volume occupied by it, when temperature kept constant".

$$P \propto \frac{1}{V} \rightarrow \text{at } T = C$$

$$\Rightarrow P = C \times \frac{1}{V}$$

$$\Rightarrow \boxed{PV = C}$$



(P-V diagram)

$$\Rightarrow \underbrace{P_1V_1}_{\text{at initial pt.}} = \underbrace{P_2V_2}_{\text{final pt.}} = C$$

ex:- When a filled balloon is squeezed, the volume↓ → P↑

Charle's Law :- [1780]

It states that the volume of an ideal gas is directly proportional to the absolute temperature at constant Pressure.

$$V \propto T \longrightarrow \text{at } P = c$$

$$V = c \times T$$

$$\Rightarrow \frac{V}{T} = c$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = c \Rightarrow \frac{V_2}{V_1} = \frac{T_2}{T_1}$$

ex:- over fill a tube on a hot day.

* By increasing the temperature the volume also increases. Similarly, lowering the temp., the volume of the gas decreases.

And, At 0°c, the volume of the gas also increases by $\frac{1}{273}^{th}$ of it's original volume for a unit degree increase in temp.

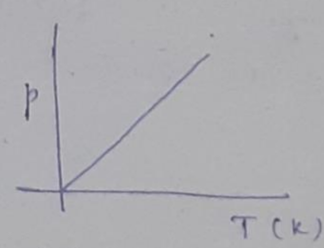
Gay - Lussac's law :- [1808]

" The Pressure exerted by a gas varies directly with the absolute temperature of the gas of a given mass and kept at a constant volume.

$$P \propto T \leftrightarrow \text{at } V = c$$

$$\Rightarrow \frac{P}{T} = c$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = c$$



ex: ① deodorant can / spray - paint can ⇒ heated ⇒ P↑.
T↑

[∴ Warning labels ⇒ Container must be kept away from the fire and stored in a cool environment]

② Pressure Cooker. [T↑ → P↑ ⇒ cook faster]

Avogadro's Law :-

" The total no. of atoms /molecules of a gas (i.e amount of gaseous substance) is directly proportional to the volume occupied by the gas at constant temp. and pressure ."

- Two dissimilar ideal gases occupying the same volume at a given temp. & pressure must contain an equal no. of molecules.

$$V \propto n \quad \text{at } P = C,\ T = \text{Constant.}$$

$$\frac{V}{n} = C$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Ideal gas equation, $PV = nRT$

$$\Rightarrow \frac{V}{n} = \underbrace{\frac{(RT)}{P}}_{\text{is a constant value}}$$

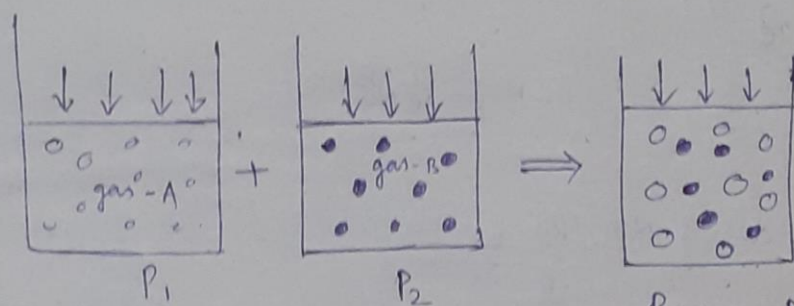
since $T = c$, $P = c$ & $R = c$ for given gas.

$$\Rightarrow \frac{V}{n} = \text{constant.}$$

ex:- The process of respiration. When humans inhale, the increase in the molar qty. of air in the lungs is accompanied by an increase in the volume of the lungs.

Dalton's law of Partial Pressure :-

"The total pressure exerted by a mixture of gases is equal to the sum of the partial pressures exerted by each individual gas in the mixture."



$P_{total} = P_1 + P_2$

$$P_{total} = \sum_i^n P_i = P_1 + P_2 + \dots + P_n$$

* Specific heat of gas :-

The amount of heat required to raise the temp. of unit mass of substance through one degree centigrade, is known as specific heat.

Specific heat, $Q = m \cdot c \cdot dT$ → rise in temp / temp. difference

$= C_p$ → for constant pressure

$= C_v$ → for constant volume

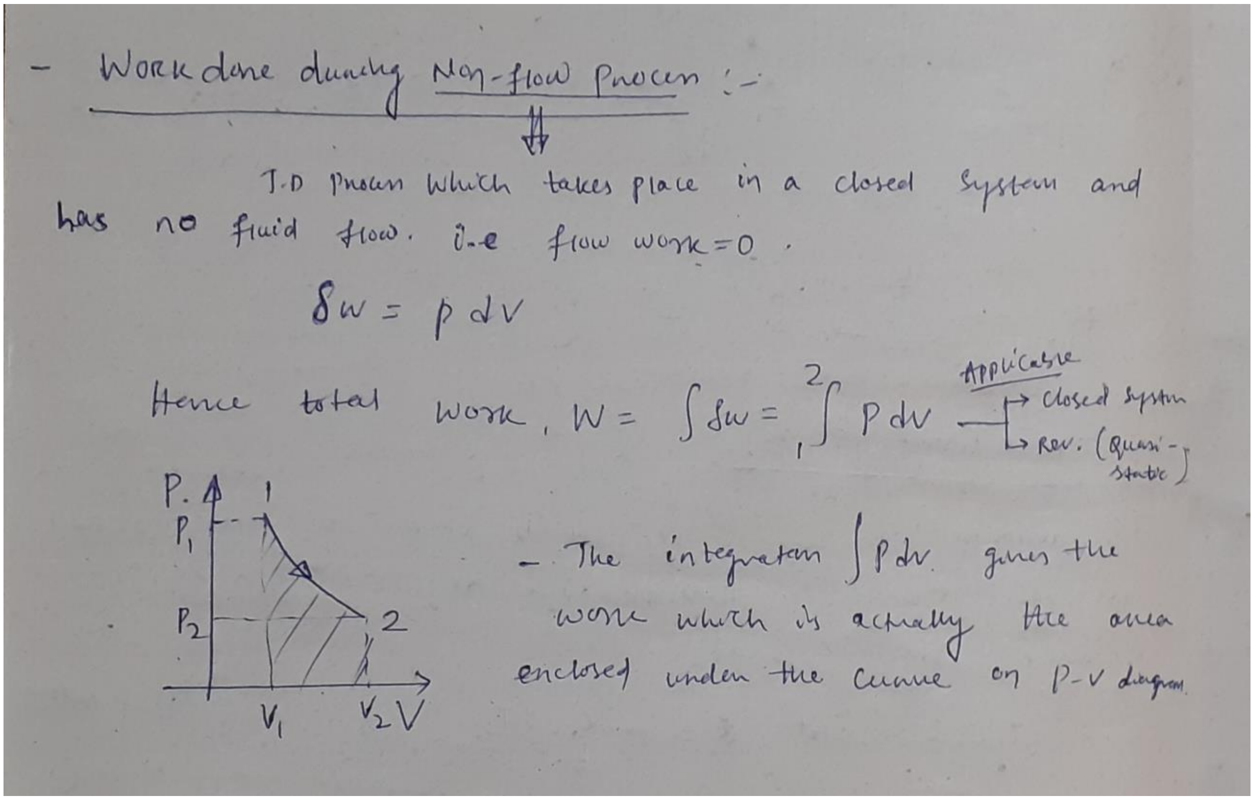
* $4.2\ J/g°C$ ($1\ cal/g.deg$)

→ Heat can be transferred to gases either at constant pressure or at constant volume.

Joule's law ⇒ $u = f(T)$

$C_p = C_v + R$

⇒ $\boxed{C_p - C_v = R}$



- Work done during Non-flow Process :-

T.D Process which takes place in a closed system and has no fluid flow. i.e flow work = 0.

$$\delta w = p\,dV$$

Hence total work, $W = \int \delta w = \int_1^2 p\,dV$ → Applicable → Closed system → Rev. (Quasi-static)

- The integration $\int p\,dV$ gives the work which is actually the area enclosed under the curve on P-V diagram.

Enthalpy:

When a process takes place at constant pressure, the heat absorbed or released is equal to the Enthalpy change. Enthalpy is sometimes known as "heat content.

Specific enthalpy , $h = u + Pv$

For an ideal gas $u = u(T)$ only

And $PV = mRT$ and hence $h = h(T)$ only.

Relation between two specific heats:

The two specific heats are related to each other.

$h = u + Pv$ or $dh = du + d(Pv)$

For an ideal gas, the above equation reduces to $dh = du + d(RT) = du + RdT$

or $dh/dT = du/dT + R$

or $C_P = C_V + R$ or

$\mathbf{C_P - C_V = R}$

for an ideal gas. $\boldsymbol{\gamma = C_P / C_V}$

or $\mathbf{C_P = R/(\gamma-1)}$ and $\mathbf{C_V = R\gamma /(\gamma-1)}$

Internal energy:

Internal energy U of a system or a body with well defined boundaries is the total of the kinetic energy due to the motion of molecules and the potential energy associated with the vibrational motion and electric energy of atoms within molecules. Internal energy also includes the energy in all the chemical bonds. From a microscopic point of view, the internal energy may be found in many different forms. For any material or repulsion between the individual molecules.

Internal Energy of a Closed System:

For a closed system the internal energy is essentially defined by

ΔU = ΔQ - ΔW

Where

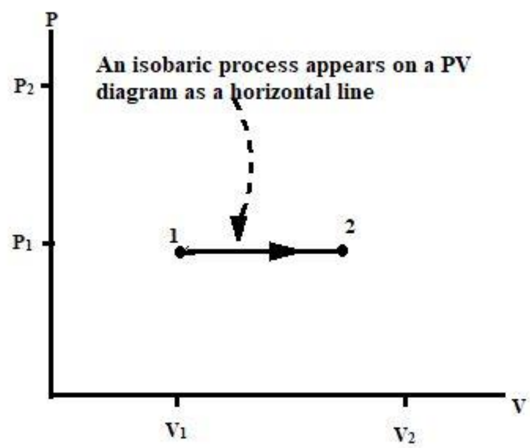
- **ΔU** is the change in internal energy of a system during a process
- **ΔQ** is the heat transfer in the system
- **ΔW** is the mechanical work on or by the system

If an energy exchange occurs because of temperature difference between a system and its surroundings, this energy appears as heat otherwise it appears as work. When a force acts on a system through a distance the energy is transferred as work. The above equation shows that energy is conserved.

Application of first law of thermodynamics to Non flow processes:

1. **Isobaric process/ Constant pressure process :**

   An Isobaric process is a thermodynamic process taking place at constant pressure.



From first law of thermodynamics for process 1 - 2

$$\delta Q = dU + \delta W$$

$$\delta Q = dU + pdV$$

(Assumption: (1) closed system, (2) Quasistatic, (3) Stationary)

or $$\delta Q = dU + d(PV)$$ (as P is constant)

$$\delta Q = d(U + PV)$$

$$(\delta Q)_P = dH$$ (by definition, $H = U + PV$)

but $$(\delta Q)_P = mc_p dT$$ (by definition of c_p)

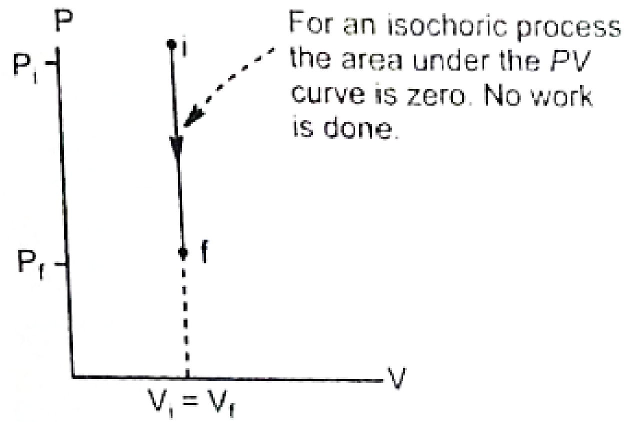
$\therefore$ $$dH = mc_p dT$$

or $$\Delta H = mc_p \Delta T$$

$\therefore$ Heat transfer at constant pressure, $Q_P = \Delta H = mc_p \Delta T$

2. Isochoric process / Constant volume process :

A thermodynamic process taking place at constant volume is known as the isochoric process. It is also sometimes called as an isometric process or constant-volume process.



For constant volume process, $dV=0$ or $V_1=V_2$

Workdone, $W=PdV=0$

From first law of thermodynamics for the process 1 – 2

$$\delta Q = dU + \delta W \qquad \text{\{assuming stationary system\}}$$

as its isochoric

$\therefore \quad \delta W = 0$

i.e. $\quad (\delta Q)_V = dU$

but $\quad (\delta Q)_V = mc_v dT$ $\qquad$ {by deflection by c_v}

$\therefore \quad dU = mc_v dT$

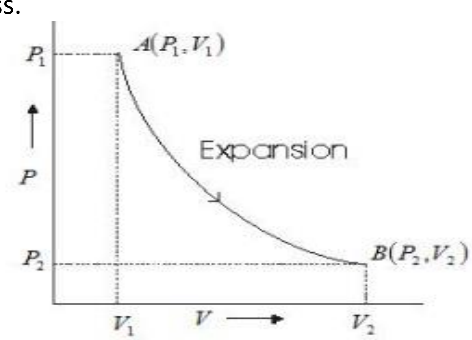
or Heat transfer at constant volume, $Q_V = \Delta U = mc_v \Delta T$

- The total heat supplied or rejected is also equal to the increase or decrease in the internal energy of the system.

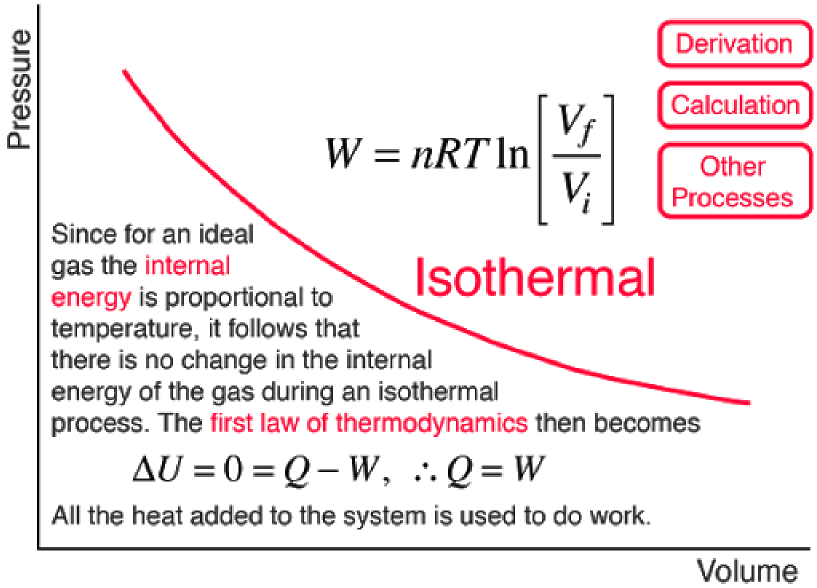
3. Isothermal process / Constant temperature process :

An isothermal process is a thermodynamic process in which the temperature of a system remains constant.

The transfer of heat into or out of the system happens so slowly that thermal equilibrium is maintained. At a particular constant temperature, the change of a substance, object or system is known as Isothermal Process.



Consider pressure and volume of ideal gas changes from (P_1, V_1) to (P_2, V_2).



- When the gas expands from a high pressure to a low pressure there is a tendency for the temperature to fall. In an isothermal expansion heat must be added continuously in order to keep the temperature at its initial value (figure 3.5).
- Similarly in an isothermal compression heat must be removed from the gas continuously during the process.
- From first law of thermodynamics for process 1 – 2

$$Q = \Delta U + W \qquad \text{\{assuming stationary system\}}$$

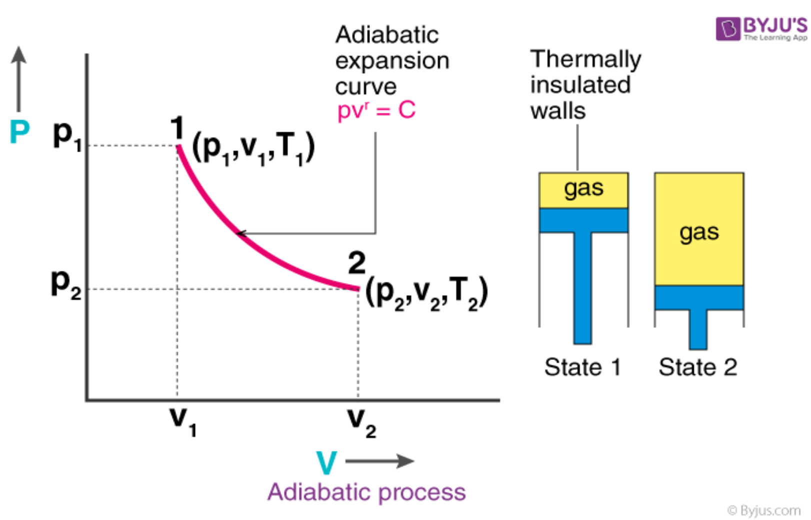
as it is isothermal, $\Delta U = C_v(T_2 - T_1) = 0$ {for ideal gas}

$\therefore \quad Q = W$

or $\quad \delta Q = \delta W$

4. Adiabatic process:

- An adiabatic process is defined as the thermodynamic process in which there is no exchange of heat from the system to its surrounding neither during expansion nor during compression.
- The system must be perfectly insulated from the surrounding.
- The process must be carried out quickly so that there is a sufficient amount of time for heat transfer to take place.



3.4.4 Reversible Adiabatic Process

- For an adiabatic process there is no heat transfer to or from the system during the process. It can either be reversible or irreversible.
- From first law of thermodynamics

$$\delta Q = dU + \delta W$$

here $\delta Q = 0$ (as adiabatic)

$\therefore$ $\delta W = -dU$ or $W = U_1 - U_2$

But the above equators are valid for both reversible as well as irreversible adiabatic process.

- But for a reversible adiabatic, the governing equation for ideal gas is $PV^{\gamma} = C$

and $W = \dfrac{P_1V_1 - P_2V_2}{\gamma - 1}$ (derived earlier)

$$\therefore \quad U_1 - U_2 = W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= \frac{mR(T_1 - T_2)}{\gamma - 1}$$

$$W_{adia} = \int_{V_1}^{V_2} P\,dV$$

$$= \int_{V_1}^{V_2} KV^{-\gamma}\,dV \qquad [\quad P = KV^{-\gamma}\,]$$

$$= K\int_{V_1}^{V_2} V^{-\gamma}\,dV$$

$$= k\left[\frac{V^{1-\gamma}}{1-\gamma}\right]_{V_1}^{V_2}$$

$$= \frac{k}{1-\gamma}\left[V_2^{1-\gamma} - V_1^{1-\gamma}\right]$$

$$= \frac{1}{\gamma-1}\left[KV_1^{1-\gamma} - KV_2^{1-\gamma}\right]$$

We know that

$$K = P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$W_{adia} = \frac{1}{1-\gamma}\left[P1\, V_1^{\gamma} V_1^{1-\gamma} - P2\, V_2^{\gamma} V_2^{1-\gamma}\right]$$

$$W_{adia} = \frac{1}{\gamma-1}[P_1V_1 - P_2V_2]$$

5. <u>Polytropic process:</u>

During actual expansion and compression processes of gases, pressure and volume are often related by **PV^n =C** , where n(polytropic index) and C are constants. A process of this kind is called Polytropic process.

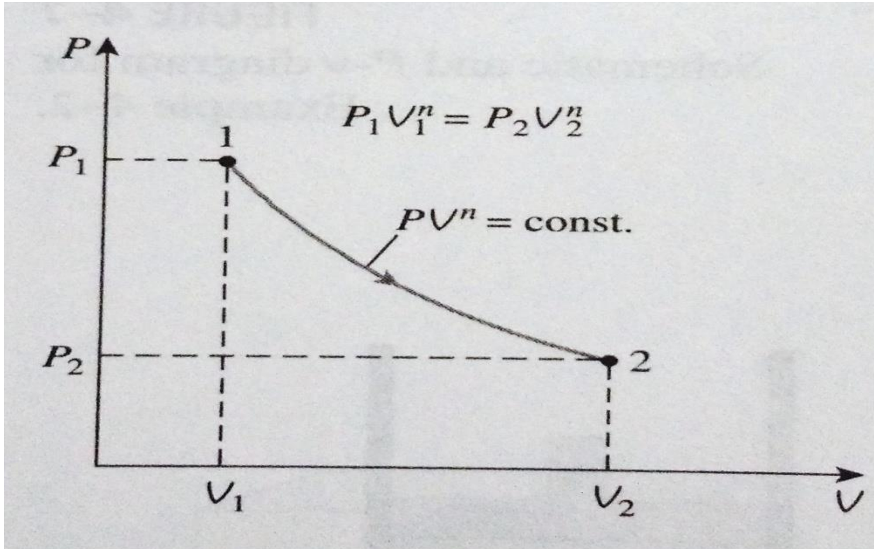


FIGURE 4–9
Schematic and P-V diagram for a polytropic process.

PV^n =C , the value of polytropic index (n) for different processes are;

n = 0, constant pressure process $\qquad w = P(v_2 - v_1)$

n = 1, constant temperature process $\qquad w = q = RT \ln \frac{v_2}{v_1}$

n = γ, reversible adiabatic process $\qquad w = \frac{P_1 v_1 - P_2 v_2}{\gamma - 1}$

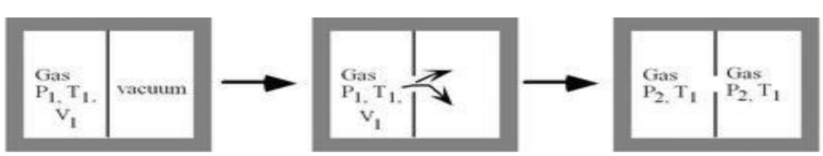
n = ∞ ,constant volume process $\qquad w = 0$

Free expansion process:

- Free expansion process is expansion against vaccum . where total energy E=U + KE and during internal energy is converted into kinetic energy .after all end of process final temperature will be equals to initial temperature.
- In free expansion process heat interaction from surrounding will be zero and integral work done will be zero.

dq=0 , dt=0, dw=0

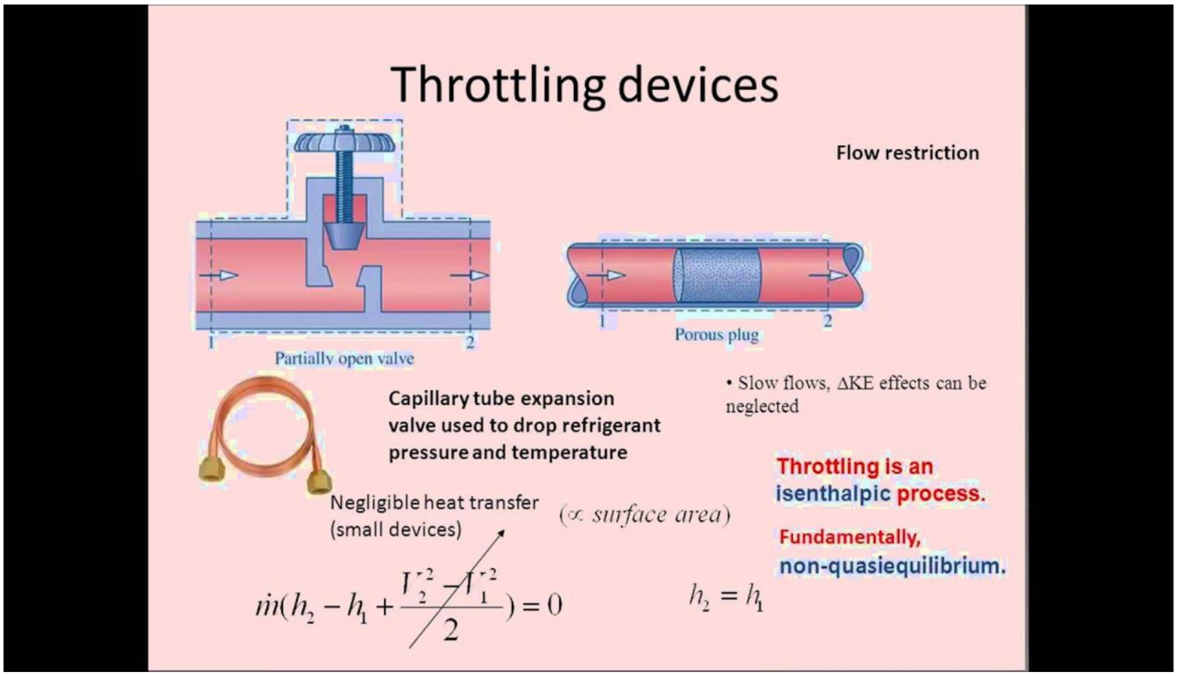
Consider a properly insulated cylinder with a partition & stopper. Now place some gas on one side & evacuate other side. When you remove stopper this gas expands freely to the other side of cylinder.



Throttling process:

The process in which a high pressure fluid is converted to low pressure by using a throttle valve is Throttling. In throttling process enthalpy remains constant , work done is 0.

- Another name of throttling process is wire drawing because the steam looks like a wire after certain extent .
- for ideal gas throttling process is isothermal.
- for real gases due to throttling the temp. may increase decrease or remain const.
- for steam due to throttling the temperature always drop.



A throttling process is a thermodynamic process, in which the enthalpy of the gas or medium **r**emains constant (h = const)**.**

In fact, the **throttling process** is one of **isenthalpic processes**. During the throttling process no work is done by or on the system (dW = 0), and usually there is no heat tranfer **(**adiabatic**)** from or into the system (dQ = 0).

Chapter-4

Internal combustion engine:

Heat engine:

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

It is classified into two types-

(a) External combustion engine

(b) Internal combustion engine

External combustion engine: In this engine, the products of combustion of air and fuel transfer heat to a second fluid which is the working fluid of the cycle.

Examples:

- In the steam engine or a steam turbine plant, the heat of combustion is employed to generate steam which is used in a piston engine (reciprocating type engine) or a turbine (rotary type engine) for useful work.
- In a closed cycle gas turbine, the heat of combustion in an external furnace is transferred to gas, usually air which the working fluid of the cycle.

Internal combustion engine:

In this engine, the combustion of air and fuels take place inside the cylinder and are used as the direct motive force.

It can be classified into the following types:

1. According to the basic engine design-
   - Reciprocating engine (Use of cylinder piston arrangement)
   - Rotary engine (Use of turbine)
2. According to the type of fuel used-
   - Petrol engine
   - diesel engine
   - gas engine (CNG, LPG)
   - Alcohol engine (ethanol, methanol etc)
3. According to the number of strokes per cycle-
   - Four stroke and
   - Two stroke engine
4. According to the method of igniting the fuel-
   - Spark ignition engine
   - compression ignition engine
   - hot spot ignition engine
5. According to the working cycle-
   - Otto cycle (constant volume cycle) engine
   - diesel cycle (constant pressure cycle) engine
   - dual combustion cycle (semi diesel cycle) engine
6. According to the number of cylinder-
   - Single cylinder and
   - multi-cylinder engine

7. Method of cooling-
- water cooled, or
- air cooled

8. Speed of the engine-
- Slow speed,
- medium speed and
- high speed engine

9. Cylinder arrangement-
- Vertical,
- horizontal,
- inline,
- V-type,
- radial,
- opposed cylinder or piston engines.

Comparison between external combustion engine and internal combustion engine:

External combustion engine	**Internal combustion engine**
Combustion of air-fuel is outside the engine cylinder (in a boiler)	Combustion of air-fuel is inside the engine cylinder (in a boiler)
The engines are running smoothly and silently due to outside combustion	Very noisy operated engine
Higher ratio of weight and bulk to output due to presence of auxiliary apparatus like boiler and condenser. Hence it is heavy and cumbersome.	It is light and compact due to lower ratio of weight and bulk to output.
Working pressure and temperature inside the engine cylinder is low; hence ordinary alloys are used for the manufacture of engine cylinder and its parts.	Working pressure and temperature inside the engine cylinder is very much high; hence special alloys are used
It can use cheaper fuels including solid fuels	High grade fuels are used with proper filtration
Lower efficiency about 15-20%	Higher efficiency about 35-40%
Higher requirement of water for dissipation of energy through cooling system	Lesser requirement of water
High starting torque	IC engines are not self-starting

Main components of reciprocating IC engines:

Cylinder:

It is the main part of the engine inside which piston reciprocates to and fro. It should have high strength to withstand high pressure above 50 bar and temperature above 2000^0 C.

The ordinary engine is made of cast iron and heavy duty engines are made of steel alloys or aluminum alloys. In the multi-cylinder engine, the cylinders are cast in one block known as cylinder block.

Cylinder head:

The top end of the cylinder is covered by cylinder head over which inlet and exhaust valve, spark plug or injectors are mounted. A copper or asbestos gasket is provided between the engine cylinder and cylinder head to make an air tight joint.

Piston:

Transmit the force exerted by the burning of charge to the connecting rod. Usually made of aluminium alloy which has good heat conducting property and greater strength at higher temperature.

Piston rings:

These are housed in the circumferential grooves provided on the outer surface of the piston and made of steel alloys which retain elastic properties even at high temperature.

2 types of piston rings-

- Compression rings: Compression ring is upper ring of the piston which provides air tight seal to prevent leakage of the burnt gases into the lower portion.
- oil rings: Oil ring is lower ring which provides effective seal to prevent leakage of the oil into the engine cylinder.

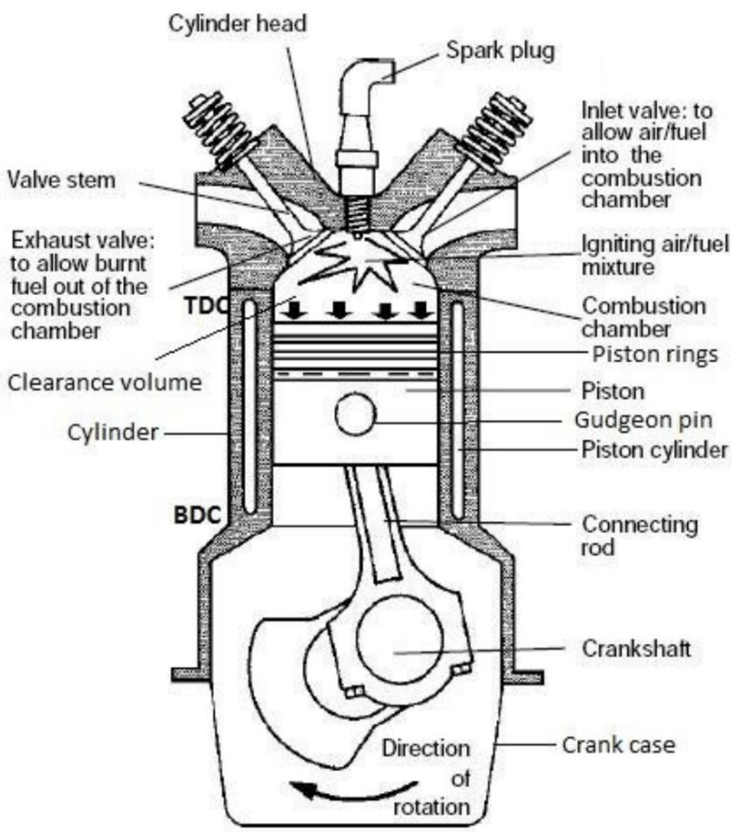


Fig.(Different parts of IC engine)

Connecting rod:

It converts reciprocating motion of the piston into circular motion of the crank shaft, in the working stroke. The smaller end of the connecting rod is connected with the piston by gudgeon pin and bigger end of the connecting rod is connected with the crank with crank pin. The special steel alloys or aluminium alloys are used for the manufacture of connecting rod.

Crankshaft:

It converts the reciprocating motion of the piston into the rotary motion with the help of connecting rod. The special steel alloys are used for the manufacturing of the crankshaft. It consists of eccentric portion called crank.

Crank case:
It houses cylinder and crankshaft of the IC engine and also serves as sump for the lubricating oil.

Flywheel:
It is big wheel mounted on the crankshaft, whose function is to maintain its speed constant. It is done by storing excess energy during the power stroke, which is returned during other stroke.

Terminology used in IC engine:

- Cylinder bore (D):
  The nominal inner diameter of the working cylinder.
- Piston area (A):
  The area of circle of diameter equal to the cylinder bore.
- Stroke (L):
  The nominal distance through which a working piston moves between two successive reversals of its direction of motion.
- Dead centre:
  The position of the working piston and the moving parts which are mechanically connected to it at the moment when the direction of the piston motion is reversed (at either end point of the stroke).
  (a) Bottom dead centre (BDC): Dead centre when the piston is nearest to the crankshaft.
  (b) Top dead centre (TDC): Dead centre when the position is farthest from the crankshaft.
- Displacement volume / swept volume (Vs):
  Swept volume can be defined as the volume swept by the engine piston during one stroke. Swept volume is also the product of piston area and stroke.
  The nominal volume generated by the working piston when travelling from the one dead centre to next one and given as,
  $$V_s = A \times L$$
- Clearance volume (Vc):
  Clearance volume can be defined as the volume that remains in the cylinder when the engine piston is in the top centre position.
  Clearance volume can also be defined as the difference between the total cylinder volume and the swept volume. The space covered by the clearance volume also forms the combustion chamber.
  The nominal volume of the space on the combustion side of the piston at the top dead centre.
- Cylinder volume (V):
  Total volume of the cylinder. $\mathbf{V = V_s + V_c}$
- Compression ratio (r):
  Compression ratio , in an internal-combustion engine, degree to which the fuel mixture is compressed before ignition. It is defined as the maximum volume of the combustion chamber divided by the volume with the piston in the full-compression position.
  Compression ratio, $\mathbf{r = V_s / V_c}$

  Piston speed:
  The mean piston speed is the average speed of the piston in a reciprocating engine. It is a function of stroke and RPM. There is a factor of 2 in the equation to account for one stroke to occur in 1/2 of a crank revolution (or alternatively: two strokes per one crank revolution) and a '60' to convert seconds from minutes in the RPM term.

- RPM(Revolution per minute):
  Revolutions per minute (abbreviated rpm, RPM, rev/min, r/min, or with the notation min^{-1}) is the number of turns in one minute. It is a unit of rotational speed or the frequency of rotation around a fixed axis.

Four stroke engine: -
Cycle of operation completed in four strokes of the piston or two revolution of the piston.

(i) Suction stroke (suction valve open, exhaust valve closed)-charge consisting of fresh air mixed with the fuel is drawn into the cylinder due to the vacuum pressure created by the movement of the piston from TDC to BDC.

(ii) Compression stroke (both valves closed)-fresh charge is compressed into clearance volume by the return stroke of the piston and ignited by the spark for combustion. Hence pressure and temperature is increased due to the combustion of fuel

(iii) Expansion stroke (both valves closed)-high pressure of the burnt gases force the piston towards BDC and hence power is obtained at the crankshaft.

(iv) Exhaust stroke (exhaust valve open, suction valve closed)- burned gases expel out due to the movement of piston from BDC to TDC.

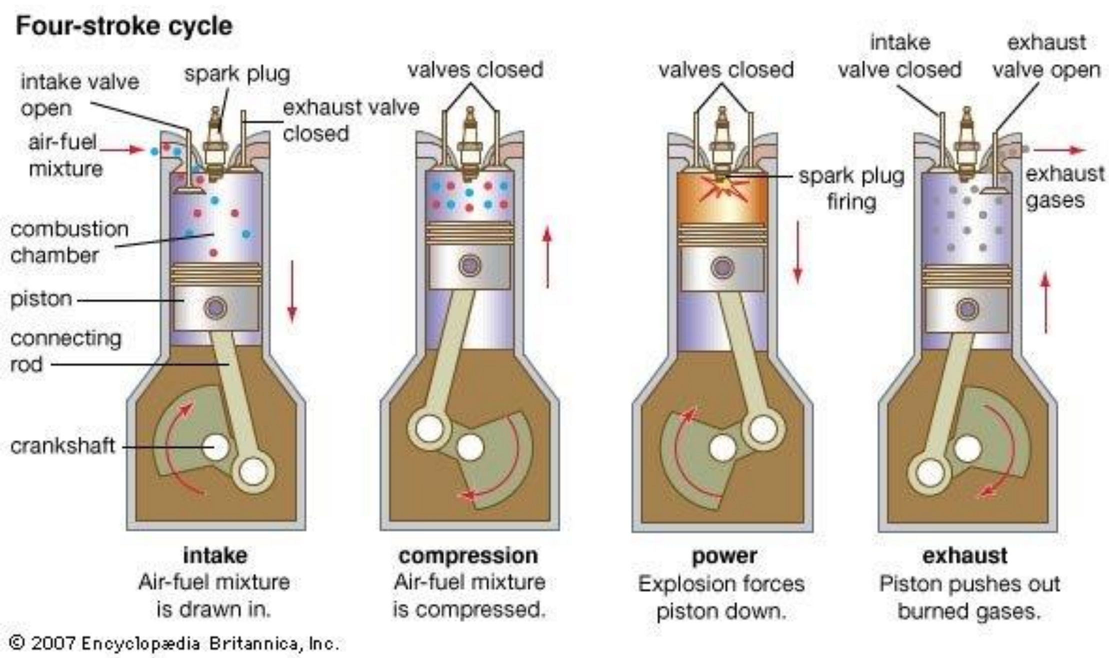
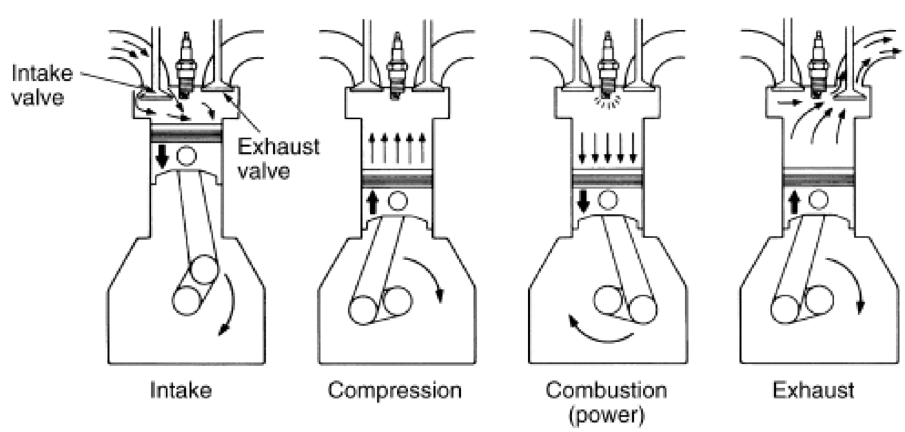


Fig. Cycle of operation in four stroke engine



Two stroke engine:

No piston stroke for suction and exhaust operations -

- Suction is accomplished by air compressed in crankcase or by a blower
- Induction of compressed air removes the products of combustion through exhaust ports
- Transfer port is there to supply the fresh charge into combustion chamber

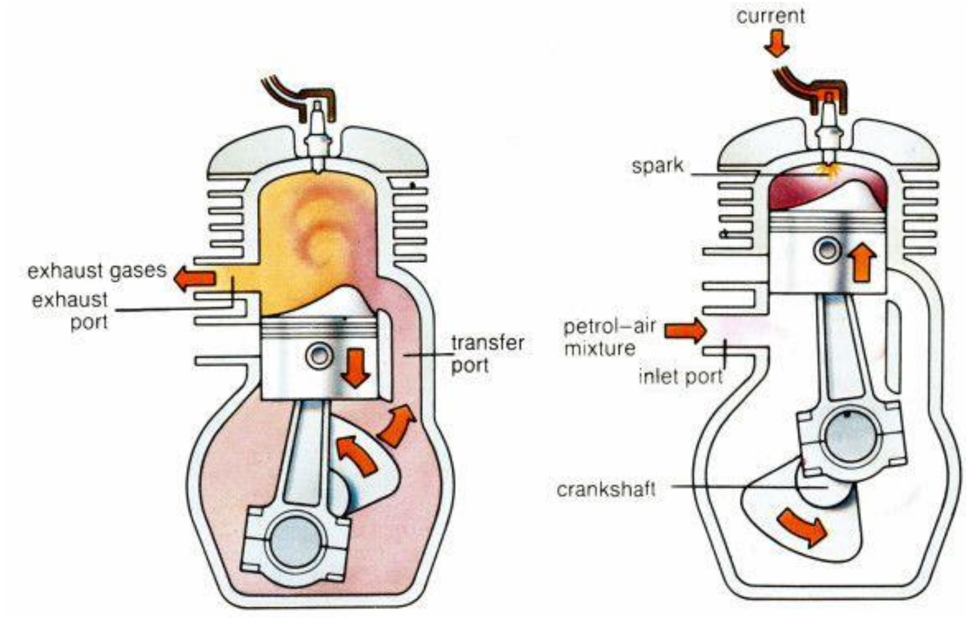


Fig. Cycle of operation in two stroke engine

- A two-stroke engine performs all the same steps, but in just two piston strokes. The simplest two-stroke engines do this by using the crankcase and the underside of the moving piston as a fresh charge pump. Such engines carry the official name "crankcase-scavenged two-strokes."
- As the two-stroke's piston rises on compression, its underside pulls a partial vacuum in the crankcase. An intake port of some kind (cylinder wall port, reed valve or rotary disc valve) opens, allowing air to rush into the crankcase through a carburetor.
- As the piston nears Top Dead Center, a spark fires the compressed mixture. As in a four-stroke, the mixture burns and its chemical energy becomes heat energy, raising the pressure of the burned mixture to hundreds of psi. This pressure drives the piston down the bore, rotating the crankshaft.
- As the piston continues down the bore, it begins to expose an exhaust port in the cylinder wall. As spent combustion gas rushes out through this port, the descending piston is simultaneously compressing the fuel-air mixture trapped beneath it in the crankcase.
- As the piston descends more, it begins to expose two or more fresh-charge ports, which are connected to the crankcase by short ducts. As pressure in the cylinder is now low and pressure in the crankcase higher, fresh charge from the crankcase rushes into the cylinder through the fresh-charge (or "transfer") ports. These ports are shaped and aimed to minimize direct loss of fresh charge to the exhaust port. Even in the best designs, there is some loss, but simplicity has its price! This process of filling the cylinder while also pushing leftover exhaust gas out the exhaust port is called "scavenging."
- While the piston is near Bottom Dead Center, mixture continues to move from the crankcase, up through the transfer ports, and into the cylinder.
- As the piston rises, it first covers the transfer ports, leaving only the exhaust port still open. If there were no way to stop it, much of the fresh charge would now be pumped out the exhaust.

- But there is a simple way to stop it—using exhaust pressure waves in the exhaust. If we shape and dimension the exhaust pipe right, a reflection of the original pressure pulse, generated as the exhaust port opened, will bounce back to the port just as fresh charge is being pumped out of it. This pressure wave stuffs the fresh charge back into the cylinder just as the rising piston covers the exhaust port

Comparison of Four-stroke and two-stroke engine:

Sl.no	Four-stroke engine	Two-stroke engine
1.	Four stroke of the piston and two revolution of crankshaft	Two stroke of the piston and one revolution of crankshaft
2.	One power stroke in every two revolution of crankshaft	One power stroke in each revolution of crankshaft
3.	Heavier flywheel due to non-uniform turning movement	Lighter flywheel due to more uniform turning movement
4.	Power produce is less	Theoretically power produce is twice than the four stroke engine for same size
5.	Heavy and bulky	Light and compact
6.	Lesser cooling and lubrication requirements	Greater cooling and lubrication requirements
7.	Lesser rate of wear and tear	Higher rate of wear and tear
8.	Contains valve and valve mechanism	Contains ports arrangement
9.	Higher initial cost	Cheaper initial cost
10.	Volumetric efficiency is more due to greater time of induction	Volumetric efficiency less due to lesser time of induction
11.	Thermal efficiency is high and also part load efficiency better	Thermal efficiency is low, part load efficiency lesser
12.	12. It is used where efficiency is important. Ex-cars, buses, trucks, tractors, industrial engines, aero planes, power generation etc.	It is used where low cost, compactness and light weight are important. Ex-lawn mowers, scooters, motor cycles, mopeds, propulsion ship etc.

Comparison of Petrol(SI) and Diesel (CI) engine:

Sl.no	Petrol(SI) engine	Diesel (CI) engine
1.	Working cycle is Otto cycle.	Working cycle is diesel cycle.
2.	Petrol or gasoline or high octane fuel is used.	Diesel or high cetane fuel is used.
3.	High self-ignition temperature.	Low self-ignition temperature
4.	Fuel and air introduced as a gaseous mixture in the suction stroke.	Fuel is injected directly into the combustion chamber at high pressure at the end of compression stroke.
5.	Carburettor used to provide the mixture. Throttle controls the quantity of mixture introduced.	Injector and high pressure pump used to supply of fuel. Quantity of fuel regulated in pump.
6.	Use of spark plug for ignition system	Self-ignition by the compression of air which increased the temperature required for combustion
7.	Compression ratio is 6 to 10.5	Compression ratio is 14 to 22

8.	Higher maximum RPM due to lower weight	Lower maximum RPM
9.	Maximum efficiency lower due to lower compression ratio	Higher maximum efficiency due to higher compression ratio
10.	Lighter	Heavier due to higher pressures

Chapter-5

Air standard cycle:

Introduction:

- Deal with systems that produce power in which the working fluid remains a gas throughout the cycle (in other words, there is no change in phase).
- Spark Ignition (gasoline) engines, Compression ignition (diesel) engines and conventional gas turbine engines (generally refer to as Internal Combustion engines or IC Engines) are some examples of engines that operate on gas cycles.
- Internal combustion engines: Combustion of fuel is non-cyclic process. Working fluid, air-fuel mixture undergoes permanent chemical change due to combustion Products are thrown out of the engine & Fresh charge is taken in.

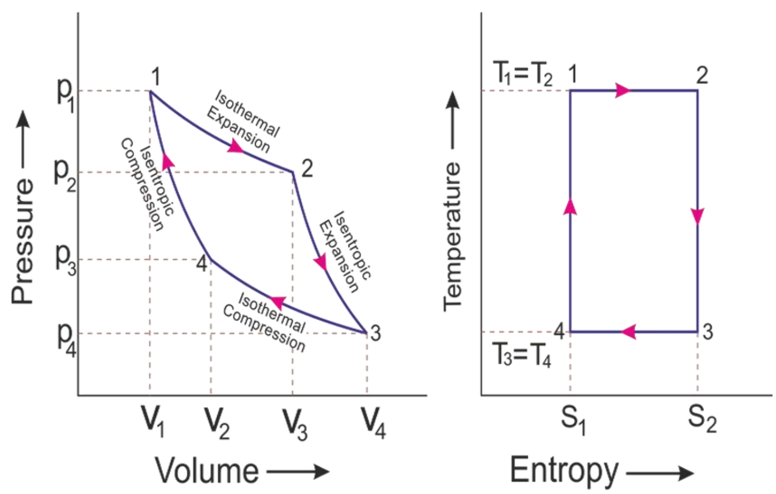
Carnot cycle:

In 1824 Carnot suggested a particular cycle of operation for a CHPP which avoided all irreversibilities.

- It consisted of four processes, two isothermal and two adiabatic.
- The process take place between a heat source at temperature (T_H) and a heat sink at temperature (T_C).
- The most efficient heat engine cycle is the Carnot cycle.

Following are the four processes of the Carnot cycle:

- The first process is reversible isothermal gas expansion. In this process, the amount of heat absorbed by the ideal gas is Q_{in} from the heat source, which is at a temperature of T_H. The gas expands and does work on the surroundings.
- The second process is reversible adiabatic gas expansion. Here, the system is thermally insulated, and the gas continues to expand and work is done on the surroundings. Now the temperature is lower, T_L.
- The third process is reversible isothermal gas compression process. Here, the heat loss Q_{Out} occurs when the surroundings do the work at temperature T_H.
- The last process is reversible adiabatic gas compression. Again the system is thermally insulated. The temperature again rises back to T_H as the surrounding continue to do their work on the gas.



(a) p-v diagram (b) T-S diagram]

Thermal Efficiency = Workdone/Amount of heat supplied
Work done (W) = Heat supplied(**Qs**) -Heat rejected(**Q_R**)

$$\text{Thermal } \eta = \frac{\text{Work done } (W)}{\text{Heat Supplied } (Q_s)} = \frac{\text{Heat Supplied} - \text{Heat Rejected}}{\text{Heat Supplied}}$$

$$\Rightarrow \eta = \frac{Q_s - Q_R}{Q_s}.$$

$$\text{Heat Supplied } 1\text{-}2;\ Q_s = P_1 V_1 \log_e\left[\frac{V_2}{V_1}\right] = mRT_1 \log_e\left[\frac{V_2}{V_1}\right]$$

$$\text{Heat Rejected } 3\text{-}4;\ Q_R = P_3 V_3 \log_e\left[\frac{V_3}{V_4}\right] = mRT_3 \log_e\left[\frac{V_3}{V_4}\right]$$

$$\left[\because \frac{V_3}{V_2} = \frac{V_4}{V_1}\right] \text{(or)}$$

$$\text{Compression ratio} = \frac{V_2}{V_1} = \frac{V_3}{V_4} = r$$

$$\eta_{th} = \frac{mRT_1 \log_e\left[\frac{V_2}{V_1}\right] - mRT_3 \log_e\left[\frac{V_3}{V_4}\right]}{mRT_1 \log_e\left[\frac{V_2}{V_1}\right]} \qquad \left[\because \frac{V_2}{V_1} = \frac{V_3}{V_4}\right]$$

$$\boxed{\eta_{th} = \left[1 - \frac{T_3}{T_1}\right]}$$

So the efficiency of carnot cycle depends upon the temperature limits (T_H & T_L)

$$\eta = 1 - \frac{T_{cold}}{T_{hot}}$$

Otto cycle:

Otto cycle is the ideal cycle for spark ignition reciprocating engines.

• Named after Nikolaus A. Otto, who built a successful four-stroke engine in 1876 in Germany.

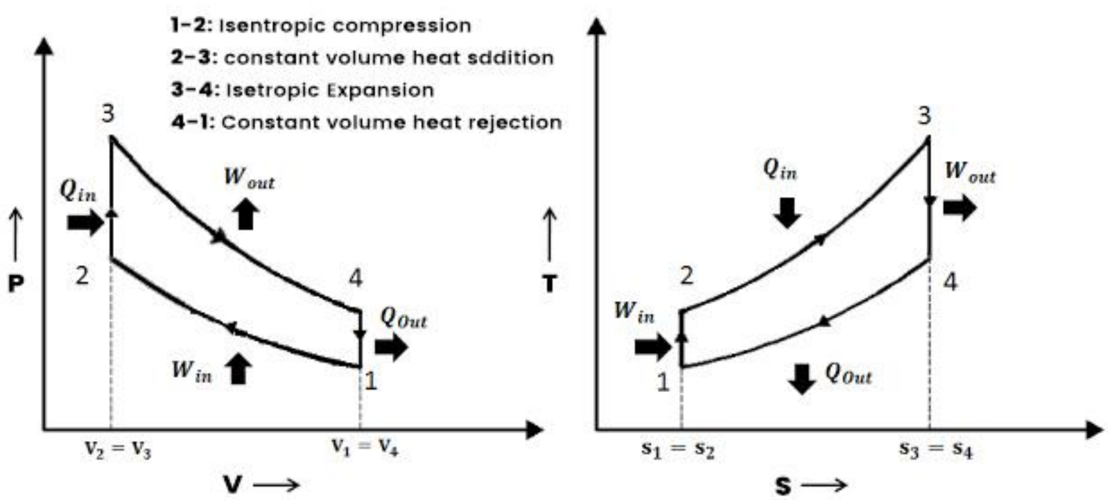
• Can be executed in two or four strokes.

• Four stroke: Intake, compression, power and exhaust stroke

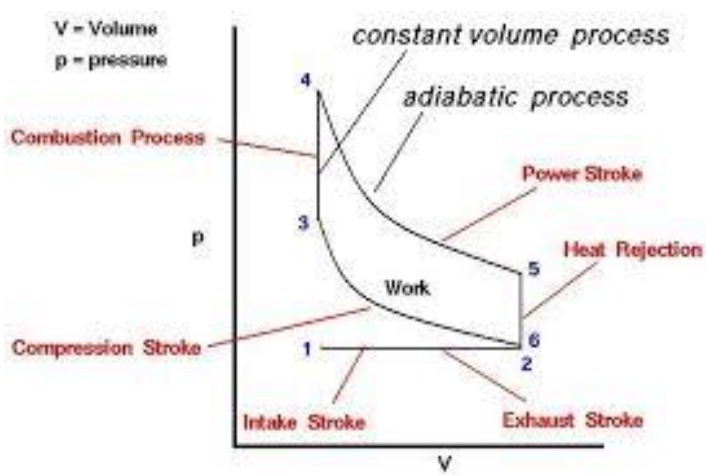
• Two stroke: Compression and power strokes.

Otto cycle consists of four processes ,all the processes are internally reversible

- Isentropic compression (1-2)
- Isochoric (constant volume) heat addition (2-3)
- Isentropic expansion (3-4)
- Isochoric (constant volume) heat rejection (4-1)



P-V and T-S Diagram of Otto Cycle



Heat supplied, $q_s = C_v(T_3 - T_2)$

Heat rejection, $q_R = C_v(T_4 - T_1)$

Compression ratio, $r_k = \frac{V_1}{V_2}$

Thermal efficiency, $\eta_{th} = \frac{q_s - q_R}{q_s} = \frac{Cv(T3-T2)-Cv(T4-T1)}{Cv(T3-T2)} = 1 - \frac{T4-T1}{T3-T2}$

In process 1-2, adiabatic compression process,

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$=> T_2 = T_1.(r_k)^{\gamma-1}$$

In adiabatic expansion process, i.e. 3-4,

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

$$=> T_3 = T_4.(r_k)^{\gamma-1}$$

$$\eta_{th} = 1 - \frac{T_4 - T_1}{T_4.(r_k)^{\gamma-1} - T_1.(r_k)^{\gamma-1}}$$

$$= 1 - \frac{1}{(r_k)^{\gamma-1}}$$

Work done (W)

Pressure ratio, $r_p = \frac{P_3}{P_2} = \frac{P_4}{P_1}$

$$\frac{P_2}{P_1} = \frac{P_3}{P_4} = \left(\frac{V_1}{V_2}\right)^{\gamma} = (r_k)^{\gamma}$$

$$W = \frac{P_3V_3 - P_4V_4}{\gamma - 1} - \frac{P_2V_2 - P_1V_1}{\gamma - 1}$$

$$= \frac{1}{\gamma - 1}\left[P_4V_4\left(\frac{P_3V_3}{P_4V_4} - 1\right) - P_1V_1\left(\frac{P_2V_2}{P_1V_1} - 1\right)\right]$$

$$= \frac{1}{\gamma - 1}[P_4V_1({r_k}^{\gamma-1} - 1) - P_1V_1({r_k}^{\gamma-1} - 1)]$$

$$= \frac{P_1V_1}{\gamma - 1}\left[r_p({r_k}^{\gamma-1} - 1) - ({r_k}^{\gamma-1} - 1)\right]$$

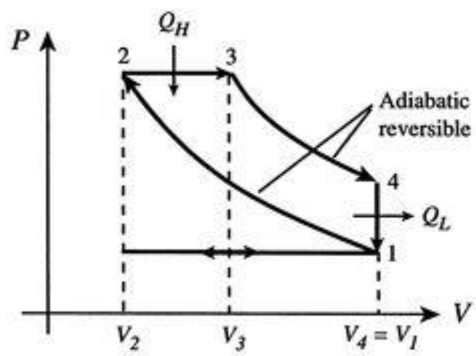
$$= \frac{P_1V_1}{\gamma - 1}\left[({r_k}^{\gamma-1} - 1)(r_p - 1)\right]$$

Mean effective pressure, $P_m = \frac{work\ done}{Swept\ volume} = \frac{work\ done}{V_1 - V_2}$

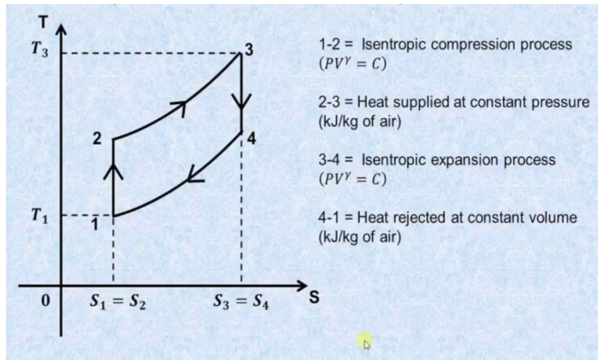
$$P_m = \frac{\frac{P_1V_1}{\gamma - 1}\left[({r_k}^{\gamma-1} - 1)(r_p - 1)\right]}{V_1 - V_2} = \frac{P_1r_k\left[({r_k}^{\gamma-1} - 1)(r_p - 1)\right]}{(\gamma - 1)(r_k - 1)}$$

Diesel cycle:

- Thermodynamic cycle for low speed CI/diesel engine -Reversible adiabatic compression and expansion process -Constant pressure heat addition (combustion) and heat rejection process (exhaust).
- This cycle can operate with a higher compression ratio than the Otto cycle because only air is compressed and there is no risk of auto-ignition of the fuel.



(P-V diagram)



(T-S diagram)

Heat supplied, $Q_1=C_p(T_3-T_2)$

Heat rejection, $Q_2=C_v(T_4-T_1)$

Compression ratio, $r_k=\frac{V_1}{V_2}$

Cut off ratio, $r_c=\frac{V_3}{V_2}$

Thermal efficiency, $\eta_{th} = \frac{Q_1-Q_2}{Q_1} = \frac{C_p(T_3-T_2)-C_v(T_4-T_1)}{C_p(T_3-T_2)} = 1 - \frac{1}{\gamma}\frac{(T_4-T_1)}{(T_3-T_2)}$

In adiabatic compression process i.e. 1-2,

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$=> T_2 = T_1.(r_k)^{\gamma-1}$$

In process 2-3, pressure constant, then

$$\frac{T_3}{T_2} = \frac{V_3}{V_2} = r_c$$

$$=> T_3 = T_2.r_c = T_1.(r_k)^{\gamma-1}.r_c$$

In adiabatic expansion process i.e. 3-4,

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{V_3}{V_2} * \frac{V_2}{V_4}\right)^{\gamma-1} = (r_c)^{\gamma-1} * \frac{1}{(r_k)^{\gamma-1}}$$

$$=> T_4 = T_3.(r_c)^{\gamma-1} * \frac{1}{(r_k)^{\gamma-1}} = T_1.(r_k)^{\gamma-1}.r_c.(r_c)^{\gamma-1} * \frac{1}{(r_k)^{\gamma-1}} = T_1.r_c$$

$$\eta_{th} = 1 - \frac{1}{\gamma}\frac{(T_4-T_1)}{(T_3-T_2)} = 1 - \frac{1}{\gamma.(r_k)^{\gamma-1}}\left[\frac{(r_c)^{\gamma}-1}{r_c-1}\right]$$

Although for a given compression ratio the Otto cycle has higher efficiency, because the Diesel engine can be operated to higher compression ratio, the engine can actually have higher efficiency than an Otto cycle when both are operated at compression ratios that might be achieved in practice.

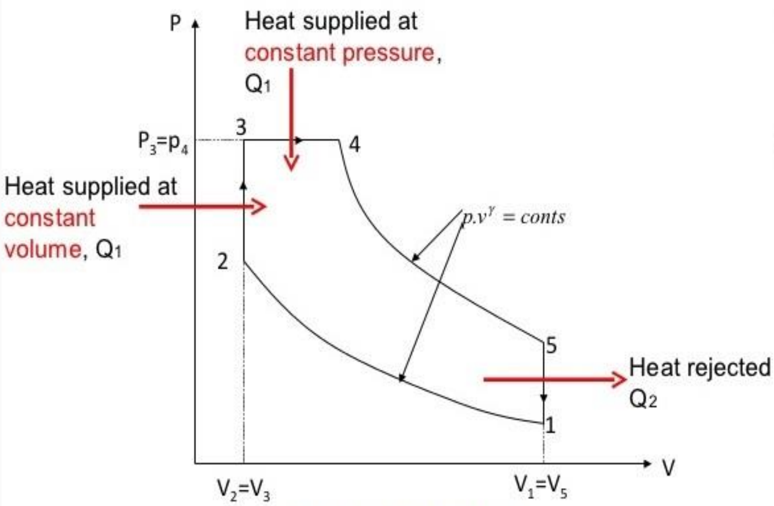
Dual combustion cycle/Dual cycle :

The combustion process in a spark ignition engine does not occur exactly at constant volume, nor does the combustion process in an actual compression ignition engine occur exactly at constant pressure, therefore another idealized cycle known as Dual cycle has been developed that more closely approximate the actual spark-ignition and compression-ignition engines.

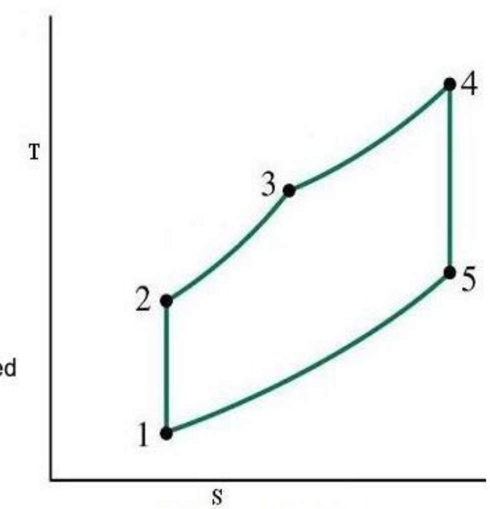
In this cycle, part of heat addition occurs at constant volume while the rest is at constant pressure. The dual cycle is also called mixed or limited pressure cycle.

The process description of Dual cycle is as below:

- Reversible adiabatic compression (1-2)
- constant volume heat addition(2-3)
- Constant pressure heat addition(3-4)
- Reversible adiabatic expansion(4-5)
- constant volume heat rejection process(5-1)



PV Diagram of Dual cycle



T-S Diagram of dual cycle

Total heat supplied, $Q_1= C_v(T_3-T_2)+ C_p(T_4-T_3)$
Heat rejection, $Q_2=C_v(T_5-T_1)$
Compression ratio, $r_k=\frac{V_1}{V_2}$
Cut off ratio, $r_c=\frac{V_4}{V_3}$
Pressure ratio, $r_p=\frac{P_3}{P_2}$

Figure 9 shows the P-V diagram of Dual cycle.

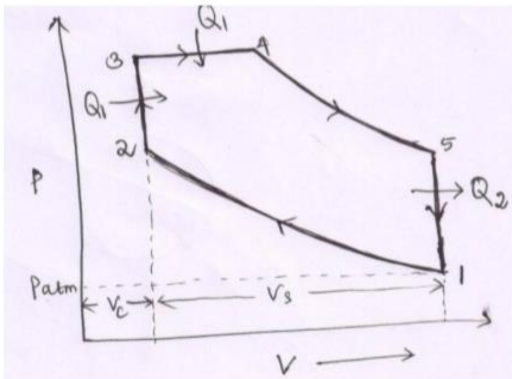


Fig. 9. Dual cycle

Thermal efficiency, $\eta_{th} = \frac{Q_1-Q_2}{Q_1} = \frac{C_v(T_3-T_2)+C_v(T_4-T_3)-C_v(T_5-T_1)}{C_v(T_3-T_2)+C_v(T_4-T_3)} = 1 - \frac{(T_5-T_1)}{(T_3-T_2)+\gamma(T_4-T_3)}$

In adiabatic compression process i.e. 1-2,

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r_k)^{\gamma-1}$$

In constant volume combustion process i.e. 2-3,

$\frac{P_3}{P_2} = \frac{T_3}{T_2} = r_p$

$$=> T_2 = \frac{T_3}{r_p}$$

In constant pressure combustion process i.e. 3-4,

$\frac{V_3}{V_4} = \frac{T_3}{T_4}$

$=> T_4 = T_3 . r_c$

In adiabatic expansion process i.e. 4-5,

$$\frac{T_4}{T_5} = \left(\frac{V_5}{V_4}\right)^{\gamma-1} = \left(\frac{V_1}{V_4}\right)^{\gamma-1} = \left(\frac{r_k}{r_c}\right)^{\gamma-1}$$

$$=> T_5 = r_c * T_3 * \left(\frac{r_c}{r_k}\right)^{\gamma-1}$$

$$\eta_{th} = 1 - \frac{(T_5 - T_1)}{(T_3 - T_2) + \gamma(T_4 - T_3)} = 1 - \frac{1}{(r_k)^{\gamma-1}}\left[\frac{r_p.(r_c)^{\gamma} - 1}{(r_p - 1) + \gamma r_p (r_c - 1)}\right]$$

<u>Work done (W)</u>

$$W = P_3(V_4 - V_3) + \frac{P_4V_4 - P_5V_5}{\gamma - 1} - \frac{P_2V_2 - P_1V_1}{\gamma - 1}$$

$$= P_3V_3(r_c - 1) + \frac{(P_4 r_c V_3 - P_5 r_k V_3) - (P_2 V_3 - P_1 r_k V_3)}{\gamma - 1}$$

$$= \frac{P_1V_1 . r_k{}^{\gamma-1}\left[\gamma r_p(r_c - 1) + (r_p - 1) - . r_k{}^{\gamma-1}(r_p r_c{}^{\gamma} - 1)\right]}{\gamma - 1}$$

Mean effective pressure,

$$P_m = \frac{\frac{P_1V_1 . r_k{}^{\gamma-1}\left[\gamma r_p(r_c - 1) + (r_p - 1) - . r_k{}^{\gamma-1}(r_p r_c{}^{\gamma} - 1)\right]}{\gamma - 1}}{V_1 - V_2}$$

$$= \frac{P_1 r_k{}^{\gamma}\left[r_p(r_c - 1) + (r_p - 1) - . r_k{}^{1-\gamma}(r_p r_c{}^{\gamma} - 1)\right]}{(\gamma - 1)(r_k - 1)}$$

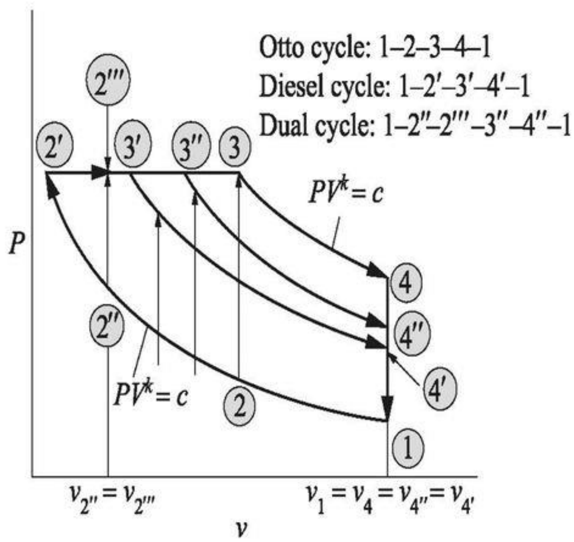
Comparison of Otto, Diesel and Dual cycles:

- **For Same Compression Ratio and Heat Rejection;**
  Efficiency$_{\text{OTTO CYCLE}}$ > Efficiency$_{\text{DUAL CYCLE}}$ > Efficiency$_{\text{DIESEL CYCLE}}$

- **For Same maximum pressure and heat input**

Comparison of Otto, Diesel and Dual Cycles

Same maximum pressure and Heat input



Let the three cycles operate with same maximum pressure and same heat input.

$$W_{net,Otto} = area\,1-2-3-4$$
$$W_{net,Diesel} = area\,1-2'-3'-4$$
$$W_{net,Dual} = area\,1-2''-2'''-3''-4''$$

It is evident that,

$$W_{net,Diesel} > W_{net,Dual} > W_{net,Otto}$$

Hence,

$$\eta_{Diesel} > \eta_{Dual} > \eta_{Otto}$$

Chapter-6

Fuels and combustion:

Fuel:

We always need a certain substance to convert one form of energy into another for accomplishing various jobs. We call such materials as fuels. In other words, any substance which upon combustion produces a usable amount of energy is known as **fuel**. Example: fossil fuels, biogas, nuclear energy, etc.

Some properties of ideal fuel are:

- An ideal fuel is readily available.
- An ideal fuel is cheap.
- An ideal fuel burns easily in the air at a moderate rate.
- It releases a large amount of energy.
- It should not leave behind any undesirable substances which can be harmful to us.
- It should not affect the environment adversely.

Types of Fuels:

Fuels can be generally classified into two factors:

1. On the basis of their fuels state:
    - Solid Fuels
    - Liquid Fuels
    - Gaseous Fuels
2. On the basis of their occurrence:
    - Natural Fuels
    - Artificial Fuels

Examples of Fuels:

Natural Fuels	Artificial Fuels
Solid Fuels	
Wood, Coal, Oil Shale	Tanbark, Bagasse, Straw, Charcoal, Coal, Briquettes

Liquid Fuels	
Petroleum	Oils from distillation of petroleum, Coal Tar, Shale-Oil, Alcohols, etc.
Gaseous Fuels	
Natural Gas	Coal gas, Producer Gas, Water Gas, Hydrogen, Acetylene, Blast Furnace Gas, Oil Gas

Solid Fuels:

Fuels which are found in their solid state at room temperature are generally referred to as Solid Fuels. They were the first kind of fuel known to be used by man, basically wood to create fire. Coal was another one of the influential fuels known to man as it leads the way for the industrial revolution, from firing furnaces to running steam engines.

Advantages:

- Easier transportation and storage.
- Low production cost.
- Moderate ignition temperature.

Disadvantages:

- Large portion of energy is wasted.
- Cost of handling is high and controlling is also hard.
- Ash content is high & burn with clinker formation.

Liquid Fuel:

Most liquid fuels are derived from the fossilized remains of dead plants and animals by exposure to heat and pressure in the Earth’s crust. The fumes of the liquid fuel are flammable instead of the liquid.

Advantages:

- Higher calorific value per unit mass.
- Burn without ash, clinkers, etc.

- Controlling the combustion is easier.
- Transportation easier through pipes and stored indefinitely without loss.
- Loss of energy is comparatively lower.
- Require less furnace space for combustion.

Disadvantages:

- Cost of liquid fuel is much higher compared to solid fuel.
- Storage methods are costlier.
- Greater risk of fire hazards.
- Special burning equipment required for more efficient combustion.

Gaseous Fuel:

Gaseous fuels occur in nature, besides being manufactured from solid and liquid fuels. Most gaseous fuels are composed of hydrocarbons, carbon monoxide, hydrogen or a mixture of them all.

Advantages:

- Transportation through pipes is easy.
- Sparking combustion is really easy.
- They have a higher heat content.
- Clean after use.
- Do Not require any special burner technology.

Disadvantages:

- Large storage tanks required.
- As they are highly inflammable, the chance for fire hazards are extremely high and strict safety measures need to be followed.

What are fossil fuels?

Fossil fuels are the dead and decayed remains of plants and animals subjected to decades of pressure and temperature under the earth’s crust. Primarily fossil fuels are hydrocarbons. They are convenient and effective. They provide the calorific value required to fulfil our needs. Even though they are available in plenty right now, they are a non-renewable source of energy. The burning of fossil fuels is responsible for a large section of the world’s pollution index.

Types of fossil fuels:

- Coal
- Oil
- Natural Gas

Nuclear Fuel:

Any material consumed to give out nuclear energy is a nuclear fuel. Technically speaking, any material can be made to give out nuclear energy. But looking at its practicality and feasibility, we pick materials which do not require extreme constraints to release nuclear energy.

Most nuclear fuels contain heavy fissile elements that are capable of nuclear fission. When these fuels are struck by neutrons, they are in turn capable of emitting neutrons when they break apart. This makes possible a self-sustaining chain reaction that releases energy at a controlled rate in a nuclear reactor or with a very rapid uncontrolled rate of a nuclear weapon.
Some common examples of nuclear fuel are uranium-235 (^{235}U) and plutonium-239 (^{239}Pu).

Heating values of fuel:

The heat value of a fuel is the amount of heat released during its combustion. Also referred to as energy or calorific value, heat value is a measure of a fuel's energy density, and is expressed in energy (joules) per specified amount (*e.g.* kilograms).

FUEL	Heating value
Hydrogen (H_2)	120-142 MJ/kg
Methane (CH_4)	50-55 MJ/kg
Methanol (CH_3OH)	22.7 MJ/kg
Dimethyl ether - DME (CH_3OCH_3)	29 MJ/kg
Petrol/gasoline	44-46 MJ/kg
Diesel fuel	42-46 MJ/kg
Crude oil	42-47 MJ/kg
Liquefied petroleum gas (LPG)	46-51 MJ/kg
Natural gas	42-55 MJ/kg
Hard black coal (IEA definition)	>23.9 MJ/kg
Hard black coal (Australia & Canada)	c. 25 MJ/kg
Sub-bituminous coal (IEA definition)	17.4-23.9 MJ/kg
Sub-bituminous coal (Australia & Canada)	c. 18 MJ/kg
Lignite/brown coal (IEA definition)	<17.4 MJ/kg
Lignite/brown coal (Australia, electricity)	c. 10 MJ/kg
Firewood (dry)	16 MJ/kg
Natural uranium, in LWR (normal reactor)	500 GJ/kg
Natural uranium, in LWR with U & Pu recycle	650 GJ/kg
Natural uranium, in FNR	28,000 GJ/kg
Uranium enriched to 3.5%, in LWR	3900 GJ/kg

Uranium figures are based on 45,000 MWd/t burn-up of 3.5% enriched U in LWR
MJ = 10^6 Joule, GJ = 10^9 J
MJ to kWh @ 33% efficiency: x 0.0926
One tonne of oil equivalent (toe) is equal to 41.868 GJ

Calorific value of fuel:

Calorific value is the amount of heat energy present in food or fuel and which is determined by the complete combustion of specified quantity at constant pressure and in normal conditions. It is also called calorific power. The unit of calorific value is kilojoule per kilogram i.e. KJ/Kg.

Fuel	**Calorific values**
Cow Dung	8000 KJ/Kg
Wood	22000 KJ/Kg
Coal	33000 KJ/Kg
Biogas	40000 KJ/Kg
Diesel	45000 KJ/Kg
kerosene	45000 KJ/Kg
Petrol	45000 KJ/Kg
Methane	50000 KJ/Kg
LPG	55000 KJ/Kg

Quality of I.C engine fuels:

Octane number:

Octane number indicates the tendency of fuels to knock. The higher the octane number the more difficult the auto-ignition.

– n-Heptane (C_7H_{16}) has a octane number 0,

– iso-octane (C_8H_{18}) has a octane number 100.

– Gasoline has a octane number 93 – 97.

Cetane number:

It can be defined as the percentage by volume of normal cetane in a mixture of normal cetane and alpha methyl naphthalene which has the same ignition characteristics as the test fuel when combustion is carried out in a standard engine under a set of specified working conditions.

Difference between octane number and cetane number:

Octane number	Cetane number
The octane number of a fuel may be defined as the percentage of iso-octane in a mixture of iso-octane and n-heptane which just matches with the knocking tendency of the fuel under test.	The cetane number of diesel oil is defined as the percentage by volume of cetane in a mixture of cetane and α-methyl naphthalene which exactly matches in its knocking characteristics with the oil under test.
The **octane Number** is a measure of the auto ignition resistance of gasoline (petrol) and other fuels used in spark-ignition internal combustion engines.	The **Cetane Number** is a measure of the combustion quality of diesel fuel under compression.
The higher the octane number, the better is the resistance of Gasoline to combustion prematurely, known as **Knocking.**	The Higher Cetane number means that the Diesel will ignite readily and, therefore, perform better in a diesel engine
Isooctane is given a maximum octane number, i.e. **100.** n-heptane is given a minimum octane number, i.e. **0.**	Cetane is given a maximum cetane number, i.e.**100** while α -methylnaphthalene is given a minimum cetane number, i.e.**0**.
Octane numbers are only used between 0 and 100. The fuels having better anti-knocking property than isooctane are rated in other scales like octane Performance.	Cetane numbers are only used for the relatively light distillate diesel oils. For heavy (residual) fuel oil two other scales are used CCAI and CII

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

THERMAL ENGINEERING-II

4TH SEMESTER

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CHAPTER-1
PERFORMANCE OF I.C. ENGINE

INTRODUCTION

- With a growing demand for transportation IC engine have gained lot of importance in automobile industry.
- It is therefore necessary to produce efficient and economical engines. While developing an IC engine it is required to take in consideration all the parameters affecting the engines design and performance.
- There are enormous parameters so it becomes difficult to account them while designing an engine. So it becomes necessary to conduct tests on the engine and determine the measures to be taken to improve the engines performance.

OBJECTIVE

- To understand the performance parameters in evaluation of IC engine performance,
- To calculate the speed of IC engine, fuel consumption, air consumption, etc.,
- To evaluate the exhaust smoke and exhaust emission.

PERFORMANCE PARAMETERS

1. Power and Mechanical Efficiency
2. Fuel Air Ratio
3. Volumetric Efficiency
4. Specific Output and specific weight
5. Specific Fuel Consumption
6. Thermal Efficiency and Heat Balance
7. Exhaust Smoke and Emissions
8. Effective Pressure and Torque

The particular application of the engine decides the relative importance of these performance parameters.

For Example: For an aircraft engine specific weight is more important whereas for an industrial engine specific fuel consumption is more important.

Power and mechanical efficiency

- An IC engine is used to produce mechanical power by combustion of fuel. Power is referred to as the rate at which work is done. Power is expressed as the product of force and linear velocity or product of torque and angular velocity. In order to measure power one needs to measure torque or force and speed. The force or torque is measured by Dynamometer and speed by Tachometer.
- The power developed by an engine and measured at the output shaft is called the **brake power (bp)** and is given by,

$$bp = \frac{2\pi N\tau}{60}$$

where:

T is the torque, in Newton meter (N.m),
N is the rotational speed, in minutes,
bp is the brake power, in watt.

However while calculating the **Mechanical efficiency** another factor called **Indicated Power (ip)** is considered. It is defined as the power developed by combustion of fuel in the engine cylinder. It is always more than brake power and is given by,

$$ip = \frac{PVNK}{60}$$

where:

P is the mean pressure,
V is the displacement volume of the piston
N is the rotational speed, in minutes
K is the number of cylinders

Therefore, the difference between ip and bp indicates the power loss in the mechanical components of engine (due to friction).

So the mechanical efficiency is defined as ratio of brake power to the indicated power.

$$E = \frac{bp}{ip} \text{ or } E = \frac{bp}{bp + fp}$$

Measurement of brake power

- The torque and the angular speed measurement of engine are involved in measurement of brake power.
- Dynamometer is used for torque measurement. The rotor of the engine which is under state is connected to stator. Rotor moves through distance $2\pi r$ against force F. Hence work done,

$$W = 2\pi rF$$

They are of two types-

1. Absorption dynamometer
2. Transmission dynamometer

1. **Absorption dynamometer**

- It absorbs and measures output power of engine. This power is dissipated in the form of heat. e.g., prony brake, hydraulic dynamometer, rope dynamometer, eddy current dynamometer, swinging field d.c. dynamometer etc.
- Absorption dynamometers are ideally suited for testing petrol engines for mopeds and electrical F.H.P. motors. Their main advantage lies in the fact that they are self-air-cooled and hence water cooling or additional air cooling is not required.

2. **Transmission dynamometer**

- In this the power is transmitted to load connected to engine. Torque meter is alternative name of this dynamometer.
- It is usually consist of strain gauge which measures the torque by angular deformation of shaft.
- These dynamometers are accurate and widely used in automatic units.

Air–fuel ratio

- It is the ratio of mass of fuel to mass or volume of air in mixture. It affects the phenomenon of combustion and used for determining flame propagation velocity, the heat released in combustion chamber. For practice always relative air fuel ratio is defined. It is the ratio of actual air–fuel ratio to that of the stoichiometric air fuel ratio required for burning of fuel which is supplied.
- Relative ratio,

$$\lambda : (A/F)=\{\text{Actual air-fuel ratio/Stoichiometric air-fuel ratio}\}$$

Volumetric efficiency

- It is the ratio of the actual volume of the charge drawn in during the suction stroke to the swept volume of the piston.
- The amount of air taken inside the cylinder is dependent on the volumetric efficiency of an engine and hence puts a limit on the

amount of fuel which can be efficiently burned and the power output.

- The value of volumetric efficiency of a normal engine lies between 70 and 80 percent, but for engines with forced induction it may be more than 100 percent.

Specific output and specific weight

- Specific output of an engine is defined as the brake power (output) per unit of piston displacement and is given by,

$$\text{Specific output} = \frac{bp}{A \times L}$$

- Specific weight is defined as the weight of the engine in kilogram for each brake power developed and is an indication of the engine bulk. Specific weight plays an important role in applications such as power plants for aircrafts.

Thermal efficiency and heat balance

- Thermal efficiency of an engine is defined as the ratio of the output to that of the chemical energy input in the form of fuel supply.
- It may be based on brake or indicated output. It is the true indication of the efficiency with which the chemical energy of fuel (input) is converted into mechanical work.

- Thermal efficiency also accounts for combustion efficiency, i.e., for the fact that whole of the chemical energy of the fuel is not converted into heat energy during combustion.

$$\text{Brake thermal efficiency} = \frac{bp}{m_f \times C_v}$$

Where,

Cv = Calorific value of fuel, kJ/kg, and
m_f = Mass of fuel supplied, kg/sec.

- The energy input to the engine goes out in various forms – a part is in the form of brake output, a part into exhaust, and the rest is taken by cooling water and the lubricating oil.
- The break-up of the total energy input into these different parts is called the heat balance.
- The main components in a heat balance are brake output, coolant losses, heat going to exhaust, radiation and other losses.
- Preparation of heat balance sheet gives us an idea about the amount of energy wasted in various parts and allows us to think of methods to reduce the losses so incurred.

Brake specific fuel consumption (BSFC)

- It is defined as the amount of fuel consumed for each unit of brake power per hour; it indicates the efficiency with which the engine develops the power from fuel. It is used to compare performance of different engines.
- The amount of fuel which an engine consumes is rated by its brake specific fuel consumption (BSFC).
- For most internal combustion engines the BSFC will be in the range of 0.5 to 0.6.
- The fuel efficiency will tend to peak at higher engine speeds. The BSFC tends to be the same for similar engines.
- The estimate of brake specific fuel consumption for two-stroke engines ranges from 0.55 to as high as 0.8 pounds of fuel per horsepower per hour.

Exhaust smoke and other emission

- Smoke and other emission are undesirable for public environment.
- Because of global warming and emphasis on air pollution all possible things are tried to keep them low.
- Smoke is an indication of incomplete combustion. It limits the output of an engine if air pollution control is the consideration.
- Here are some tips of what you can adopt as air pollution solutions:
- Air conditioning systems and electrical gadgets within the vehicle (e.g. sound system, mobile tv systems) also take up energy. So if they are not in use, turn them off.
- Keep your car in efficient working condition.
- check the pressure of your car tires regularly.
- Get rid of excess load in your car.

Mean effective pressure and torque

Mean effective pressure is an important parameter for comparing the performance of different engines. It is defined as the average pressure acting over piston throughout a power stroke. It is given by the following relation;

$$p = \frac{ip60}{LARK}$$

where: P is the Mean Effective Pressure,
ip is Indicated Power
A is the Area of the Piston
R is the Rotational Speed
K is the Number of Cylinders,
L is stroke length

- If mean effective pressure is based on brake power(bp) then it is referred to as brake mean effective pressure(bmep). If it is based on indicated power(ip) it is called indicated mean effective pressure(imep).
- Mean effective pressure also has an effect on torque. Torque could be expressed by following relation also,

$$\tau = \frac{bmepARK}{2\pi}$$

- Mean effective pressure and torque both are affected by the size of engine. A large engine produces more Torque for the same mean effective pressure. For this reason engines mean effective pressure gives indication of its displacement utilization and not torque.
- Power of an engine is dependent on its size so it is not possible to compare different engines based on their power or torque. Therefore, mean effective pressure is the true indication of the relative performance of different engines.

CHAPTER-2

AIR COMPRESSOR

Intoduction

Compressors are work absorbing devices which are used for increasing pressure of fluid at the expense of work done on fluid. The compressors used for compressing air are called air compressors. Some of popular applications of compressor are, for driving pneumatic tools and air operated equipments, spray painting, compressed air engine, supercharging in internal combustion engines, material handling (for transfer of material), surface cleaning, refrigeration and air conditioning, chemical industry etc.

Classification of Compressors

(a) ***Based on principle of operation:*** Based on the principle of operation compressors can be classified as,
(i) Positive displacement compressors
(ii) Non-positive displacement compressors

In positive displacement compressors the compression is realized by displacement of solid boundary and preventing fluid by solid boundary from flowing back in the direction of pressure gradient. Positive displacement compressors can be further classified based on the type of mechanism used for compression.
(i) Reciprocating type positive displacement compressors
(ii) Rotary type positive displacement compressors

Reciprocating compressors generally, employ piston-cylinder arrangement where displacement of piston in cylinder causes rise in pressure. **Reciprocating compressors are capable of giving large pressure ratios but the mass handling capacity is limited or small**. Reciprocating compressors may also be single acting compressor (one delivery stroke per revolution) or double acting (two delivery strokes per revolution of crank) compressor.

Rotary compressors employing positive displacement have a rotary part whose boundary causes positive displacement of fluid and thereby compression. Rotary compressors of this type are available in the names as given below;
(i) Roots blower
(ii) Vaned type compressors
(iii) Screw compressor
(iv) Scroll compressor

Non-positive displacement compressors, also called as steady flow compressors use dynamic action of solid boundary for realizing pressure rise. Non-positive displacement compressor can be classified depending upon type of flow in compressor
(i) axial flow type
(ii) centrifugal type

(b) ***Based on number of stages:*** Compressors can be single stage or multistage.
(i) Single stage compressor, for delivery pressure up to 5 bar
(ii) Two stage compressor, for delivery pressure between 5 and 35 bar
(iii) Three stage compressor, for delivery pressure between 35 and 85 bar
(iv) Four stage compressor, for delivery pressure more than 85 bar

(c) ***Based on capacity (air delivered per unit time) of compressors:***
(i) Low capacity compressors, having air delivery capacity of 0.15 m3/s or less
(ii) Medium capacity compressors, having air delivery capacity between 0.15 and 5 m3/s.
(iii) High capacity compressors, having air delivery capacity more than 5 m3/s.

(d) ***Based on highest pressure developed:*** Typical values of maximum pressure developed for different compressors are as under;
(i) Low pressure compressor, having maximum pressure up to 1 bar
(ii) Medium pressure compressor, having maximum pressure from 1 to 8 bar
(iii) High pressure compressor, having maximum pressure from 8 to 10 bar
(iv) Super high pressure compressor, having maximum pressure more than 10 bar.

RECIPROCATING COMPRESSORS

Reciprocating compressor has piston cylinder arrangement as shown in Fig. (1)

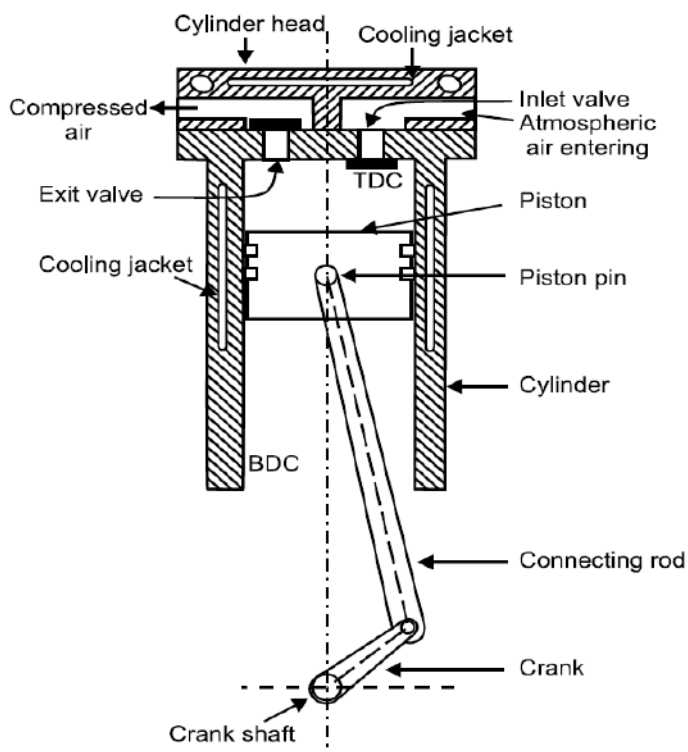


Fig. (1) Line diagram of reciprocating compressor

Construction: Reciprocating compressor has piston, cylinder, inlet valve, exit valve, connecting rod, crank, piston pin, crank pin and crank shaft. Inlet valve and exit valves may be of spring loaded type which get opened and closed due to pressure differential across them.

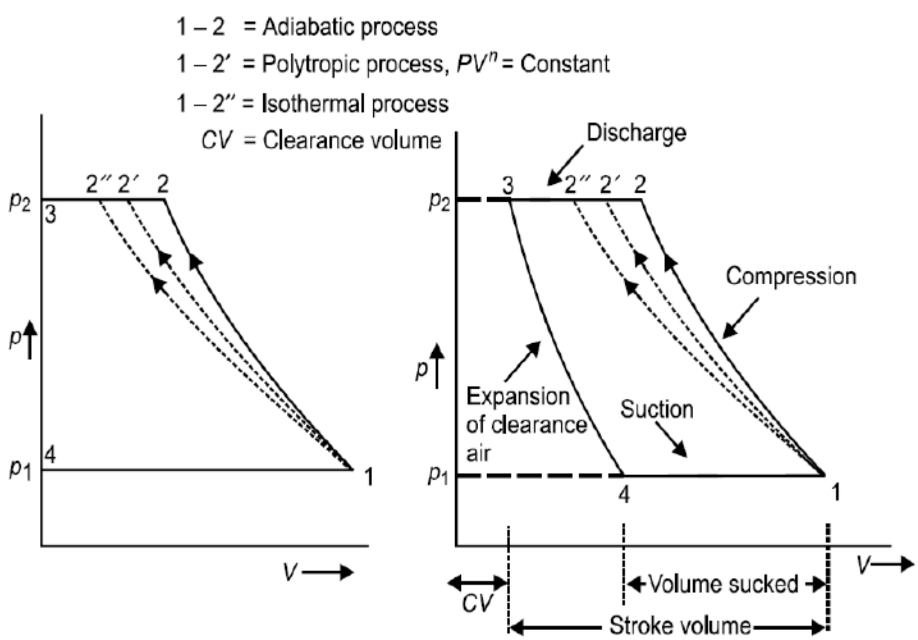
Working: Let us consider piston to be at top dead centre (TDC) and move towards bottom dead centre (BDC). Due to this piston movement from TDC to BDC suction pressure is created causing opening of inlet valve. With this opening of inlet valve and suction pressure, atmospheric air enters the cylinder. Air gets into cylinder during this stroke and is subsequently compressed in next stroke with both inlet valve and exit valve closed. After piston reaching BDC it reverses its motion and compresses the air inducted in previous stroke. Compression is continued till the pressure of air inside becomes sufficient to cause deflection in exit valve. At the moment when exit valve plate gets lifted the exhaust of compressed air takes place. This piston again reaches TDC from where downward piston movement is again accompanied by suction. This is how reciprocating compressor keeps on working as flow device.

See the working of reciprocating compressor ⟹ https://www.youtube.com/watch?v=F5Tcv8VxuG4
⟹ https://www.youtube.com/watch?v=bJluUxA7aaY

Thermodynamic Analysis of Reciprocating Compressor

Compression of air in compressor may be carried out in three different ways of thermodynamic processes such as isothermal compression, polytropic compression or adiabatic compression. Figure (2) shows the thermodynamic cycle involved in compression. Clearance volume is provided in reciprocating compressor. Purpose of clearance volume in cylinder is twofold. One is to accommodate valve mechanism and another one is to prevent collision of piston with cylinder head.

On *p*-*V* diagram process 4–1 shows the suction process followed by compression during 1–2, discharge process 2–3 and expansion of clearane air 3-4 (if clearance volume is provided).



(a) (b)

Fig. (2) Compression cycle on *p*-*V* diagram (a) without clearance volume (b) with clearance volume

Air enters compressor at pressure p_1 and is compressed up to p_2. Compression work requirement can be estimated from the area bounded by the curves comprising the cycle. Area on *p*–*V* diagram shows that work requirement shall be minimum with isothermal process $1 - 2''$. Work requirement is maximum with process 1–2 i.e. adiabatic process. As an engineer one shall attempt to minimise the requirement of compression-work. Therefore, ideally compression should occur isothermally for minimum work input. In practice, it is not possible to realise isothermal compression. Reason is maintaining constant temperature during compression is very difficult. Generally, compressors run at substantially high speed while isothermal compression requires compressor to run at very slow speed so that heat produced during compression is dissipated out and temperature remains constant. High running speed of compressor lead compression process near to adiabatic or polytropic process. It is thus obvious that actual compression process should be compared with isothermal compression process. A mathematical parameter called isothermal efficiency is defined for quantifying the degree of deviation of actual compression process (adiabatic or polytropic process) from ideal compression process (isothermal compression process). Isothermal efficiency is defined as the ratio of isothermal work to actual indicated work in reciprocating compressor.

$$Isothermal\ Efficiency = \frac{Isothermal\ Work}{Actual\ Indicated\ Work}$$

Compression process following three different processes is also shown on *T-s* diagram in Fig. (3).

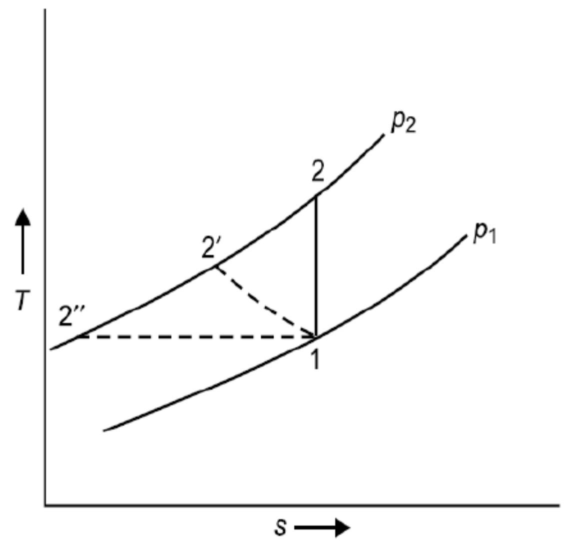


Fig. (3) Compression process on *T-S* diagram.

Compression Work, W_C (without clearance volume)- Assuming compression process follow polytropic process i.e. $pV^n = C$

$$W_c = \text{Area on } p\text{-}V \text{ diagram}$$

$$= \left[p_2V_2 + \left(\frac{p_2V_2 - p_1V_1}{n-1}\right)\right] - p_1V_1$$

$$= \left(\frac{n}{n-1}\right)[p_2V_2 - p_1V_1]$$

$$= \left(\frac{n}{n-1}\right)(p_1V_1)\left[\frac{p_2V_2}{p_1V_1} - 1\right]$$

$$W_c = \left(\frac{n}{n-1}\right)(p_1V_1)\left[\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right]$$

$$\boxed{W_c = \left(\frac{n}{n-1}\right)(mRT_1)\left[\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right]}$$

or, $$\boxed{W_c = \left(\frac{n}{n-1}\right) mR\,(T_2 - T_1)}$$

In case of compressor having isothermal compression process, *n=1* i.e. $p_1V_1 = p_2V_2$

$$W_{c,\ \text{iso}} = p_2V_2 + p_1V_1 \ln r - p_1V_1$$

$$W_{c,\ \text{iso}} = p_1V_1 \ln r, \text{ where } r = \frac{V_1}{V_2}$$

In case, compressor follow adiabatic compression process, $n = \gamma$

$$\boxed{W_{c,\ \text{adiabatic}} = \left(\frac{\gamma}{\gamma-1}\right) mR\,(T_2 - T_1)}$$

Or, $$W_{c,\ \text{adiabatic}} = mC_p\,(T_2 - T_1)$$

$$\boxed{W_{c,\ \text{adiabatic}} = m\,(h_2 - h_1)}$$

Hence isothermal efficiency

$$\boxed{\eta_{\text{iso}} = \frac{p_1V_1 \ln r}{\left(\frac{n}{n-1}\right)(p_1V_1)\left[\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right]}}$$

As an engineer one should attempt to design a compressor which efficiency approaches 100%, thereby meaning that actual work of compression should approach isothermal work of compression. This can be achieved by adopting following method

I. Provide fins over the surface of cylinder. Fins facilitate quick heat transfer from air (which is being compressed) to atmosphere.
II. Water jacket may be provided around compressor cylinder so that heat can be picked by cooling water circulating through water jacket.
III. Water may also be injected at the end of compression process in order to cool the air being compressed.
IV. In case of multistage compression in different compressors operating serially, the air leaving one compressor may be cooled up to ambient state or somewhat high temperature before being injected into subsequent compressor.

All these methods restrict the temperature rise during compression. Hence actual compression process approaches to isothermal compression.

Compression Work, W_C (with clearance volume)- With clearance volume the cycle is represented on Fig. (2-b). The work done for compression of air polytropically can be given by the area enclosed in cycle 1–2–3–4.

$$W_{c,\text{ with CV}} = \text{Area}1234$$

$$= \left(\frac{n}{n-1}\right)(p_1V_1)\left[\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right] - \left(\frac{n}{n-1}\right)(p_4V_4)\left[\left(\frac{p_3}{p_4}\right)^{\frac{(n-1)}{n}} - 1\right]$$

$$W_{c,\text{ with } CV} = \left(\frac{n}{n-1}\right)(p_1V_1)\left[\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right] - \left(\frac{n}{n-1}\right)(p_1V_4)\cdot\left[\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right]$$

$$(\because\ p_1 = p_4\ \&\ p_2 = p_3)$$

$$\boxed{W_{c,\text{ with } CV} = \left(\frac{n}{n-1}\right)p_1\cdot\left[\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right]\cdot(V_1 - V_4)}$$

This $(V_1 - V_4)$, say V_d, is actually the volume of air inhaled in the cycle and delivered subsequently.

$$\boxed{W_{c,\text{ with } CV} = \left(\frac{n}{n-1}\right)p_1V_d\left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right]}$$

Assuming air behaves as a perfect gas. Now temperature and pressure can be related as

$$\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} = \frac{T_2}{T_1} \qquad \text{And} \qquad \left(\frac{p_4}{p_3}\right)^{\frac{(n-1)}{n}} = \frac{T_4}{T_3} \Rightarrow \left(\frac{p_1}{p_2}\right)^{\frac{(n-1)}{n}} = \frac{T_4}{T_3}$$

Substituting,

$$W_{c,\text{ with } CV} = \left(\frac{n}{n-1}\right)(m_1RT_1 - m_2RT_4)\left[\frac{T_2}{T_1} - 1\right]$$

Ideally there shall be no change in temperature during suction and delivery i.e. $T_1 = T_4$ & $T_2 = T_3$. Above equation can be written as

$$W_{c,\text{ with } CV} = \left(\frac{n}{n-1}\right)(m_1RT_1 - m_2RT_1)\left[\frac{T_2 - T_1}{T_1}\right]$$

Or,

$$\boxed{W_{c,\text{ with } CV} = \left(\frac{n}{n-1}\right)(m_1 - m_2)\,R(T_2 - T_1)}$$

Where $(m_1 - m_2)$ indicates the mass of air sucked or delivered. For unit mass of air delivered the work done per kg of air can be given as,

$$\boxed{W_{c,\text{ with }CV} = \left(\frac{n}{n-1}\right) R(T_2 - T_1), \text{ per kg of air}}$$

Thus from above expressions it is obvious that the clearance volume reduces the effective swept volume i.e. the mass of air handled but the work done per kg of air delivered remains unaffected.

Power required to run the compressor
For single acting compressor,

$$\text{Power required} = \left[\left(\frac{n}{n-1}\right)p_1(V_1 - V_4)\left\{\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right\}\right] \times N$$

$$\text{for double acting compressor, power} = \left[\left(\frac{n}{n-1}\right)p_1(V_1 - V_4)\left\{\left(\frac{p_2}{p_1}\right)^{\frac{(n-1)}{n}} - 1\right\}\right] \times 2N$$

Volumetric Efficiency

It is defined as the ratio of actual volume of air sucked into the cylinder during suction stroke to the piston displacement (PD) or swept volume (V_s) of the cylinder. Volumetric efficiency of compressor is often referred to at free air conditions, i.e., temperature and pressure of the environment, which may be taken as 15°C & 101.325 kPa, if not mentioned.

Consideration for free air is necessary as otherwise the different compressors can not be compared using volumetric efficiency because specific volume or density of air varies with altitude. This concept is used for giving the capacity of compressor in terms of 'free air delivery' (FAD). "Free air delivery is the volume of air delivered being reduced to free air conditions". In case of air the free air delivery can be obtained using perfect gas equation as,

$$\frac{p_a \cdot V_a}{T_a} = \frac{p_1(V_1 - V_4)}{T_1} = \frac{p_2(V_2 - V_3)}{T_2}$$

Volumetric efficiency referred to free air conditions,

$$\eta_{vol} = \frac{\text{Volumeof air sucked referred to free air conditions (FAD)}}{\text{Swept Volume}}$$

$$= \frac{V_1 - V_4}{V_1 - V_3}$$

$$= \frac{(V_s + V_c) - V_4}{V_s}$$

Here V_c is clearance volume, $V_c = V_3$ and $V_s = V_1 - V_3$.

CHAPTER-4

STEAM GENERATOR

Introduction

A steam generator or boiler, usually, a closed vessel made of steel. Its function is to transfer the heat produced by the combustion of fuel (solid, liquid or gaseous) to water, and ultimately to generate steam. The steam produced may be supplied :

1. To an external combustion engine, i.e. steam engines and turbines.

2. At low pressures for industrial process work in cotton mills, sugar factories, breweries, etc, and

3. For producing hot water, which can be used for heating installations at much lower pressures.

Classification of steam boilers.

Though there are many classification of steam boilers, yet the following are important from the subject point of view :

1. ***According to the contents in the tube***. The steam boilers, according to the contents in the tube may be classified as :

(a) Fire tube or smoke tube boiler and

(b) Water tube boiler.

In fire tube steam boilers, the flames and hot gases, produced by the combustion of fuel, pass through the tubes (called multi-tubes) which are surrounded by water. The heat is conducted through the walls of the tubes from the hot gases to the surrounding water. Examples of fire tube boilers are : Simple vertical boiler, Cochran boiler, Lancashire boiler, Cornish boiler, Scotch marine boiler, Locomotive boiler and Velcon boiler.

In water tube steam boilers, the water is contained inside the tubes (called water tubes) which are surrounded by flames and hot gases from outside. Examples of water tube boilers are : Babcock and Wilcox boiler, Stirling boiler, La-Mont boiler, Benson boiler, Yarrow boiler and Loeffler boiler.

2. ***According to the position of the furnace***. The steam boilers, according to the position of the furnace are classified as :

(a) Internally fired boilers, and

(b) Externally fired boilers

In internally fired steam boilers, the furnace is located inside the boiler shell. Most of the fire tube steam boilers are internally fired.

In externally fired steam boilers, the furnace is arranged underneath in a brick-work setting. Water tube steam boilers are always externally fired.

3. ***According to the axis of the shell***. The steam boilers, according to the axis of the shell, may be classified as :

(a) Vertical boilers and

(b) Horizontal boilers.

In vertical steam boilers, the axis of the shell is vertical. Simple vertical boiler and Cochran boiler are vertical boilers.

In horizontal steam boilers, the axis of the shell is horizontal. Lancashire boiler, Locomotive boiler and Babcock and Wilcox boiler are horizontal boilers.

4. ***According to the number of tubes***. The steam boilers, according to the number of tubes, may be classified as :

(a) Single tube boilers and

(b) Multi tubular boilers

In single tube steam boilers there is only one fire tube or water tube. Simple vertical boiler and Cornish boiler are single tube boilers.

In Multitubular steam boilers, there are two or more fire tubes or water tubes. Lancashire boiler, Locomotive boiler, Cochran boiler, Babcock and Wilcox boiler are multitubular boilers.

5. ***According to the method circulation of water and steam***. The steam boilers, according to the method of circulation of water and steam, may be classified as :

(a) Natural circulation boilers, and

(b) Forced circulation boilers.

In natural circulation steam boilers, the circulation of water is by natural convention currents, which are set up during the heating of water. In most of the steam boilers, there is a natural circulation of water.

In forced circulation steam boilers, there is a forced circulation of water by a centrifugal pump driven by some external power. Use of forced circulation is made in high pressure boilers such as La-Mont boiler, Benson boiler, Loeffler boiler and Velcon boiler.

6. ***According to the use.*** The steam boilers, according the their use, may be classified as

(a) Stationary boilers, and

(b) Mobile boilers

The stationary steam boilers are used in power plants, and in industrial process work. These are called stationary because they do not move from one place to another.

The mobile steam boilers are those which move from one place to another. These boilers are locomotive and marine boilers.

7. ***According to the source of the heat***. The steam boilers may also be classified according to the source of heat supplied for producing steam. The sources maybe the combustion of solid, liquid or gaseous fuel, hot waste gases as by-products of other chemical processes, electrical energy or nuclear energy etc.

Cochran Boiler or Vertical Multitubular Boiler

These are various designs of vertical multitubular boilers, A Cochran boiler is considered to be one of the most efficient type of such boilers. It is an improved type of simple vertical boiler.

This boiler consists of an external cylindrical shell and a fire box as shown in Fig. The shell and fire box are both hemispherical. The hemispherical crown of the boiler shell gives pressure of steam and strength to withstand the pressure of steam inside the boiler. The hemispherical crown of the fire box is also advantageous for resisting intense heat. The fire box and the combustion chamber is connected through a short pipe. The flue gases from the combustion chamber flow to the smoke box through a number of smoke tubes. Then tubes generally have 62.5 mm external diameter and are 165 in number. The gases from the smoke box pass to the atmosphere through a chimney. The combustion chamber is lined with fire bricks on the shell side. A manhole near the top of the crown on the shell is provided for cleaning.

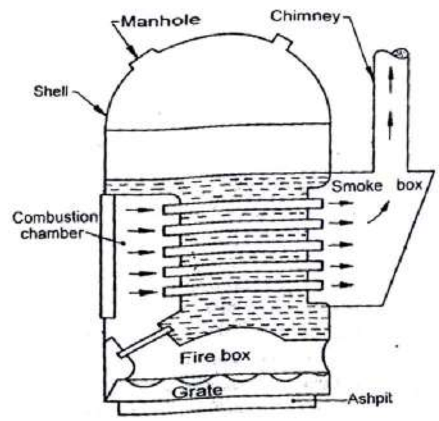


Fig. Cochran Boiler

At the bottom of the fire box, there is a grate (in case of coal firing) and the coal is fed through the fire hole. If the boiler is used for oil firing, no grate is provided, but the bottom of the fire box is lined with firebricks. The oil burner is fitted at the fire hole.

Babcock and Wilcox Boiler

It is a straight tube, stationary type water tube boiler, as show in Fig. It consist of a stem and water drum (1). It is connected by a short tube with uptake header or riser (2) at the back end.

The water tubes (5) (100mm diameter) are inclined to the horizontal and connects the uptake head to the down take header. Each row of the tubes is connected with two headers, and there are plenty of such rows. The headers are curved when viewed in the direction of tubes so that one tube is not in the space of other, and hot gases can pass properly after heating all the tubes. The headers are provided with hand holes in the front of the tubes and are covered with caps (18).

A mud box (6) is provided with each down take header and the mud, that settles down is removed. There is slow moving automatic chain grate on which the coal is fed from the hopper (21). A fire bricks baffle causes hot gases to move upwards and downwards and again upwards before entering shell by a chain (22) which passes over a pulley to the boiler is suspended on steel girders, and surrender on all the four sides by fire brick walls. The doors (4) are provided for a man

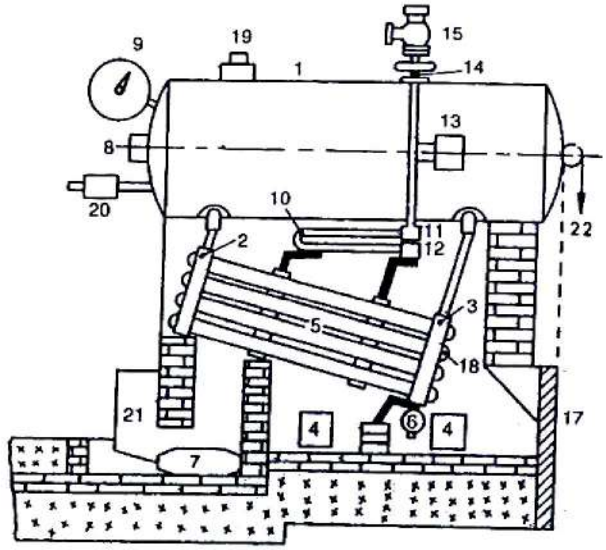


Fig. Babcock and Wilcox Boiler

to enter the boiler for repairing and cleaning. Water circulates from the drum (1) into the header (2) and through the tubes (5) to header (3) and again to the drum. Water continues to circulate like this till it is evaporated. A steam superheater consists of a large number of steel tubes (1) and contains two boxes; one is superheated steam box (11) and other is saturated steam box (12).

The steam generated above the water level in the drum flows in the dry pipe (13) and through the inlet tubes into the superheated steam box (11). It then passes through the tubes (10) into the becomes superheated. The steam, during the passage through tubes (10), gets further heated and through the outlet pipe (14) to the stop valve (15).

The boiler is fitted with usual mountings, such as safely vale (19), feed valve (20), water level indicator (8) and pressure gauge (9).

Comparison between Water and Fire Tube boilers

Following are the few points of comparison between a water tube and a fire tube boiler.

	Water tube boiler	Fire tube boiler
1.	The water circulates inside the tubes which are surrounded by hot gases from the furnace.	The hot gases from the furnance the furnace pass through the tubes which are surrounded by water.
2.	It generates steam at a higher pressure upto 165 bar.	It can generation of steam only up to 24.5 bar.
3.	The rate of generation of steam is high i.e. upto 450 tonnes per hour.	The rate of generation of steam is low, i.e. upto 9 tonnes per hour.
4.	For a given power, the floor area required for the generation of steam is less, i.e. about 5 m^2 per tone per hour of steam generation.	The floor area required is more, i.e. about 8m^2 per tonne per hour of steam generation.
5.	Overall efficiency with economizer is upto 90%.	Its overall efficiency is only 75%.
6.	It can be transported and erected easily as its various parts can be separted.	The transportation and erection is difficult.
7.	It is preferred for widely fluctuating loads.	It can also cope reasonably with sudden increase in load but for a shorter period.
8.	The direction of water circulation is well defined.	The water does not circulate is a definite direction.
9.	The operating cost is high.	The operating cost is less.
10.	The bursting chance are more.	The bursting chances are less.
11.	The bursting does not produce any destruction to the whole boiler.	The bursting produces greater risk to the damage of the property.
12.	It is used for large power plants.	It is not suitable for large plants.

Boiler Mountings and Accessories

Introduction

Boiler mountings and accessories are reuiqred for the proper and satisfactory functioning of the steam boilers. Now in this chapter, we shall discuss these fittings and appliances which are commonly used these days.

Boiler Mountings

These are the fittings, which are mounted on the boiler for its proper and safe functioning. Though there are many types of boiler mountings, yet the following are important from the subject point of view :

1. Water level indicator
2. Pressure gauge
3. Safety valves
4. Stop valve
5. Blow off cock
6. Feed check valve and
7. Fusible plug

1. Water level indicator

It is important fitting, which indicates the water level inside the boiler to an observer. It is a safety device upon which the correct working of the boiler depends. This fitting may be seen in front of the boiler, and are generally two in number.

A water level indicator, mostly employed in the steam boiler is shown in Fig.   It consists of the cocks and a glass tube. Steam cock C_1 Keeps the glass tube in connection with the steam space. Water cook C_2 Puts the glass tube in connection with the water in the boiler. Drain cock C_3 is used at frequent intervals to ascertain that the steam and water cocks are clear.

In the working of a steam boiler and for the proper functioning of the water level indicator, the steam and water cocks are opened and the drain cock is closed. In this case, the handles are place in a vertical position as shown in Fig. The rectangular passage at the ends of the glass tube contains two balls.

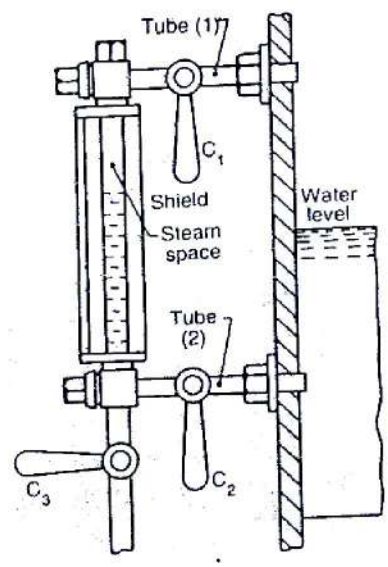


Fig.   Water level indicator

In case the glass tube is broken, the two balls are carried along its passages to the ends of the glass tube. It is thus obvious, that water and steam will not escape out. The glass tube can be easily replaced by closing the steam and water cocks and opening the drain cock.

When the steam boiler is not working, the bolts may be removed for cleaning. The glass tube is kept free from leaking by means of conical ring and the gland nut.

2. **Pressure gauge**

A pressure gauge is used to measure the pressure of the steam inside the steam boiler. It is fixed in front of the steam boiler. The pressure gauges generally used are of bourden type.

A bourden pressure gauge, in its simplest form, consists of an elliptical elastic tube ABC bent into an arc of a circle, as shown in Fig. This bent up tube is called bourden's tube.

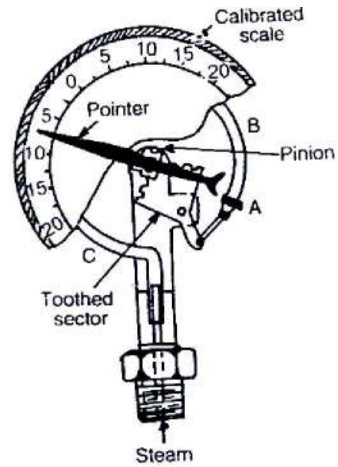


Fig. Water level indicator

One end of the tube gauge is fixed and connected to the steam space in the boiler. The other end is connected to a sector through a link. The steam, under pressure, flows into the tube. As a result of this increase pressure, the bourden's tube tends to straighten itself. Since the tube is encased in a circular curve, therefore it tends to become circular instead of straight. With the help of a simple pinion and sector arrangement, the elastic deformation of the bourdens tube rotates the pointer. This pointer moves over a calibrated scale, which directly gives the gauge pressure.

3. **Safety valves**

These are the devices to the steam chest for preventing explosions due to excessive internal pressure of steam. A steam boiler is, usually, provided with two safety valves. These are directly placed on the boiler. In brief, the function of a safety valve is to blow off the steam when the pressure of steam inside the boiler exceeds the working pressure. The following are the four types of safety valves :

(i) Lever safety valve,

(ii) Dead weight safety valve

(iii) High steam and low water safety valve

(iv) Spring loaded safety valve.

It may be noted that the first three types of the safety valves are usually employed with stationary boilers, but the fourth type is mainly used for locomotive and marine boilers.

(i) Lever safety valve

A lever safety valve used on steam boiler is shown Fig. It serves the purpose of maintaining constant safe pressure inside the steam boiler. If the pressure inside the boiler exceeds the designed limit, the valve lifts from its seat and blows off the steam pressure automatically.

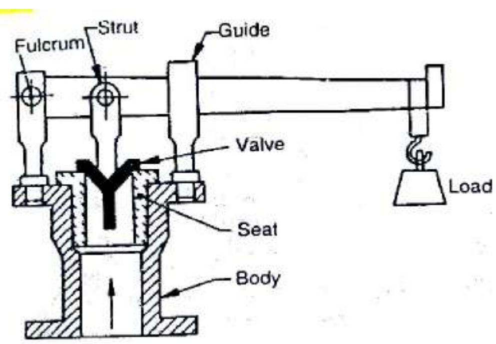


Fig. Lever safety valve

A lever safety valve consists of a valve body with a flange fixed to the steam boiler. The bronze valve seat is screwed to the body, and the valve is also made of bronze. It may be noted that by using the valve and seat of the same material, rusting is considerably reduced. The thrust on the valve is transmitted by the strut. The guide keeps the lever in a vertical plane. The load is properly adjusted at the other end of the lever.

(ii) Dead weight safety valve

A dead weight safely valve, used for stationary boilers, is shown in Fig. The valve is made of gun metal, and rests on its gun metal seat. It is fixed to the top of a steel pipe. This pipe is bolted to the mountings block, riveted to the top of the shell. Both the valve and the pipe are covered by a case which contains weights. These weights keep the valve on its seat under normal working pressure. The case hangs freely over the valve to which it is secured by means of a nut.

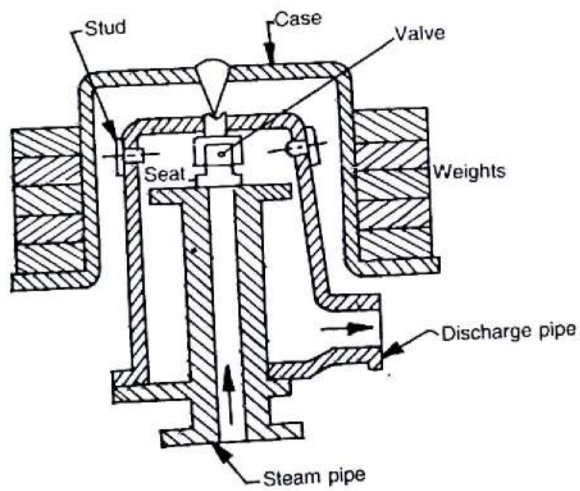


Fig. Dead weight safety valve

When the pressure of steam exceeds the normal pressure, the valve as well as the case (along with the weights) are lifted up from its seat. This enables the steam to escape through the discharge pipe, which carries the steam outside the boiler house.

The lift of the valve is controlled by the studs. The head of the studs projects into the interior of the casing. The centre of gravity of the dead weight safety valve is considerably below the valve which ensures that the load hangs vertically.

The dead weight safety valve has the advantage that it cannot be readily tempered because any added weight be equal to the total increases pressure of steam on the valve. The only disadvantage of these valves, is the heavy which these valves carry.

(iii) High steam and low water safety valve

These valves are placed at the top of Cornish and Lancashire boilers. It is combination of two valves, one of which is the lever safety valve which blows off steam when the working pressure of steam exceeds. The second valve operates blowing off the steam when the water level becomes too low.

A best known combination of high steam low water safety valve is shown in Fig. It consists of a main valve (known as lever safety valve) and rests on its seat. In the centre of the main valve, a seat for a hemispherical valve is formed for low water operation. This valve is loaded directly by the dead weights attached to the valve by a long rod. There is a lever J.K, which has its fulcrum at K. the lever has weight E suspended at the K. when it is fully immersed in water, it is balanced by a weight F at the other end J of the lever.

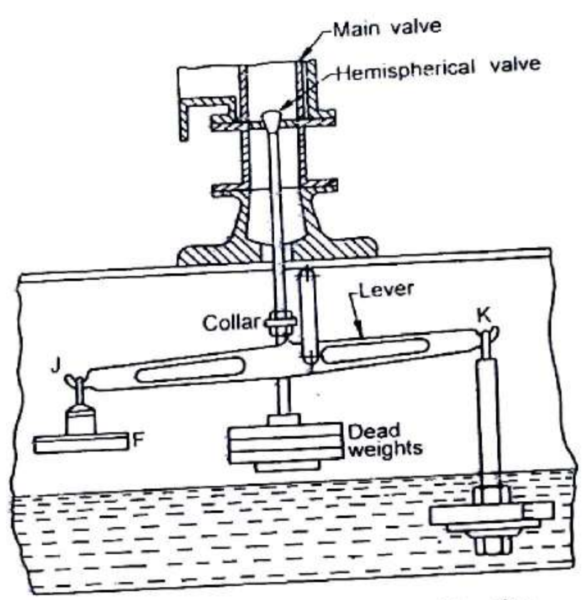


Fig. High steam and low water safety valve

When the water level falls, the weight E comes out of water and the weight F will not be sufficient to balance weight E. Therefore weight E comes down. There are two projections on the lever to the left of the fulcrum which comes in contact with a collar attached to the rod. When weight E comes down, the hemispherical valve is lifted up and the steam escapes with a loud noise, which warns the operator. A drain pipe is provided to carry water, which is deposited in the valve casing.

(iv) Spring loaded safety valve.

A spring loaded safety valve is mainly used for locomotives and marine boilers. It is loaded with spring instead of weights. The spring is made of round or square spring steel rod in helical form. The spring may be in tension or compression, as the steam pressure acts along the axis of the spring. In actual practice, the spring is placed in compression.

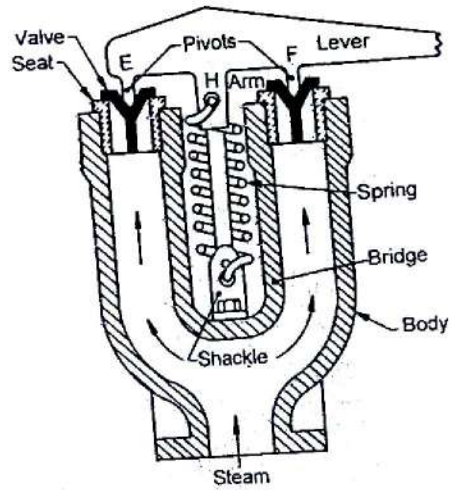


Fig. Spring loaded safety valve

A Ramsbottom spring loaded safety valve is shown in Fig. It I, usually, fitted to locomotives. It consists of a cast iron body connected to the top of a boiler. It has two separate valves of the same size. These valves have their seating's in the upper ends of two hallow valve chests. These valve chests are united by a bridge and a base. The base is bolted to a mounting block on the top of a boiler over the fire box.

The valves are held down by means of a spring and a lever. The lever has two pivots E and F. the pivot E is joined by a pin to the lever, while the pivot F is forged on the lever. These pivots rest on the centre's of the valves. The upper end of the spring is hooked to the arm H, while the lower end of the shackle, which is secured to the bridge by a nut. The spring has two safety links, one behind the other, or one either side of the lever connected by pins at the ends. The lower pin passes through the shackle while the upper one passes through slot in arm H of the lever. The lever has an extension, which projects into the driver's cabin. By pulling or raising the lever, the driver can release the pressure from either valve separately.

4. Steam Stop valve

It is the largest valve on the steam boiler. It is, usually, fitted to the highest part of the shell by means of a flange as shown in Fig. The principal functions of a stop valve are :

1. To control the flow of steam from the boiler to the main stream pipe.

2. To shut off the steam completely when required.

The body of the stop valve is made of cast iron or cast steel. The valve, valve seat and the nut through which the valve spindle works, are made of brass or gun metal.

The spindle passes through a gland and stuffing box. The spindle is rotated by means of a hand wheel. The upper

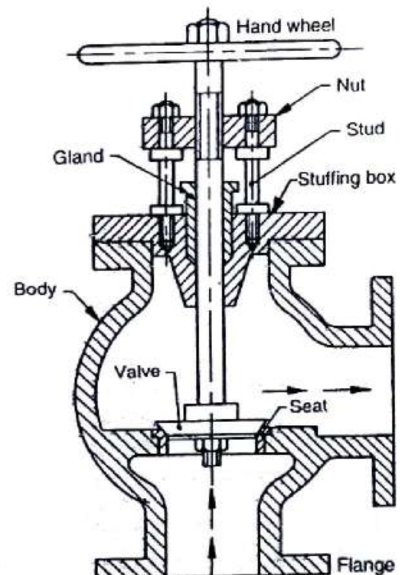


Fig. Steam Stop valve

portion of the spindle is screwed and made to pass through a nut in across head carried by two pillars. The pillars are screwed in the cover of the body as shown in the figure. The boiler pressure acts under the valve, so that the valve must be closed against the pressure. The valve is, gen¬erally, fastened to the spindle which lifts it up.

A non-return valve is, sometimes, fitted near the stop valve to prevent the acciden¬tal admission of steam from other boilers. This happens when a number of boilers are con¬nected to the same pipe, and when one is empty and under repair.

5. Blow off cock

The principal functions of a blow-off cock are :

3. To empty the boiler whenever requited.

4. To discharge the mud, scale or sediments which are accumulated at the bottom of the boiler.

The blow-off cock, as shown in Fig. , is fitted to the bottom of a boiler drum and consists of a conical plug fitted to the body or casing. The casing is packed, with asbestos packing, in grooves round the top and bottom of the plug. The asbestos packing is made tight and plug bears on the packing. It may be noted that the cocks packed in this way keep the grip better under high pressure and easily operated than unpacked.

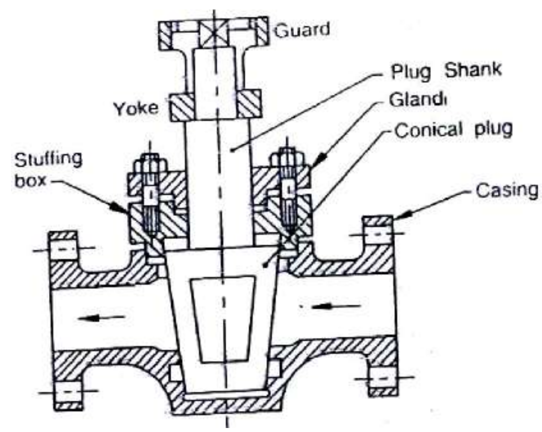


Fig. Blow off cock

The shank of plug passes through a gland and stuffing box in the cover. The plug is held down by a yoke and two stud bolts (not shown in the figure). The yoke forms a guard on it. There are two vertical slots on the inside of a guard for the box spanner to be used for operating the cock.

6. Feed check valve

It is a non-return valve, fitted to a screwed spindle to regulate the lift. Its function is to regulate the supply of water, which is pumped into the boiler, by the feed pump. This valve must have its spindle lifted before the pump is started. It is fitted to the shell slightly below the normal water level of the boiler.

A feed check valve for marine boilers is shown in Fig. . It consists of a valve whose lift is controlled by a spindle and hand wheel. The body of the valve is made of brass casting and except spindle, its every part is made of brass. The spindle is made of muntz metal. A flange is bolted to the end of boiler at a point from which perforated pipe leads the feed water. This pipe distributes the water in the boiler uniformly.

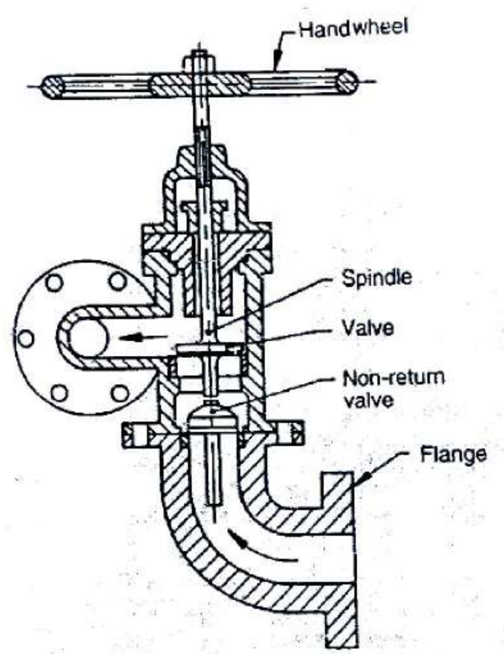


Fig. Feed check valve and

7. Fusible plug

It is fitted to the crown plate of the furnace or the fire box. Its object is to put off the fire in the furnace of the boiler when the level of water in the boiler falls to an unsafe limit, and thus avoids the explosion which may take place due to overheating of the furnace plate.

A fusible plug consists of a hollow gun metal plug P, as shown in Fig. It is screwed to the furnace crown. A second hollow gun metal plug P2 is screwed to the first plug. There is also a third hollow gun metal plug P3 separated from P, by a ring of fusible metal. The inner surface of P2 and outer surface of P3 are grooved so that when the fusible metal is poured into the plug, P2 and P3 are locked together. A hexagonal flange is provided on plug P, to take a spanner for fixing or removing the plug Pr There is a hexagonal flange on plug P2 for fixing or removing it. The fusible metal is protected from fire by the flange on the lower end of plug P2. There is also a contact at the top between P2 and P3 so that the fusible metal is completely enclosed.

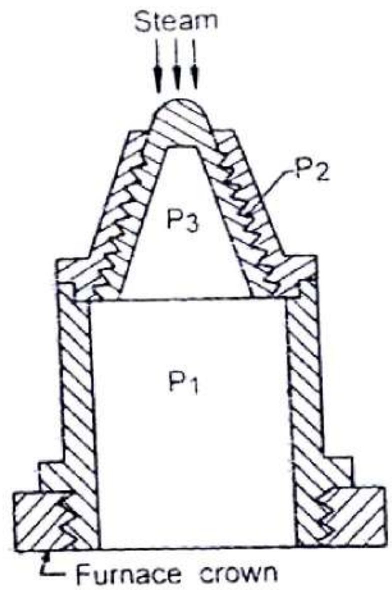


Fig. Fusible plug

The fusible plugs must be kept in a good condition and replaced annually. A fusible plug must not be refilled with anything except fusible metal.

Boiler Accessories

These are the devices which are used as integral parts of a boiler, and help in running efficiently. Though there are many types of boiler accessories, yet the following are important from the subject point of view :

1. Feed pump
2. Superheater
3. Economiser and
4. Air Preheater

Fig. shows the schematic diagram of a boiler plant with the above mentioned accessories.

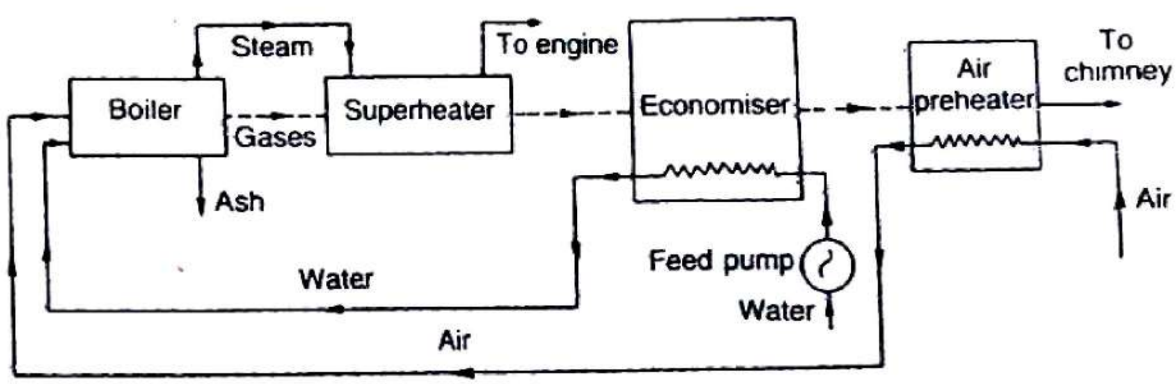


Fig. schematic diagram of a boiler plant

1. Feed Pump

We know that water, in a boiler, is continuously converted into steam, which is used by the engine. Thus we need a feed pump to deliver water to the boiler.

The pressure of steam inside a boiler is high. So the pressure of feed water has to be increased proportionately before it is made to enter the boiler. Generally, the pressure of feed water is 20% more than that in the boiler.

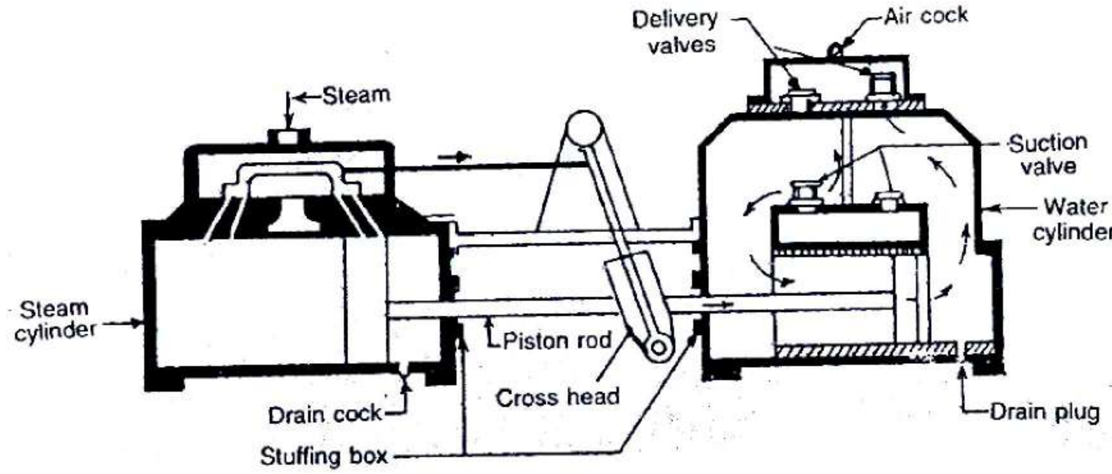


Fig. Duplex feed Pump

A feed pump may be of centrifugal type or reciprocating type. But a double acting reciprocat¬ing pump is commonly used as a feed pump these days. The reciprocating pumps are run by the steam from the same boiler in which water is to be fed. These pumps may be classified as simplex, duplex and triplex pumps according to the number of pump cylinders. The common type of pump used is a duplex feed pump, as shown in Fig. This pump has two sets of suction and delivery valves for forward and backward stroke. The two pumps work alternately so as to ensure continuous supply of feed water.

2. Superheater

A superheater is an important device of a steam generating unit. Its purpose is to increase the temperature of saturated steam without raising its pressure. It is generally an integral part of a boiler, and is placed in the path of hot flue gases from the furnace. The heat, given up by these flue gases, is used in superheating the steam. Such superheaters, which are installed within the boiler, are known as integral superheaters.

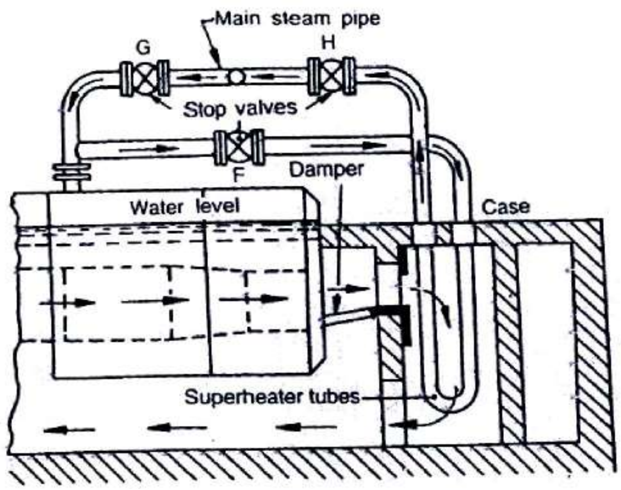


Fig. Superheater

A Sudgen's superheater commonly employed with Lancashire boilers is shown in Fig. It consists of two mild steel boxes or heaters from which hangs a group of solid drawn tubes bent to U-form. The ends of these tubes are expanded into the headers. The tubes are arranged in groups of four and one pair of headers generally carries ten of these groups or forty tubes in all. The outside of the tubes can be cleaned through the space between the headers. This space is closed by covers.

The steam enters at one end of the rear header and leaves at the opposite end of the front header. The overheating of superheater tubes is prevented by the use of a balanced damper which is operated by the handle. The superheater is in action when the damper is in a position as shown in the figure. If the damper is in vertical position, the gases pass directly into the bottom flue without passing over the superheater tubes. In this way, the superheater is out of action. By placing the damper in intermediate position, some of the gases will pass over the superheater tubes and the remainder will pass directly to the bottom flue. It is thus obvious, that required degree of heat for superheating may be obtained by altering the position of the damper.

It may be noted that when the superheater is in action, the stop valves G and H are opened and F is closed. When the steam is taken directly from the boiler, the valves G and H are closed and F is open.

3. Economiser

An economiser is a device used to heat teed water by utilising the heat in the exhaust Hue gases before leaving through the chimney. As the name indicates, the economiser improves the economy of the steam boiler.

A well known type of economiser is Greens economiser. It is extensively used for stationary boilers, especially those of Lancashire type. It consists of a large number of vertical pipes or tubes placed in an enlargement of the flue gases between the boiler and chimney as shown in Fig. These tubes are 2.75 meters long, 114 mm in external diameter and 11.5 mm thick and are made of cast iron.

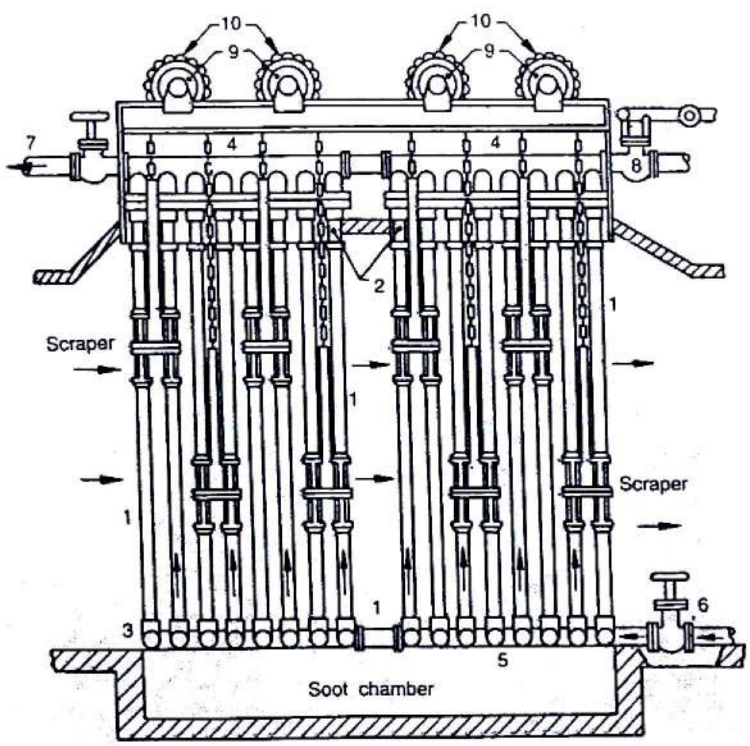


Fig. Economiser

The economiser is built-up of transverse section. Each section consists of generally six or eight vertical tubes (1). These tubes are joined to horizontal pipes or boxes (2) and (3) at the top and bottom respectively. The top boxes (2) of the different sections are connected to the pipe (4), while the bottom boxes are connected to pipe (5). The pipes (4) and (5) are on opposite sides, which are outside the brickwork enclosing the economiser.

The feed water is pumped into the economiser at (6) and enters the pipe (5). It then passes into the bottom boxes (3) and then into the top boxes (2) through the tubes (1). It is now led by the pipe (4) to the pipe (7) and then to the boiler. There is a blow-off cock at the end.of the pipe (5) opposite to the feed inlet (6). The purpose of this valve is to remove mud or sediment deposited in the bottom boxes. At the end of pipe (4) (opposite to the feed outlet) there is a safety valve.

It is essential that the vertical tubes may be kept free from deposits of soot, which greatly affect efficiencies of the economiser. Each tube is provided with scraper for this purpose. The scrapers of two adjoining sections of tubes are grouped together, and coupled by rods and chains to the adjacent group of scrapers. The chain passes over a pulley (9) so that one group of scrapers balance the adjacent group. The pulley (9) of each chain is connected to a worm wheel (10) which is driven by a worm on a longitudinal shaft (not shown in the figure). The scrapers automatically reverse when they reach the top or bottom end of the tubes. These are kept in motion continuously when the economiser is in use. The speed of scraper is about 46 m/h.

It may be noted that the temperature of feed should not be less than about 35° C, otherwise there is a danger of corrosion due to the moisture in the flue gases being deposited in cold tubes. Following are the advantages of using an economiser

4. There is about 15 to 20% of coal saving.

5. It increases the steam raising capacity of a boiler because it shortens the time required to convert water into steam.

6. It prevents formation of scale in boiler water tubes, because the scale tormed in the economiser tubes, can be cleaned easily.

7. Since the feed water entering the boiler is hot, therefore strains due to unequal expansion are minimised.

4. Air Preheater

An air preheater is used to recover heat from the exhaust flue gases. It is installed between the economiser and the chimney. The air required for the purpose of combustion is drawn through the air preheater where its temperature is raised. It is then passed through ducts to the furnace. The air is passed through the tubes of the heater internally while the hot flue gases are passed over the outside of the tubes.

The following advantages are obtained by using an air preheater:

1. The preheated air gives higher furnace temperature which results in more heat transfer to the water and thus increases the evaporative capacity per kg of fuel.

2. There is an increase of about 2% in the boiler efficiency for each 35-40° C rise in temperature of air.

3. It results in better combustion with less soot, smoke and ash.

It enables a low grade fuel to be burnt with less excess air.

CHAPTER-5

STEAM POWER CYCLE

STEAM POWER PLANT CYCLE:

Water is the working fluid here. It undergoes a change of phase in the course of cycle. Energy is released by the continuous burning of the fuel in the combustion chamber of a steam generation plant that includes a boiler and superheater. The working fluid is charged to the boiler via a BFW feed pump. Heat is transferred to the water in the boiler whereupon a high pressure and high temp saturated steam is generated in the boiler. The dry saturated HP steam is converted into a HP superheated steam in the super heater.

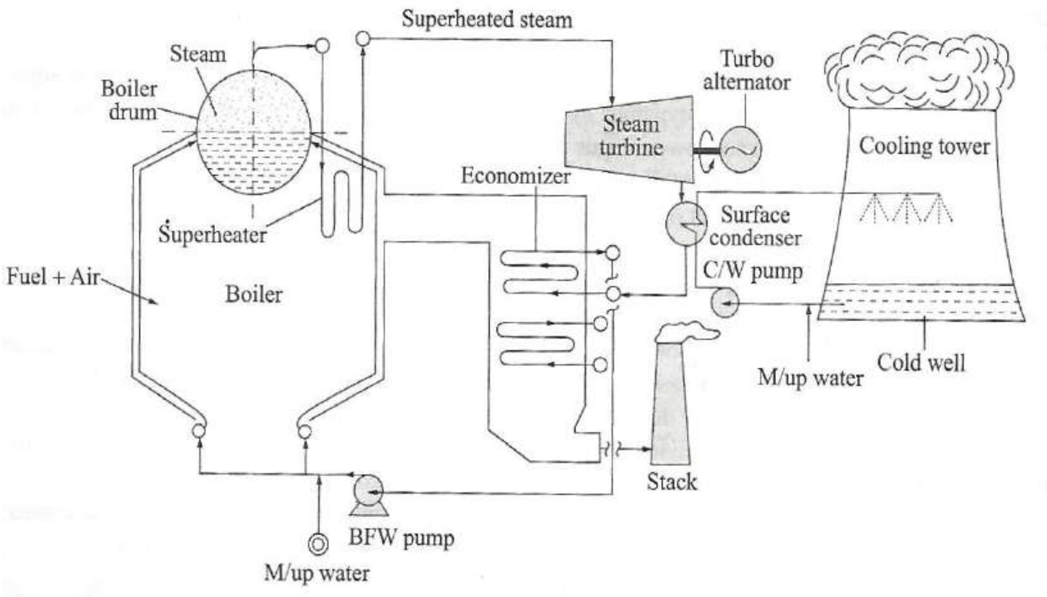
The high pressure and high temperature superheated steam is then allowed to expand through the steam turbine. As the steam passes over the blades of the turbine, it sheds its enthalpy which is converted into shaft work of the turbine which then generates power from the turbo alternator coupled to the turbine.

The steam after expansion in the ST is exhausted into a total condenser which is essentially a water steam heat exchanger wherein the exhaust steam is condensed into a condensate only to be recycled to the boiler via the boiler feed pump.

So a simple steam power cycle comprises a boiler + turbine + condenser + BFW pump where water is acting as the working fluid.`

Sometimes a vapour power cycle is referred to as a pressure limited cycle indicating the power plant operates between two pressure limits:

- The higher pressure limit is the boiler pressure
- The lower pressure limit is the condenser pressure.



As the case of first approximation, the steam power plant cycle is idealized as a quasi- static process approximating an ideal heat engine cycle:

$$\sum_{cycle} \text{Qnet} = \sum_{cycle} \text{Wnet}$$

Or $Q_1 - Q_2 = W_T - W_P$

Where Q_1= the heat input to water in the SGP(BFW preheater +boiler + superheater) in $kj\,.\,kg^{-1}$

Q_2 = the heat rejected from the working fluid (in the surface condenser) $kj\,.\,kg^{-1}$

W_T = the work output(the shaft work of the steam turbine) $kj\,.\,kg^{-1}$

W_P = the mechanical work input(the BFW pump work) $kj\ .kg^{-1}$

The efficiency of the ideal vapour power cycle,η_{cycle} = $\frac{\sum Wnet}{Q1}$

Thermal efficiency (η) :

Thermal efficiency is an important index of performance of a heat engine or steam power plant cycle. It is obtained from the first law: η = $\frac{w}{Qinput}$

CARNOTS CYCLE:

An ideal vapour power cycle would follow a carnot vapour cycle that comprises two iso-thermal and two adiabatic processes. In the vapour cycle ,the working substances changes phases .these are attainable by two internally reversible isothermal processes in the form of boiling of the liquid and condensation of the vapour. But, the heat transfer from a high temp. reservoir as well as from the condensing vapour to a low temp. reservoir will remain externally irreversible.

Process 4-1:

Isothermal heat addition to the water. The water is converted into a dry saturated steam
Heat added = Qadd

Process1-2:

Isentropic expansion of the steam in the steam turbine i.e; the steam is expanding adiabatically.

Heat interaction is nil,   positive work output=W

Process2-3:

Isothermal heat rejection. Heat is extracted from the waste steam exhausted by the steam turbine to the condenser,

Heat rejected = Qrej

Process 3-4:

The steam water mixture is pumped to the boiler.

Input work = pump work = Wp

Net work output Wnet = Woutput - Wp

Therefore, efficiency, $\eta = \frac{Wnet}{Qadd} = \frac{Qadd - Qrej}{Qadd}$

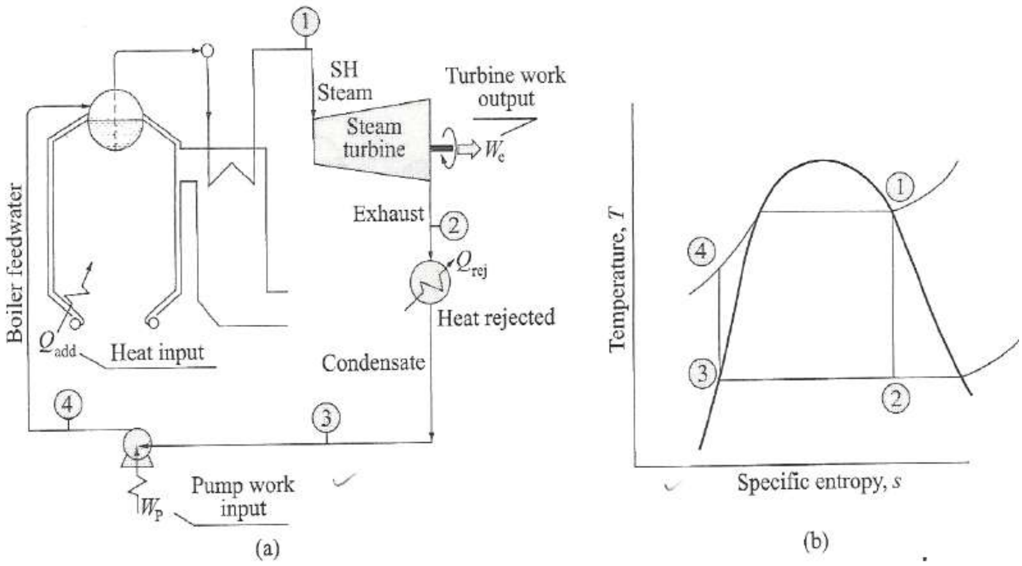
$$= 1 - \frac{Qrej}{Qadd}$$

$$= 1 - \frac{m(h2 - h3)}{m(h1 - h4)}$$

Also, $\eta = 1 - \frac{T2}{T1}$

RANKINE CYCLE:

A rankine vapour cycle is based on a modified carnot cycle to overcome its limitations. It consists of four steady flow processes as in figure



Process 4-1:

Heat is added in the boiler to the BFW, which is a constant pressure process generating a dry, saturated steam at saturation temp. corresponding to the boiler operating pressure,

$$Qadd = m(h1 - h4)$$

Process 1-2:

The steam is reversibly and adiabatically expanded in the turbine. So, turbine work input = We = m(h1 - h2)

Process 2-3:

Constant pressure heat rejection in the condenser. The cooling water extracts the latent heat of condensation from the exit steam exhausted to the condenser.the condensation is complete. The entire vapour is converted into a condensate.

Therefore heat rejection = m(h2 - h3)

Process 3-4:

Pump work. This work must be apportioned from the turbine output.

Wp = m(h4 - h3)

Net work output,Wnet = We - Wp

Therefore, efficiency,

$$\eta = \frac{Wnet}{Qadd}$$

$$= \frac{We - Wp}{Qadd}$$

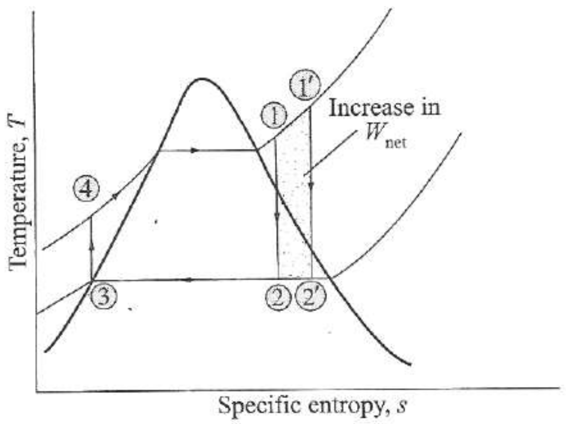
$$= \frac{m(h1-h2)-m(h4-h3)}{m(h1-h4)}$$

RANKINE CYCLE WITH SUPERHEATED STEAM:

If the heating of the working fluid(BFW) is continued beyond the dry saturation point, i.e; well into superheat regime before feeding it to the turbine,i.e; state$1'$ instead of state 1 , the amount of heat added increase bringing about an incipient increase in the work output

$(\Delta . Woutput = area\ 1 - 1' - 2' - 2)$

So, superheating begets a higher cycle efficiency.



RANKINE CYCLE WITH SUPERHEATED STEAM:-

EFFECT OF INCREASING PRESSURE WHILE BEING TEMPERATURE CONSTANT:

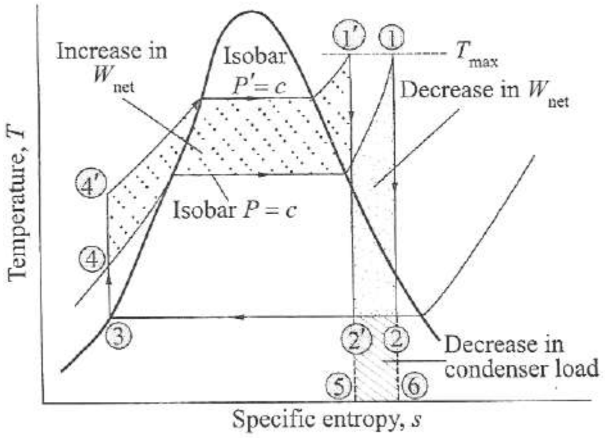
The steam pressure at the SHP exit is increased from p to p' while maintaining a constant superheated steam temperature,i.e; $T_1 = T1'$.

The operating conditions of the condenser remain unchanged. The work output remains nearly the same,i.e; there is no drastic gain in the work output;

$$\Delta.Woutput,p = area\ 1-2-3-4-1$$

$$\Delta.Woutput,p' = area\ 1'-2'-3-4'-1'$$

$$\Delta.Woutput,p \approx \Delta\ .Woutput,p'$$



However, the heat rejection area is reduced due to the higher pressure steam utilization(area 2- 2′-5-6).

This increases the efficiency of the cycle.

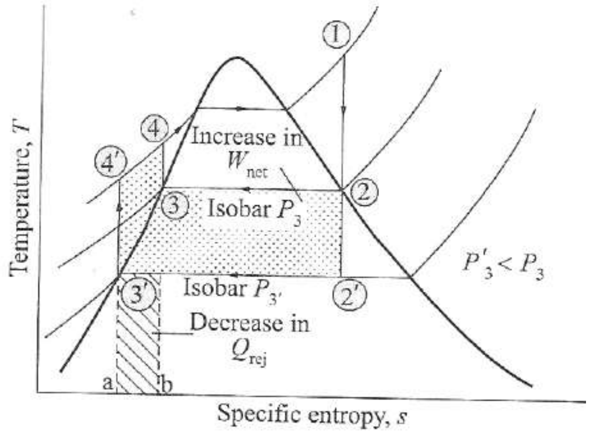
Efficiency,

$$\eta = \frac{Qadd - Qrej}{Qadd}$$

$$=1- \frac{Qrej}{Qadd}$$

RANKINE CYCLE WITH SUPERHEATED STEAM:
EFFECT OF REDUCING CONSTANT PRESSURE:

If the condenser pressure is reduced ,the net work is increased by area 2-$2 - 2'-3' - 4' - 4 - 3 - 2$..



When the operating pressure of the condenser is decreased ,the heat added area automatically increases and at the same time Qrej also decreases with the net effect;the cycle efficiency increases..

QUALITIES OF IDEAL WORKING FLUID FOR VAPOUR POWER CYCLES:

The desirable characteristics of the working fluid in a vapour power cycle to ensure the best thermal efficiency of the cycle are :

1. The maximum permissible limits of operating pressure and temp. is set by the metallurgy boiler and super heater tubes ,pipes lines, and headers. The working fluid should better have a high critical temp. so that its saturation pressure at the maximum permissible working temp. is relatively low. It should have a large enthalpy of evaporation at that pressure
2. To draw vaccum in the condenser is another costly setup that calls for adequate maintenance as less than the desired vaccum level will tell on the overall cycle efficiency. So it is better that the saturation pressure at the temp. of heat rejection should lie above the atmospheric pressure.
3. The specific heat of liquid should be low so as to boil it out with a relatively little heat transfer. However ,low specific heat means a low enthalpy content-not a desirable criterion for a high cycle efficiency.

4. The saturated vapour line in the T-s diagram should be steep rather than flat. This will safeguard the last stages of the turbine blades from an excessive level of condensation of the working fluid as it expands through the successive stages of the turbine.
5. The freezing point of the working fluid should be below the ambient temp. to avert pipeline chocking due to freezing.
6. Obviously the working fluid should be chemically stable and non-reactive with the materials of construction of the operating system at the maximum working temp
7. The working fluid must be abundantly available to buy economy.
8. It must be non-toxic,non-corossive, and not excessively viscous.

BINARY VAPOUR POWER CYCLES:

A binary cycle comprises two different cycles working in tanderm with two different fluids so that the sink of one becomes the source of the other.

The highest achievable efficiency is that of carnots

$$.\eta_{\text{thermal}} = \frac{T1-T2}{T1}$$

$$= 1 - \frac{T2}{T1}$$

Which necessitates heat absorption at a constant temp. T1 and heat rejection at a constant temp. T2. Now, the efficiency is fixed byT1 asT2 is fixed by the natural sink. This makes it imperative that T1 should be as large as possible,consistent with the vapour being saturated.

When water is used as the working fluid its critical temp. is 374.15℃ and the critical pressure is 225 bar. Operating with a critical or supercritical steam entails design complicacy and enhances cost, operational and maintenance problems, and controlling difficulties . in order to obviate these difficulties ,it would be better to harness some fluid other than steam, which is having more desirable thermodynamic properties than water. The most fitting fluid for this purpose should have a very high critical temp. yet at a low pressure. Mercury, biphenyl oxide and similar other compounds, aluminium bromide, and zinc aluminium chloride are the fluids which posseses the requisite properties in varying degrees. Mercury, among them

,is the best candidate. It has a high critical temp. of 588.4℃ yet at low critical pressure. Mercury alone can not be used as its saturation temp. at the atmospheric pressure is high(355℃). Hence ,a binary vapour cycle is used to increase the overall efficiency of the plant.

The most important binary vapour cycle is the mercury steam cycle, which comprises two cycles—mercury cycle and steam cycle.

MERCURY CYCLE:

The mercury cycle is super imposed on the steam cycle. Liquid mercury is circulated through the evaporator tubes in the boiler whereupon the liquid mercury is converted into vapour which is then charged to the mercury turbine where the Hg – vapour expands to generate electric power. The turbine is then exhausted to the mercury condenser boiler where the vapour mercury condenses and then pumped back to the boiler.

STEAM CYCLE:

The heat rejected by the vapour mercury in the mercury condenser boiler is absorbed by the BFW to generate steam at a desired pressure. This steam is then superheated and then charged to the steam turbine to produce an additional power output.

Fuel is burned in the mercury boiler furnace. The liberated heat goes to vaporize the mercury, superheat the steam , and preheat the combustion air and the boiler feedwater.

The heat rejected during the condensation of mercury is transferred to boil water to saturated steam(stage 5-6). The saturated steam is then superheated to state 1 by an external heat source(stage 6-1).

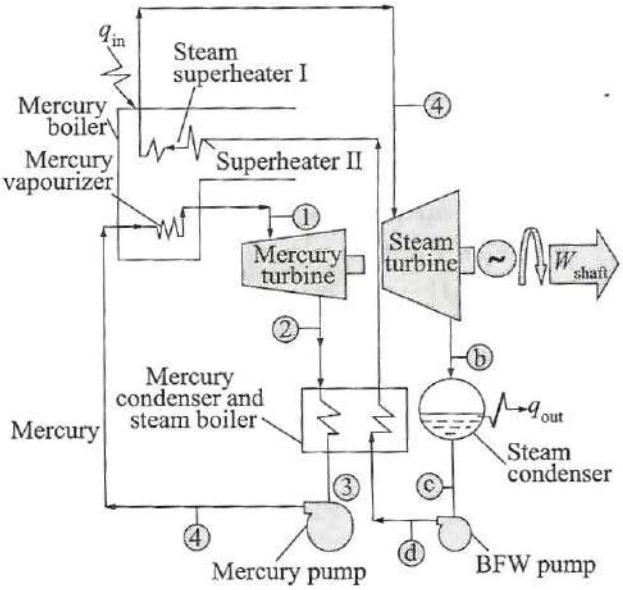
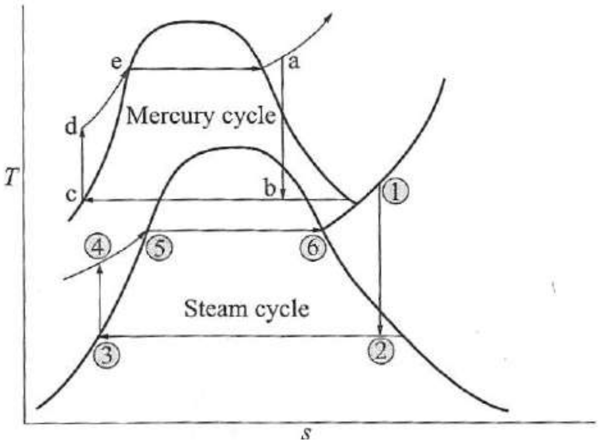


Fig. Schematic diagram of a mercury–steam binary cycle.



This superheated steam is then allowed to expand in the steam turbine(stage 1-2) and the waste steam is then exhausted to the surface condenser where the condensation is completed(stage 2-3). The condensate is then pumped back (by the BFW group) to the boiler(stage 3-4) . This is then heated in the economizer to the saturated liquid(stage 4-5) and then goes to the mercury condenser steam boiler, where the latent heat is absorbed.

Heat supplied = Q1= Qm = m(ha-hd) + (h1 - h6) + (h5 - h4)

Heat rejected= Q2=Qout=(h2-h3)

Turbine work= Wshaft = m(ha-hb)+(h1-h2)

Pump work= Wpump=m(hd-hc)+(h4-h3)

The thermal efficiency of the mercury-steam cycle

= ɳthermal,mer-wat = $\frac{Wnet}{Qin}$

$= \frac{Wshaft - W\,pump}{Qin}$

Steam rate = $\frac{3600}{Wshaft - W\,pump}\,(kg\ kwh^{-1})$

Energy balance= m(h_b-h_c) =h6-h5

∴ m=$\frac{h6-h5}{hb-hc}$

ADVANTAGES OF MERCURY-STEAM CYCLE:

1. High overall plant efficiency
2. High degree of availability (-85%)
3. Simplicity in operation
4. Reasonable plant maintenance
5. No operational trouble (cf. mercury is toxic)

CHAPTER-6

HEAT TRANSFER

MODES OF HEAT TRANSFER:

CONDUCTION:-

A physical law for heat transfer by conduction is given by fourier according to which the rate of heat conduction is proportional to the area measured normal to the direction of heat flow, and to the temp. gradient in that direction.

$$Q = -kA\frac{\partial T}{\partial n}$$

$$\text{or } q = -k.\frac{\partial T}{\partial n}$$

The constant of proportionality is called the coefficient of thermal conductivity, which is a physical property of the substance and is defined as the ability of a substance to conduct heat,.

The quantity of heat transferred per unit time per unit area of isothermal surface is defined as the heat flux is determined by the relation

$$Q = - n_{i.}\, k\frac{\partial T}{\partial n}$$

The heat flux q, is normal to the isothermal surface, and is positive in the direction of decreasing temp. because according to the second law of thermodynamics, heat always flow from a hotter point to a colder one. Hence .the vectors grad T and q are both normal to isotherms but run in opposite directions. This also explains the existence of the minus sign in equation.

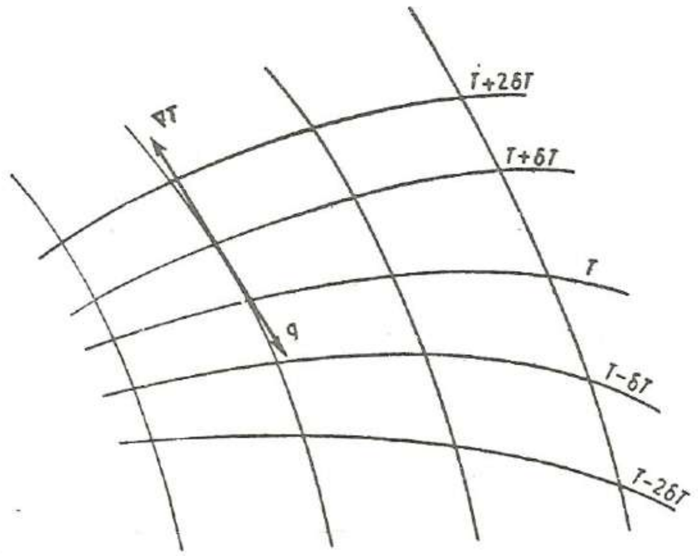


Fig. Lines of Heat Flow and Isotherms

The greatest rate of heat flow will be along the lines normal to the isothermal surfaces. Then, in accordance with equation we have

$$Q_X = - K_x.A\frac{\partial T}{\partial X} \quad \text{or } q_x= \frac{QX}{A} = - K_X . \frac{\partial T}{\partial X}$$

$$Q_Y = - K_{Y.}A\frac{\partial T}{\partial Y} \quad \text{or } q_{y} = \frac{QY}{A} = - K_Y. \frac{\partial T}{\partial Y}$$

$$Q_Z = - K_Z.A\frac{\partial T}{\partial Z} \quad \text{or } q_z = \frac{Qz}{A} = - k_z.\frac{\partial T}{\partial Z}$$

A material having $K_X = K_Y = K_Z = K$ is called an isotropic material. For an isotropic material, the heat transfer equation reduces to $Q_X = - K_A. \frac{\partial T}{\partial X}$

The heat flow vector q can be written as; $q = i.q_x + j\, q_y + k\, q_z$

For a plane wall of thickness L with temp. T_O and T_L on its two sides integration of equation yields:

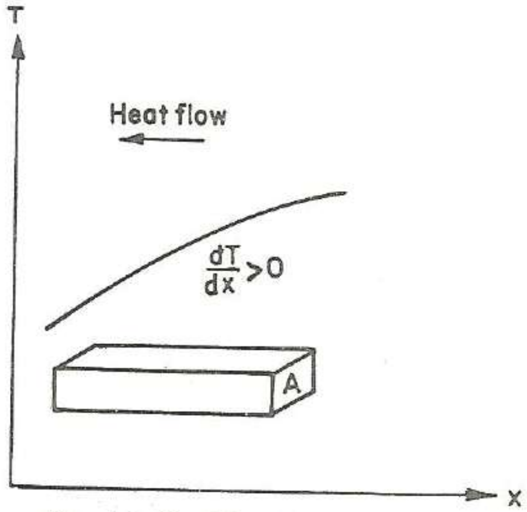


Fig. One-Dimensional Conduction

$Q_X \int_0^L dx = -kA \int_{T0}^{TL} dT$

$Q_X = \frac{kA}{L}(T0 - TL)$

The unit of thermal conductivity k, is $W/_{m°C}$ or $W/_{m.k}$

Since conduction is a molecular phenomenon , fourier law is similar to newtons viscosity law for laminar flow: $\tau = \mu.\frac{dv}{dy}$

Thermal conductivity is a physical property of a substance and like viscocity , it is primarily a function of temp. and/ or position , nature of the substance. It varies significantly with pressure only in the case of gases subjected to high pressure. However for many enginnering problems , materials are often considered to process a constant thermal conductivity .

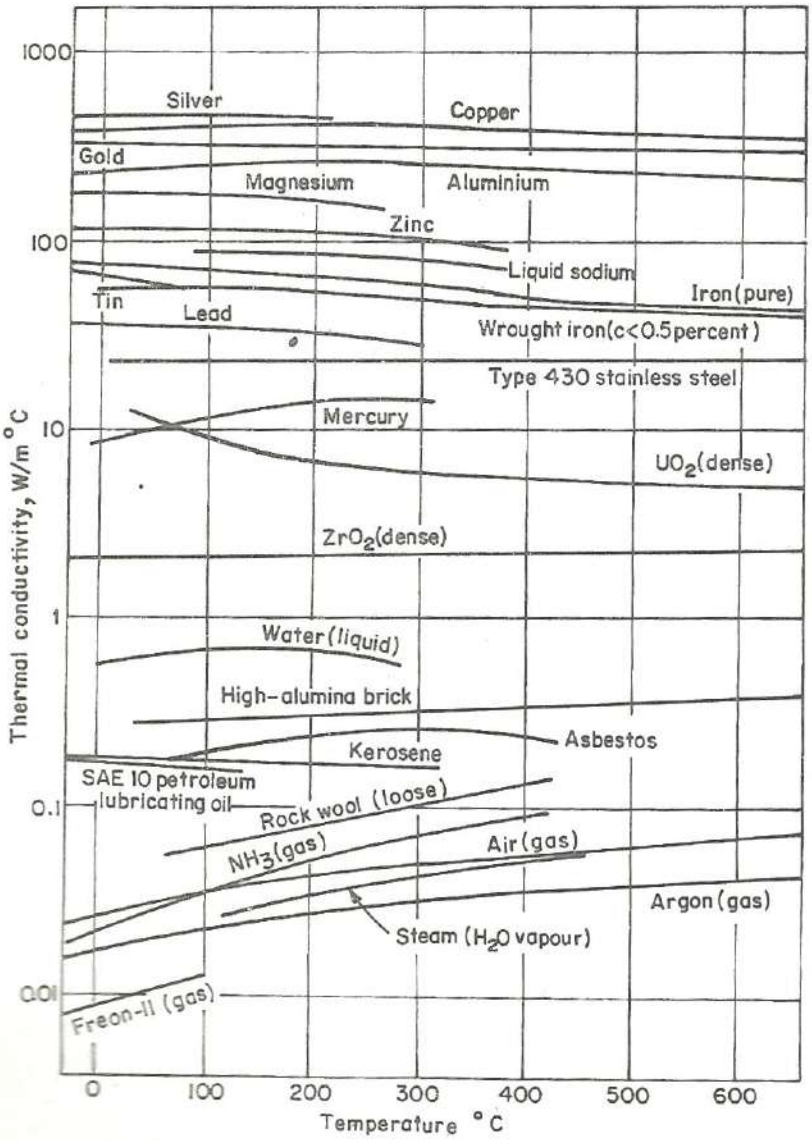


Fig. Thermal Conductivity of Some Engineering Materials.

The thermal conductivity for most materials can be determined experimentally by measuring the rate of heat flow and temp. gradient of the substance most commonly used.

From table ,We see that pure metals have the highest value of thermal conductivities while gases and vapours have the lowest; insulating materials and inorganic liquids have thermal conductivities that lie in between those of metals and gases.

Table Thermal Conductivities of Common Substances at 20 °C

Substance	$k(W/mK)$
Silver, pure	407.0
Copper pure	386.0
Aluminium, pure	175.6
Mild Steel	37.2
Lead	29.8
Stainless Steel	19.3
Wood	0.15
Asbestos, fibre	0.095
Water	0.51
Air	0.022

Thermal conductivity is also a function of temperature. For most pure metals it decreases with increasing temp, whereas for gases and insulating materials it increases with rise in temp. . Appendix A gives the thermal conductivity and other physical properties of some the most commonly used substances.

EXAMPLE 1

A stainless steel plate 2 cm thick is maintained at a temperature of 550°C at one face and 50°C on the other. The thermal conductivity of stainless steel at 300°C is 19.1 W/m·K. Compute the heat transferred through the material per unit area.

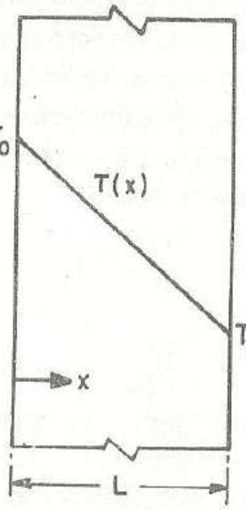


Fig. Ex. 1.1 Example 1.1

Solution This is the case of a plane wall as shown in Fig. Ex. 1.1. Using Eq. (1.12),

$$Q_x = \frac{kA}{L}(T_0 - T_L)$$

or
$$\frac{Q_x}{A} = q_x = \frac{k}{L}(T_0 - T_L) = \frac{(19.1)(550-50)}{2 \times 10^{-2}} = 477.5 \text{ kW/m}^2$$

CONVECTION:

For a fluid flowing at a mean temp. T∞ over a surface at a temp. T_S , newton proposed the following heat convection equation; q = $\frac{Q}{A} = h(Ts - T\infty)$ = hΔT

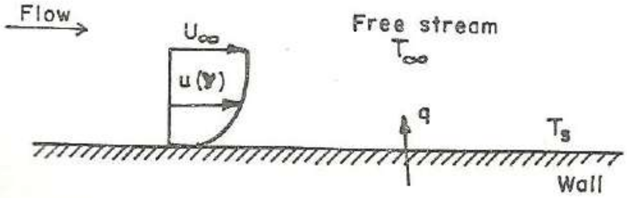


Fig. Convection from a Heated Plate

Where q is the heat flux at the wall. This equ. is called newton law of cooling. The heat transfer coefficient h has units $W/_{m2°C}$ or $W/_{m2\ k}$ when the heat flux q is given in the units of $\frac{W}{M2}$ and the temp. in °C.

In fig. it is seen that the viscosity of fluid layer at the wall is zero so the heat must be transferred only by conduction over there. Thus we may use to compute heat transfer at the wall. Then question arises , why consider convection at all when we can easily compute q by conduction. The answer is simple; the temp. gradient is dependent upon the rate at which the fluids carries the heat away, which in turn depends upon viscosity and other thermal properties of the fluid. Comparing these equations at the wall, h = - $\frac{k}{Ts-T\infty}\frac{\partial T}{\partial Y}\ |y = 0$.

Equation relates h with thermal conductivity and the temp. gradient at wall ,and is used in the determination of h experimentally.

It has been found that the heat transfer coefficient h varies significantly with the type of fluid and temperature . table gives the approximation ranges of convective heat transfer coefficient for forced and free convection encountered in typical engineering application.

EXAMPLE 1

A flat plate of length 1 m and width 0.5 m is placed in air stream at 30°C blowing parallel to it. The convective heat transfer coefficient is 30 W/m²K. Calculate the heat transfer if the plate is maintained at a temperature of 300°C.

Solution

$$Q = hA\ (T_s - T_\infty)$$
$$= (30)\ (1.0)\ (0.5)\ (300-30)$$
$$= 4.05\ \text{kW}.$$

THERMAL RADIATION:

According to the Stefan-boltzmann law , the radiation energy emitted by a body is proportional to the fourth power of its absolute temperature. Q = $\sigma A T_1^4$.

Where σ is called Stefan-boltzmann constant with the value of $5.6697*10^{-8}\ \frac{W}{m2\ .k4}$, and T_1 is the surface temp. in degree Kelvin.

Consider a black body of surface area A and at an absolute temp. T_1 exchanging radiation with another black body at a temp. T_2. The net heat exchange is proportional to the difference in T^4.

Q = $\sigma A(T_1^4 - T_2^4)$

The real surface , like a polished metal plate, do not radiate as much as energy as a black body. The gray nature of real surfaces can be accounted for by introducing a factor ∈ is called emissivity which relates radiation between gray and black bodies. $Q=\sigma A\in(T_1^4-T_2^4)$

To account for geometry and orientation of two black surfaces exchanging radiation is modified to $Q=\sigma AF(T_1^4-T_2^4)$

When the factor F, is called view vector, is dependent upon geometry of the two surfaces exchanging radiation.

EXAMPLE 1

A 'radiator' in a domestic heating system operates at a surface temperature of 55°C. Determine the rate at which it emits radiant heat per unit area if it behaves as a black body.

Solution

$$\frac{Q}{A} = q = \sigma T^4 = 5.6697 \times 10^{-8} (273 + 55)^4 = 0.66 \text{ kW/m}^2$$

FOURIER LAW OF HEAT CONDUCTION:-

$Q \propto A.\frac{dT}{dX} = k.\ A.\frac{dT}{dX}$

Where Q= amount of heat flow through the body in a unit time

A= surface area of heat flow

dT= temperature difference on the two faces of body

dX= thickness of the body through which the heat flows. It is taken along the direction of heat flow

k= constant of proportionality known as thermal conductivity of the body

THERMAL CONDUCTIVITY:-

$.\ Q = \frac{k.A.(T_1 - T_2).t}{x}$

The thermal conductivity of a material is numerically equal to the quantity of heat which flows in one second through a slab of material of area 1 m^2 and thickness 1 m when its faces differ in temperature by 1 k.

Example 1. *The glass windows of a room have a total area of 10 m^2 and the glass is 4 mm thick. Calculate the quantity of heat that escapes from the room by conduction per second when the inside surfaces of windows are at 25° C and the outside surfaces at 10° C. The value of k is 0.84 W/m K.*

Solution. Given : $A = 10\ m^2$; $x = 4\ mm = 0.004\ m$; $T_1 = 25°\ C = 298\ K$; $T_2 = 10°\ C = 283\ K$; $k = 0.84\ W/m\ K$

We know that the quantity of heat that escapes from the room per second,

$$Q = \frac{k A (T_1 - T_2)}{x} = \frac{0.84 \times 10\ (298 - 283)}{0.004} = 31\ 500\ J$$

$$= 31.5\ kJ\ \textbf{Ans.}$$

HEAT CONDUCTION THROUGH PLANE WALLS:-

Consider a plane wall of materials of uniform thermal conductivity k, which is assumed to be extending to infinity in y and z directions. For this problems, the temp. is only a function of x . the walls of a room may be considered as a plane if energy lost through the edges is negligible. Starting the general conduction equation $\frac{\partial 2T}{\partial x2}+\frac{\partial 2T}{\partial Y2}+\frac{\partial 2T}{\partial z2}+\frac{q}{k}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$

For this case $\frac{\partial T}{\partial t}$ =0(steady state)

$\frac{\partial 2T}{\partial Y2} = \frac{\partial 2T}{\partial z2}$ =0(one-dimensional) ,$\frac{q}{k}$ =0(no heat generation)

The conduction equation simplifies to $\frac{\partial 2T}{\partial x2}$ =0 or $\frac{d2T}{dx2}$ = 0------------------------(1)

Above equation is a second order differential equation requiring two boundary conditions for its solution.

These are $T = T_1$ at $x = 0$

$T = T_2$ at $x = L$

Integrating this above equation twice , we get $T = C_1x+C_2$

Where C1 and C2 can be determined from the boundary conditions

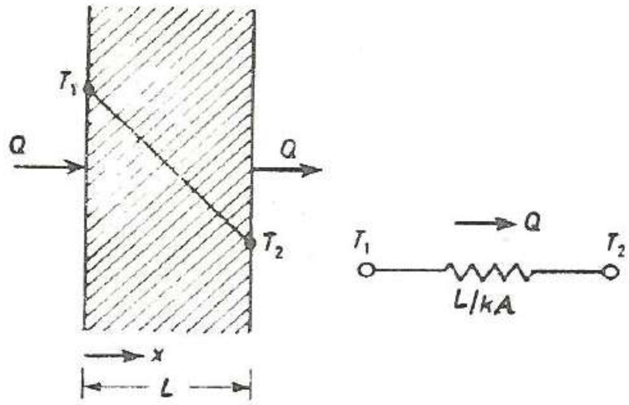


Fig. Steady State Conduction Through a Plane Wall

At $x = 0$, $T = T_1$, so that $C_2 = T_1$

At $x = L$, $T = T_2$, so that $T_2 = C_1 L + T_1$

Or $C_1 = \frac{T2-T1}{L}$

So the equation for temp. distribution becomes $T = \frac{T2-T1}{L} x + T_1$

Or $\frac{dT}{dx} = \frac{T2-T1}{L}$ $\quad\therefore Q = -K.A\frac{dT}{dx} = \frac{-kA(T2-T1)}{L} = \frac{kA(T1-T2)}{L}$ -----------------(2)

This quantity of heat Q, must be supplied to the low face of the wall to maintain a temp. difference

$(T1 - T2)$ across it. The thermal resistance is defined for a plane wall is Rth = $\frac{L}{KA}$

Equation -2 can also be obtained by fourier equation, $Q = -KA\frac{dT}{dx}$------------------(3)

Integrating this equation between the boundaries of the plane wall,

we get $\int_0^L Qdx = -kA\int_{T1}^{T2} dT$

$$QL = -KA(T2 - T1)$$

$$\text{Or} \quad Q = \frac{-kA(T2-T1)}{L}$$

$$= \frac{kA(T1-T2)}{L}$$

The temp. at any point x along the wall can be obtained by integrating equation-3 between 0 and x

$$Q.x = -KA(T - T_1)$$

and comparing with equation-2 , $T = \frac{(T2-T1).x}{L} + T_1$

HEAT CONDUCTION THROUGH HOLLOW CYLINDER:-

`Consider a long cylinder of inside radius r_i , outside radius r_0, and length L. we consider the cylinder to be long so that the end losses are negligible. The inside and outside surfaces are kept at constant temperature Ti and To respectively. A steam pipe in a room can be taken as an example of a long hollow cylinder. The general heat conduction equation in cylindrical coordinates is

$$\frac{\partial 2T}{\partial r2} + \frac{1}{r}\left(\frac{\partial T}{\partial r}\right) + \frac{1}{r2}\frac{\partial 2T}{\partial \emptyset 2} + \frac{\partial 2T}{\partial z2} + \frac{q}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

Assuming the heat flows only a radial directions, the above equation under steady state takes the form:

$$\frac{\partial 2T}{\partial r2} + \frac{1}{r}\left(\frac{\partial T}{\partial r}\right) = 0$$

$$\text{or} \quad \frac{d}{dr}\left(r\frac{dT}{dr}\right) = 0$$

Subject to the boundary conditions, $T = T_1$ at $r = r_1$

$T = T_0$ at $r = r_0$

Integrating twice we get , $T = C_1 \ln r + C_2$ -----------------(1)

Using the boundary conditions , at $r = r_1$,$T = T_1$; $T_1 = C_1 \ln r_1 + C_2$

at $r = r_0$,$T = T_0$;$T_0 = C_1 \ln r_0 + C_2$

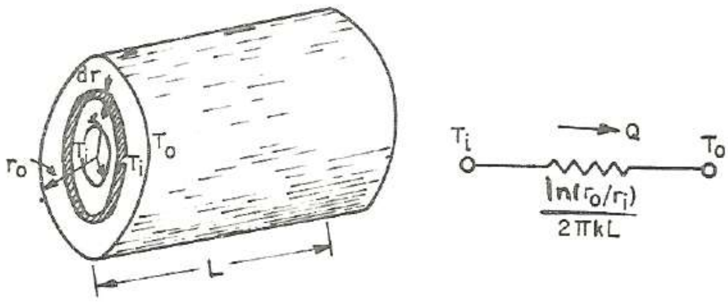


Fig. Steady State Conduction through a Hollow Cylinder i

$C_1 = \frac{T1 - T0}{\ln\frac{r0}{r1}} \ln r_1$

$= \frac{T0 - T1}{\ln\frac{r1}{r0}}$

$C_2 = T_1 - \frac{T0 - T1}{\ln\frac{r0}{r1}} \ln r_1$

$= \frac{T1 \ln r0 - T0 \ln r1}{\ln\frac{r0}{r1}}$

Substituting the values of C_1 and C_2 in equation -1 ,

$T = \frac{T0 - T1}{\ln\frac{r1}{r0}} \ln r + \frac{T1 \ln r0 - T0 \ln r1}{\ln\frac{r0}{r1}}$

$Q = -KA_r \frac{dT}{dr} |r = ri$

$= -K.2\pi r_1 L.\frac{C1`}{R1} = -K.2\pi r_1 L(T_0 - T_i) .\frac{1}{ri \ln\frac{r0}{r1}}$

$= \frac{2\pi KL(T1 - T0)}{\ln\frac{r0}{r1}}$--------------(2)

Equation-2 can alternatively be derived as follows:

$Q = - KA\frac{dT}{dr}$, where $A = 2\pi rL$

Or $Q .\frac{dr}{r} = -2\pi KL dT$

Integration of this equation gives

$Q.\int_{r1}^{r0} \frac{dr}{r} = -2\pi KL \int_{T1}^{T0} dT$

$Q. (\ln \frac{r0}{r1}) = -2\pi KL (T_0 - T_1)$

$Q = \frac{2\pi KL(T1 - T0)}{\ln\frac{r0}{r1}}$

The thermal resistance for the hollow cylinder would be, $Rth = \frac{\ln\left(\frac{r0}{r1}\right)}{2\pi KL}$

HEAT CONDUCTION THROUGH HOLLOW SPHERE:

Consider a hollow sphere whose inside and outside surfaces are held at constant temperature T_1 and T_0 respectively . if the temperation is only in the radial direction , then for steady state conditions with no heat generation , the heat conduction equation simplifies to

$$\frac{\partial 2T}{\partial r2} + \frac{2}{r}\left(\frac{\partial T}{\partial r}\right) = 0$$

Multiplying throught by r^2 , we get $r^2 . \frac{\partial 2T}{\partial r2} + 2\ r. \frac{\partial T}{\partial r} = 0$

Or $\frac{d}{dr}\left(r^2 \frac{dT}{dr}\right) = 0$----------------------------- (1)

Integration of equation-1 gives $dT = C_1 \frac{dr}{r^2}$

Integrating again, we get $T = \frac{-C_1}{r} + C_2$

Applying the boundary conditions ,

$T = T_1$ at $r = r_1$; $T_1 = \frac{-C_1}{r_1} + C_2$

$T = T_0$ at $r = r_0$; $T_0 = \frac{-C_1}{r_0} + C_2$

Solving for C_1 and C_2

$C_1 = \frac{T_1 - T_0}{\left[\frac{1}{r_0} - \frac{1}{r_1}\right]}$, $C_2 = T_1 + \frac{1}{r_1} \frac{T_1 - T_0}{\left[\frac{1}{r_0} - \frac{1}{r_1}\right]}$

$\therefore$ $T = T_1 - \frac{T_1 - T_0}{\left[\frac{1}{r_0} - \frac{1}{r_1}\right]}\left[\frac{1}{r} - \frac{1}{r_1}\right]$

$= \frac{r_0}{r}\left[\frac{r - r_1}{r_0 - r_1}\right][T_0 - T_1] + T_1$

Knowing that $Q = -KA_r \frac{dT}{dr} |r = r_1$,

where $A_r = 4\pi r^2$

We can know that ,

$Q = \frac{4\pi r_1 r_0 . K(T_1 - T_0)}{(R_0 - R_1)}$ --------------------------(2)

Equation-2 can also be obtained by integration of fourier equation as follows:

$Q = -KA\frac{dT}{dr} = -4\pi K r^2 \frac{dT}{dr}$

$Q\int_{r_1}^{r_0}\frac{dr}{r^2} = -4\pi K\int_{T_1}^{T_0} dT$

$-Q\left[\frac{1}{r_0} - \frac{1}{r_1}\right] = -4\pi K[T_0 - T_1]$

Or , $-Q\left(\frac{r_1 - r_0}{r_0 r_1}\right) = -4\pi K[T_0 - T_1]$

And , $Q = \frac{4\pi r_1 r_0 . K(T_1 - T_0)}{(R_0 - R_1)}$----------------------(3)

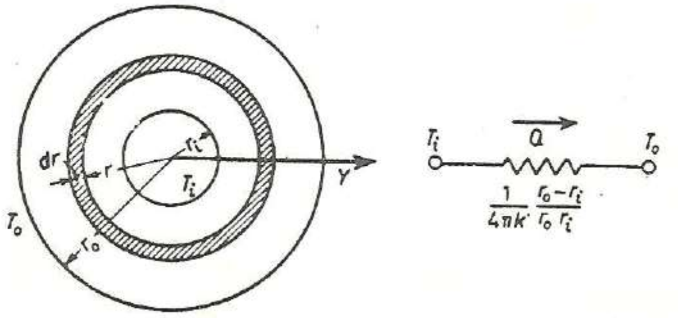


Fig. Steady State Conduction Through a Hollow Sphere

Equation-3 can also be put as , $Q = \frac{(T_1 - T_0)}{\frac{1}{4\pi K}\frac{[(r_0 - r_1)]}{r_0 r_1}}$

$$= \frac{T_1 - T_0}{R_{sph}}$$

Where the thermal resistance of a sphere is defined as $R_{sph} = \frac{1}{4\pi K}\frac{[(r_0 - r_1)]}{r_0 r_1}$

Geometric mean area: R_{sph} can be rearranged as

$R_{sph} = \frac{1}{4\pi K}\frac{[(r_0 - r_1)]}{r_0 r_1}$

$= \frac{r_0 - r_1}{K.\sqrt{(4\pi r_0{}^2)(4\pi r_1{}^2)}}$

$= \frac{L_{sph}}{K\,.\sqrt{A_0 A_1}}$

$= \frac{L_{sph}}{A_g . K}$------------------------(4)

Where A_1 and A_0 are the areas of the inner and outer surfaces of the sphere.

L_{sph} = $(R_0 - R_1)$ = thickness of sphere

A_g = $\sqrt{A_0 A_1}$ is called the geometric mean area of the sphere.

The thermal resistance of a sphere given by equation-4 is similar to that of a plane wall except that the area is replaced by the geometric mean area.

NEWTON LAW OF COOLING:-

It states that, " heat transfer from a hot body to a cold body is directly proportional to the surface area and difference of temperature between the bodies.

It is a general law, for the heat transfer which can not be applied to all sets of conbdition. But it paved the way for other laws dealing in the heat loss.

ABSORPTION, REFLECTION, AND TRANSMISSION:-

When incident radiation is called irradiation impinges on a surface, three things happen; a part is reflected back, a part is transmitted through and the remainder is absorbed, depending upon the characteristics of the body.

By conservation of energy particle, Ga + Gr + Gt = G

Dividing both sides by G, we get , $\frac{Ga}{G} + \frac{Gr}{G} + \frac{Gt}{G} = \frac{G}{G}$

So, $\propto + \rho + \tau = 1$

Black body:- For perfectly absorbing body, $\propto = 1$, $\rho = 0$, τ=0. Such a body is called black body.it is one which neither reflect nor transmit any part of the incident radiation but absorb all of it.

White body:- If all the incident radiation falling on a body are reflected, it is called white body. Gases such as hydrogen, oxygen, nitrogen have a transmittivity of practically unity.

Gray body:- If the radiative properties of a body are assumed to be uniform over the entire wavelength spectrum, then such a body is called gray body. It is also defined as one whose absorpivity of a surface does not vary with temperature and wavelength of the incident radiation.

CONCEPT OF BLACK BODY:- A black body is an object that absorbs all the radiant energy reaching its surface. No actual body is perfectly black; a black body has following properties:

1. It absorbs all the incident radiation falling on it and does not transmit or reflect regardless of wavelength and direction
2. It emits maximum amount of heat radiation at all wavelength at any specified temperature.
3. It is a diffuse emitter .

KIRCHHOFF'S LAW:-

The law states that any temp.the ratio of total emissive power E to the total absorpivity $\propto$ is a constant for all substances which are in thermal equilibrium with their environment.
Let us consider a large radiating body of surface area A which encloses a small body of surface area A_1 . let the energy fall on the unit surface of the body at a rate E_b.by considering generality of bodies, we obtain, $E_b = \frac{E_1}{\propto_1} = \frac{E_2}{\propto_2} = \frac{E}{\propto}$

Also , as per the definition of emissivityε , $we\ have\ \varepsilon = \frac{E}{E_b}$. By comparing ,we obtain , $\varepsilon = \propto$

PLANCK;S LAW :-

In 1900 Max Planck showed by quantum arguments that the spectral distribution of the radiation intensity of a black body is given by

$$(E_\lambda)_b = \frac{2\pi c^2 h \lambda^{-5}}{\exp\left(\frac{ch}{\lambda kT}\right) - 1} \quad \text{... (Planck's law)} \qquad \text{...(11.14)}$$

where, $(E_\lambda)_b$ = Monochromatic (single wavelength) emissive power of a black body,
c = Velocity of light in vacuum, $2.998 \times 10^8 \simeq 3 \times 10^8$ m/s
h = Planck's constant = 6.625×10^{-34} j.s
λ = Wavelength, μm
k = Boltzmann constant = 1.3805×10^{-23} J/K, and
T = Absolute temperature, K

Hence the unit of $(E_\lambda)_b$ is W/m^2. μm.

Quite often the Planck's law is written as

$$(E_\lambda)_b = \frac{C_1 \lambda^{-5}}{\exp\left(\frac{C_2}{\lambda T}\right) - 1} \qquad \text{...(11.15)}$$

where, $C_1 = 2\pi c^2 h = 3.742 \times 10^8$ W.μm^4/m^2;

$C_2 = \frac{ch}{k} = 1.4388 \times 10^4\ \mu m K$

Equation (11.14) is of great importance as it provides quantitative results for the radiation from a black body.

MAXWELL EQUATION:-

Now let us derive the Maxwell's equation.

We know that for a system undergoing an infinitesimal reversible process from one equilibrium state to another :

1. Internal energy, $dU = \delta Q - \delta W$ . . . (General gas energy equation)

$$= T\,dS - p\,dv \quad \ldots (\because \delta Q = T\,dS \text{ and } \delta W = p\,dv) \quad \ldots (i)$$

The above equation (*i*) is of the form

$$dz = M\,dx + N\,dy$$

where $M = T,\ N = -p,\ x = S$ and $y = v$

$$\therefore \quad \left(\frac{\partial T}{\partial v}\right)_S = -\left(\frac{\partial p}{\partial S}\right)_v \quad \ldots (ii)$$

2. Enthalpy, $dH = dU + d\,(pv)$

$$= dU + p\,dv + v\,dp$$

$$= (T\,dS - p\,dv) + p\,dv + v\,dp \quad \ldots (\because dU = T\,dS - p\,dv)$$

$$= T\,ds + v\,dp \quad \ldots (iii)$$

The above equation (*iii*) is of the form

$$dz = M\,dx + N\,dy$$

where $M = T,\ N = v,\ x = S$ and $y = p$

$$\therefore \quad \left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial v}{\partial S}\right)_p \quad \ldots (iv)$$

3. Helmholtz function (*A*),

$$dA = dU - d\,(T\,S)$$

$$= dU - T\,dS - S\,dT$$

$$= (T\,dS - p\,dv) - T\,dS - S\,dT \quad \ldots (\because dU = T\,dS - p\,dv)$$

$$= -p\,dv - S\,dT \quad \ldots (v)$$

The above equation (*v*) is of the form

$$dz = M\,dx + N\,dy$$

where $M = -p, N = -S, x = v, y = T$

$$\therefore \quad -\left(\frac{\partial p}{\partial T}\right)_v = -\left(\frac{\partial S}{\partial v}\right)_T$$

or

$$\left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial S}{\partial v}\right)_T \quad \ldots (vi)$$

4. Gibbs function (*G*), $dG = dH - d\,(T\,S)$

$$= dH - T\,dS - S\,dT$$

$$= (T\,dS + v\,dp) - T\,dS - S\,dT \quad \ldots (\because dH = T\,dS + v\,dp)$$

$$= v\,dp - S\,dT \quad \ldots (vii)$$

The above equation (*vii*) is of the form

$$dz = M\,dx + N\,dy$$

where $M = v, N = -S,\ x = p, y = T$

$$\therefore \quad \left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial S}{\partial p}\right)_T \quad \ldots (viii)$$

The equations (*ii*), (*iv*), (*vi*) and (*viii*) are known as *Maxwell's equations* in thermodynamics.

HEAT EXCHANGER:-

It may be defined as an equipment which transfer the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running cost.

In heat exchanger the temperature of each fluid changes it passes through the exchangers, and hence the temperature of the dividing wall between the fluids also changes along the length of the exchanger.

CLASSIFICATION OF HEAT EXCHANGER:-

1. NATURE OF HEAT EXCHANGER PROCESS:-
   (i) Direct contact heat exchanger
   (ii) Indirect contact heat exchanger
      (a) Regenerators
      (b) Recuperators
2. RELATIVE DIRECTION OF FLUID MOTION:-
   (i) Parallel flow
   (ii) Counter flow
   (iii) Cross flow
3. DESIGN AND CONSTRUCTIONAL FEATURES:-
   (i) Concentric tube
   (ii) Shell and tube
   (iii) Multiple shell and tube passes
   (iv) Compact heat exchanger
4. PHYSICAL STATE OF FLUIDS:-
   (i) Condenser
   (ii) Evaporator

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

ENTREPRENEURSHIP-MANAGEMENT SMART-TECHNOLOGY

3RD SEMESTER

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UNIT 1

ENTREPRENEUR

Entrepreneurship : Entrepreneurship is a process of actions of an entrepreneur who is a person always in search of something new and exploits such ideas into gainful opportunities by accepting the risk and uncertainty with the enterprise. Entrepreneurship is the process to develop, organize and run a new business enterprise by accepting some risks and challenges in order to make profit. Entrepreneurship is considered to be the combination of "Entrepreneur" and "Enterprise". Organizing an enterprise is described as Entrepreneurship. Here enterprise is defined as a unit of economic activities or an economic organization especially a business organization.

Entrepreneurship refers to the general trend of setting up new enterprise in a society. Entrepreneurship was traditionally believed to be an inborn quality and hence it was believed that entrepreneurship are born and not made but recent studies have proved that entrepreneurship ca ne planned and developed through creation of opportunities, extending facilities, allowing incentives and developing sensitiveness to the above factors in a person. So, it can be believed that entrepreneurs are not only born but entrepreneur can be made and anyone can become an entrepreneur.

According to J.Schumpter "Entrepreneurship can be defined as a creative activity, the entrepreneur being an innovator who introduces something new in to the economy".

Entrepreneur : The word "entrepreneur" is derived from the **French** verb **entrepreneur**, which means 'to undertake'. This refers to those who "undertake" the risk of new enterprises. An enterprise is created by an entrepreneur. The process of creation is called "entrepreneurship". An Entrepreneur is an individual who starts a new business accepting some risks and challenges and enjoying the profits. In other words Entrepreneurs is described as an individual who takes risk to organize a business to make his career. Entrepreneur is one who organizes, manages and assume the risk of a business enterprise.

Entrepreneur is also described as a person who runs a business at his own financial risk. Entrepreneurs are usually calculated risk taker. An entrepreneur avoids low risk situation because there is a lack of challenges in it. He also avoids high risk situation because he wants to succeed. That is why an entrepreneur likes achievable challenges and is called a calculated risk taker.

According to Webster dictionary an Entrepreneur is defined as someone who runs a business at his own financial risk.

Need of Entrepreneurship : The following are the needs of Entrepreneurship:

1. **Increased profit**: Profits can be increased in any enterprise either by increasing sales revenue or reducing cost.
2. **Employment opportunity**: Entrepreneurship provides the maximum employment. Entrepreneurship firms contributed a large share of new jobs. The small enterprises are the only sector that generates a large portion of total employment every year.
3. **Social benefit**: It is not only beneficial to the business enterprise but to the society in the form of providing diversified products, good quality products and services at the lower cost by their innovation.. The standard of living is a concept built on an increase in the amount of consumption of a variety of goods and services over a particular period by a household.
4. **Provide Innovation**: Entrepreneurship provides new ideas, imagination and vision to the enterprise. An entrepreneur is an innovator as he tries to find new technology, products and markets which leads to increases Gross Domestic Products and standard of living of the people.
5. **Lifeline of a Nation**: No country can progress without the development of entrepreneurship. Every country try to promote its trade so that it is able to share the benefits of development.
6. **Develops Entrepreneurship**: Entrepreneurship is the nursing ground for new inexperienced entrepreneurs. It is the field where a person can start his/her idea of the venture, which may be ended up in a giant enterprise. All the large industrial ventures started as a small entrepreneurial enterprise.
7. **Impact on community development :** It promotes, a higher level of township, better sanitation facilities and promote recreation, and religious activities along with educations. Thus, entrepreneurship leads to more stability and a higher quality of community life.

8 **Promotes research and development**: Entrepreneurship promotes different types of techniques, ideas and methodology which can be tested through different experiments. Therefore entrepreneurship provides funds for research and development with universities and research institutions. This promotes the general development, research and development in the economy.

Characteristics of Entrepreneur

1. Ability to take Risks

This is the first and foremost trait of entrepreneurship. Starting any business involves a considerable amount of risk of failure. Therefore, the courage and capacity to take the said risk are essential for an entrepreneur.

2. Innovation

In a world, where almost everything has been done, innovation is a priceless gift to have .

Innovation basically means generating a new idea with which you can start a business and achieve a substantial amount of profits. Innovation can be in the form of a product, i.e., launching a product that no one is selling in the market. It can also be in the form of process, i.e., doing the same work in a more efficient and economical way.

3.Leadership

An entrepreneur has a vision. However, it takes a lot of resources to turn that vision into reality. One of these resources are the people that the entrepreneur hires to perform various functions like production, supplying, accounting, etc. A single person cannot perform all the tasks and therefore it is important to bring some more people to do it. In this regard leadership is very important because a leader provides the required direction to the efforts of the employees. Without proper leadership, everyone would be working independently without achieving the desired results.

4.Open Minded

A good entrepreneur realizes that every situation can be a business opportunity. Thus can be utilized for the benefit of the organization.

5.Confident and Well Informed

An entrepreneur needs to be confident about his ideas and skills. This confidence also inspires the confidence of the people working for him as well as the other stakeholders involved in his business.

6.Flexible- An entrepreneur should be flexible and open to change according to the situation. To be on the top, a businessperson should be equipped to embrace change in a product and service as and when needed.

7.Know about the Product-A company owner should be the product offerings, and also the latest trend in the market. It is essential to know if the available product or service meets the demands of the current market. The entrepreneur should know the detail information about the product.

8.Creativity : Entrepreneurship starts with an idea. To be successful, a person needs to always be thinking of new ideas and better ways of doing things.

9.Initiative: This is the unique characteristic of an entrepreneur. He should have the potential to take the initiative regarding different products, ways of actions, production techniques, etc. Therefore, taking initiative with such end and qualification is the prime characteristic of entrepreneur in every economy.

10. **Independent thought and action:** Every entrepreneur should have potential to take independent thought as well as way of action for the benefit of the enterprise. They should not depend upon the others.

11. Problem solving attitude: Now a days in the competitive market the entrepreneur may face many problems and in this regard he should have the problem solving attitude to overcome all types of problem.

12.Ability to find opportunities: This is one of the major characteristic of an entrepreneur. He always tries to find the opportunities along with take the benefits of that opportunities which will ultimately lead to the benefit of the enterprise.

Qualities of Entrepreneur:

1.Hard Work:

The successful entrepreneurs are very handworkers. They are not the lazy people. They believe in smart work. They think logically and then act. They continuously make planning. They never sit idle. They always try to progress expand the business.

2. Strong Leadership:

Starting a new company can be a harrowing experience full of uncertainty and risk. Successfully bringing a small organization through these trying periods requires a lot of leadership skills.

3. The Organizer:

An entrepreneur is one who is expert in organizing the resources for building the business and running it successfully. He combines labor, land, machines, finance and material for the business and has a great knowledge of utilizing all the resources in an optimum way. He sells products in the market earns profit, pays loan, distributes salaries of employees, purchases required stuff for business and keep remaining for his own.

4. Risk Takers:

Entrepreneurial success is usually experienced by people who are not afraid to take a chance with a new idea or concept. These folks are more daring than most and tend more of a 'what if' approach by following through on innovative ideas that others may shy away from. These people are not only thinking outside the box but they are also living there as well and in most cases quite comfortably! They watch the crowd and go in the opposite direction because they know there will be less Competition.

5. The Creative or Artist:

This business personality is the reserved but highly creative type. Their creativity moves forward their business. They are very artistic person and also they show their artistic work in the business. They hold the things in a different way. They have expertise in providing the things in a different way. They have the unique ideas.

6.Open Minded:

Entrepreneurs develop the habit of learning from experience the limitations of achievements. They modify the goal according to the environmental challenges and threats. This modification does not mean avoiding the problems or the tasks instead they like to face it. The modification is done in order to make it possible to achieve the goal within the given environmental conditions.

7.Creativity:

Mental ability consists of intelligence, an analytical approach and creative things. An entrepreneur should have creative thinking and be able to engage in the analysis of various problems and situations in order to deal with them. The entrepreneur should anticipate changes and must be able to study various situations in which decisions may have to be made.

8. Clarity:

An entrepreneur should have clear objective as to the exact nature of the business, the nature of the goods to be produced and the subsidiary activities to be undertaken.

9.Commitment:

He must be a person with full commitment to his objectives to his tasks and to his profession. This commitment must be extended to his entire principles of running his business and also commitment to his life.

10. Competence:

An entrepreneur should be a man of competence which would involve knowledge, information and wisdom. The knowledge is so fast exploding, thanks to the rapid changes in technology, that his knowledge must be up-to-date and relevant to his responsibilities. An entrepreneur must be a well-informed person and he must take all decisions based on verified facts and figures. The information he collects must be up-to-date and relevant.

11.Credibility:

Credibility is the foundation of the entire enterprise. The enterpriser will have to remember that he is credible to his customers and also to everyone who is directly or indirectly contributing to his business. All the decisions that he takes must be relevant to the needs of customers. He just exists for customers just as doctors exist for their patients and teachers are supposed to exist for their students.

12. Self-Confidence:

An entrepreneur must have self-confidence in his ability to complete the task or to meet a challenge.

Once he takes a decision, he has to be firm in the implementation of the decision, though there may be initially no success or there may be some opposition to his decision. Opposition is not to be ruled out arrogantly. The enterpriser must listen carefully to the points made by those opposing the decision.

13. Expertise:

An entrepreneur accumulates expertise day in and day out. He learns by trial and error. He is up-to-date regarding latest technology and also is aware of the trends in marketing. He should have the skill in managing finance before starting the business as also of managing cash flow and the funds flow during the course of the business.

14. Sense of Effectiveness:

Entrepreneurs like to see the problem solved through their involved efforts. They do not like to avoid the problems but like to be effective or be instrumental in solving problems rather than avoiding them. Their attitudes towards a problem is always one of directing the efforts and finding ways and means to give solution to such problems.

15.Honesty – Honesty is the basic requirement of an entrepreneur. With the quality of honesty, an entrepreneur gets profits by producing goods at low cost with durability and sale to customer at less price.

16. Loyal – An entrepreneur should be loyal towards enterprise, employees and external party. Under external party, it include customers, investors, government, other firms etc. '

17. Co-operative – Co-operation is one of the important qualities of an entrepreneur. An entrepreneur should do all functions and efforts by keeping this fact in mind. By co-operation, he can maintain the conducive and healthy environment within enterprise as well as outside too.

18. Politeness – Politeness is one of the important qualities of an entrepreneur. By politeness, he can develop sound relation with employees and customers, investors and other persons too.

Types of Entrepreneur

1.Trading Entrepreneur:

As the name itself suggests, the trading entrepreneur undertake the trading activities. They procure the finished products from the manufacturers and sell these to the customers directly or through a retailer. These serve as the middlemen as wholesalers, dealers, and retailers between the manufacturers and customers.

2. Manufacturing Entrepreneur:

The manufacturing entrepreneurs manufacture products. They identify the needs of the customers and then explore the resources and technology to be used to manufacture the products to satisfy the customers' needs. In other words, the manufacturing entrepreneurs convert raw materials into finished products.

3. Agricultural Entrepreneur:

The entrepreneurs who undertake agricultural items are called agricultural entrepreneurs. They cover a wide verities of agricultural activities like cultivation, marketing of agricultural products ,irrigation, mechanization and technology.

4. Small-Scale Entrepreneur*:*

An entrepreneur who has made investment in plant and machinery up to Rs 1.00 crore is called 'small-scale entrepreneur.'

5. Medium-Scale Entrepreneur:

The entrepreneur who has made investment in plant and machinery above Rs 1.00 crore but below Rs 5.00 crore is called 'medium-scale entrepreneur.'

6. Large-Scale entrepreneur:

The entrepreneur who has made investment in plant and machinery more than Rs 5.00 crore is called 'large-scale entrepreneur.'

7.Imitating Entrepreneur: The imitating entrepreneurs are those who immediately copy the new inventions made by the innovative entrepreneurs. .

8.Innovative Entrepreneur :An **innovative entrepreneur** is a person who discovers totally new things. An **innovative** owner is a person who creates **innovative** products and services. An **innovative entrepreneur** is a person who innovates the business processes in his business. An **innovative** person is a person who is not afraid to take a risk.

9.Fabian Entrepreneur : **Fabian entrepreneurs** are those **entrepreneurs** who are very much doubt or skeptical in their approach in adopting or innovating new technologies in their enterprise. They are not adaptable to the changing environment. They love to remain in the existing business with the age-old technique of production.

10.Drone Entrepreneur :These **entrepreneurs** are reluctant to change since they are very conservative and do not want to make any changes in the organization. They are happy with their present mode of business and do not want to change even if they are suffering the losses.

11. Industrial Entrepreneur: Industrial entrepreneur is essentially a manufacturer who identifies the needs of customers and creates products or services to serve them. He is product-oriented who starts through an industrial unit to create a product like electronic industry, textile unit, machine tools.

12.Corporate Entrepreneur: These entrepreneurs used his innovative skill in organizing and managing a corporate undertaking. A corporate undertaking is a form of business organization which is registered under some statute or Act like a trust registered under the Trust Act, or a company registered under the Companies Act. These corporate work as separate legal entity. He is thus an individual who plans, develops and manages a corporate body.

Function of Entrepreneur

1.Innovation: A very important function performed by entrepreneur is that of innovation. They analyze the existing state of company's affairs and try to reach a new level of equilibrium by trying new and productive combinations of existing resources. They think of creative ideas and use their managerial and innovative skills to put those ideas into reality. They combine the productive factors, bring them together and help in the economic development of a nation. According to Schumpeter, innovation can occur in the following forms: introduction of new goods, the use of new method of production, the opening of a new market and t e reorganization of any industry.

2.Organizing and Management: An entrepreneur brings together various resources of production, organizes them properly and converts them into a productive unit. An entrepreneur manages the following activities :

a) measuring the suitability of business idea.

b) Market Research and Selection of Product Line: The next important function of the entrepreneur is market research and product market research is the systematic collection of data regarding the product which the entrepreneur wants to manufacture. Entrepreneur has to undertake market research persistently in order to know the details of the intending product, i.e., the demand for the product, selection of product line, the price of the substitute product, the size of the customer, etc. while starting an enterprise.

c) Studying the government rules, regulation and policies.

d) Performing government formalities.

e) Determination of Objectives: The next function of the entrepreneur is to determine and lay down the mission, vision, objectives and goals of the business. In other words, entrepreneur should be very much clear about future prospect of the venture.

f) Managing of Funds: Fund raising is the most important function of an entrepreneur. All the activities of a business depend upon the finance and its proper management. It is the responsibility of the entrepreneur to raise funds internally as well as externally.

g) Procurement of Raw Material : Entrepreneur has to identify the cheap and regular sources of supply of raw materials, which will help him to reduce the cost of production and face the competition.

h) Procurement of Machinery: The next function of the entrepreneurs is to procure the machineries• and equipments for establishment of the venture.

3. Assumption of Risk:. Entrepreneurs assume the risk of success or failure of the enterprise that they wish to launch. Such risks are not insurable. If they materialize, the entrepreneur has to bear the loss himself. Thus, risk-bearing or uncertainty-bearing still remains the most important function of an entrepreneur which he tries to reduce by his initiative, skill and good judgement.

4. Idea Generation: Entrepreneurs do not immediately think of ideas and put them into practice. Ideas can be generated through market survey. It is the function of the entrepreneurs to generate as many ideas as he can for the purpose of selecting the best business opportunities. They think of a variety of ideas, apply quantitative techniques to test their applicability, supplement them with empirical findings, arrive at the best alternative and apply it in practice.

5. Decision Making: Arther H. Cole has described the entrepreneur as a 'decision maker'. He takes various decisions regarding following matters:

a) The development of an organization, including efficient relations with subordinates and all employees
b)Securing adequate financial resources, and maintaining good relations with the existing and potential investors .
c) The requisition of efficient technological equipment and the revision of it as new machinery appeared
d)The development of a market for the products and the devising of new products to meet or anticipate ϖ consumer's demand: and The maintenance of good relations with public authorities and with the society at large

6. Leading: As an entrepreneurial venture flourish, an entrepreneur takes on a new role of a leader. He acts as a visionary leader. The entrepreneur's leading function is drawing the best out of his human resources. He must create teamwork, motivation among employees. As a leader, entrepreneurs must shift from the command-and-control style of managing to a coach-and-collaboration style. 66

7. Managing Growth: The entrepreneur must manage the enterprise's growth. It includes such activities as developing and designing appropriate growth strategies, dealing with crises, exploring various ways for financing growth and placing a value on the venture.

8. Support to Social Environment: Social environment is characterized by social customs, culture, values and beliefs. Changes are not easily acceptable in a given socio-economic environment of a country. Entrepreneurs discover new sources of materials, new markets, and new opportunities and establish new and more profitable forms of organizations. This is a reflection of their will power, enthusiasm and energy and helps in overcoming the society's resistance to change.

9.Economic Development: Entrepreneurs play an important role in accelerating the rate of economic development of developed and under-developed countries. They exploit the country's resources (land, labor, capital and technology) and optimize their utilization to result in development of that country.

Barrier to Entrepreneurship
1.Finances

Finance is the major barriers to entrepreneur. And getting a sound financial investment or funding can be one of the biggest Barriers to Entrepreneurship as many of banks, private investors and organizations find it quite difficult to believe in the start-up ideas owing to the risk of failure and losing their money.

2. Fear of not to be a success

We all go through the fear of failure. And if the fear is associated with the risks and stakes taken in the stream of business and entrepreneurship, the level of fear increases

3. No strategic plan in place

Lack of proper planning and strategy in place is one of the most common Barriers to Entrepreneurship. Many of us think to build a business out of a hobby without having any sort of long term and short term vision and plan in mind. Running a fully-fledged business or being an entrepreneur requires a huge amount of skill set, passion for excelling, strategic vision, the mission to accomplish the goals, market research, and a lot more. Right from the target market, finances, human resources and proper strategic plan is required to build a successful business or a brand in the market.

4. Human resource issues

Entrepreneurs cannot handle and run a business alone by themselves. They require the support of human resource to carve a niche in the market.

Employees with the required knowledge, expertise, and experience are needed for the efficiency of the business processes and high levels of productivity.

First of all, it is quite difficult to find the employees that share the same vision and wavelength of the business. And secondly, it is also difficult to manage human resources as each of us work with a different mindset and perspective. Hence, human resources and employees can be as one of the Barriers to Entrepreneurship.

5. Stringent rules and regulations of the market

It is not very easy for entrepreneurs to enter the new market as there are quite many rules and regulations imposed by the government authorities. Apart from, there are various laws and compliances to be adhered to such as taxation, environmental regulations, licenses, property rights, and much more than act as the Barriers to Entrepreneurship.

6. Fewer opportunities

Even though there is a lot of talent and ambiguous entrepreneurs having with the ideas, but the opportunities presented to them are quite less and fewer which are become the main Barriers to Entrepreneurship.

7. Lack of capacity

Even if there are opportunities presented to the wiling entrepreneurs, there is a lack of capacity in some them to accept the opportunities with open arms. The reasons can vary from lack of knowledge, lack of education, lack of willingness, lack of strategic knowledge, and cultural barriers amongst others; but the factor of motivation and zeal gets missing. To start a new business venture amidst all the risks and market-related issues, it requires a lot of hard work, passion, and high capacity to handle all of it.

8. Less market experience

The experts always mention that one should never rush in setting up a business. It is quite necessary to gain a relative amount of work experience by working in the industry domain or sector of choice and as per the education levels. It also helps to sharpen the required expertise and find the ground in the career graph. Once the person is ready to take risks and have a relative amount of market exposure, he is ready to take the entrepreneurial challenge.

9. Lack of risk-taking capacity

It is always said that entrepreneurs never sail in safe waters and are never confined to their comfort zones. Lack of risk-taking capacity is the psychological mindset and perspective towards the business and acts as one of the major Barriers to Entrepreneurship. The budding entrepreneur has to have a structured and organized approach towards the various business elements and should risks rather than averting them.

10. Corrupt business situations

If the business situations and the environment are not very supportive and corrupt for the young and aspiring entrepreneurs, it acts as one of the top Barriers to Entrepreneurship. Bribing, rampant corruption, unfriendly ties of government with other nations, inconsistent laws, stringent compliances, and enforcing regulations that are unhealthy and negative in their approach hamper the growth of businesses in the country. Russia is one of the examples of having an unhealthy and unsupportive business environment.

11. Inadequate training

With no proper education, development, training, entrepreneurial skills, and technical knowledge an entrepreneur ca not be succeed and that will become the Barriers to Entrepreneurship.

12. Lack of practical knowledge

Having a strong educational background is just not enough to pursue business as it requires practical knowledge as well to stay relevant amidst the various market cycles. And many entrepreneurs lack practical knowledge.

Entrepreneur vs. Manager

The difference between entrepreneur and manager can be drawn clearly on the following grounds:

- A person who creates an enterprise, by taking a financial risk in order to get profit, is called an entrepreneur. An individual who takes the responsibility of controlling and administering the organization is known as a manager.
- An entrepreneur focuses on business startup whereas the main focus of a manager is to manage ongoing operations.
- Achievements work as a motivation for entrepreneurs. On the other hand, the primary motivation of manager is the power.
- The manager's approach to the task is formal which is just opposite of an entrepreneur.
- An entrepreneur is the owner of the enterprise while a manager is just an employee of the company.
- A manager gets salary as remuneration for the work performed by him. Conversely, profit is the reward for the entrepreneur.
- The major driving force of an entrepreneur is creativity and innovation. As against this, a manager maintains the existing state of affairs.
- While entrepreneur is a risk taker, the manager doesn't take any risk.

- Entrepreneur works as a single person while manager works as a team.
- Entrepreneur sets goal while manager executes to achieve the goal.
- He takes full risk of losses while manager is not directly responsible for losses.
- He gets full return of profit while manager may not get profit.
- An entrepreneur is not getting involved in fraudulent behavior while a manager may involve or cheat by not working hard.
- An entrepreneur is an innovator while manager is the executor.

Forms of Business Ownership

There are different forms of business organization depending on how they have been started and managed which are given below :

A) **Sole –Proprietorship**

B) **Partnership**

C) **Joint Hindu Family**

D) **Cooperative Society**

E) **Joint Stock Company(Private Limited Company, Public Limited company and Public Sector Undertakings)**

A) Sole–Proprietorship : Sole Proprietorship in simple words is a one-man business organization. Furthermore, a sole proprietor is a natural person(not a legal person/entity) who fully owns and manages this type of entity. In fact, the business and the man are the same, it does not have a separate legal entity.

Features :

1) Lack of Legal Formalities

A sole proprietorship does not have a separate law to govern it. And so there are not many special rules and regulations to follow. Furthermore, it does not require registration of any kind. In fact, in most cases, it need only the license to carry out the desired business.

2) Liability

Since there is no separation between the owner and the business, the personal liability of the owner is also unlimited. So if the business is unable to meet its own debts or liabilities, it will fall upon the proprietor to pay them. For instance, he may have to sell all of his personal assets (like his car, house, other properties etc) to meet the debts or liabilities of the business.

3**) Risk and Profit**

The business owner is the only risk bearer in a sole proprietorship. Since he is the only one financially invested in the company. As a result, he must also bear all the risk. In other words, if the business fails or suffers losses he will be the one affected. However, he also enjoys all the profits from the business. He does not have to share his profits with any other stakeholders since there are none. So he must bear the full risk in exchange for enjoying full profits.

4) No Separate Identity

In legal terms, the business and the owner are one and the same. No separate legal identity will be bestowed upon the sole proprietorship. So the owner will be responsible for all the activities and transaction of business.

5) Continuity

As seen above the business and the owner has one identity. So a sole proprietorship is entirely dependent on its owner. The death, retirement, bankruptcy. insanity, imprisonment etc will have an effect on the sole proprietorship. In such situations, the proprietorship will the business will come to an end.

SOLE PROPRIETORSHIP ADVANTAGES

- Owner receives all the profits.
- Owner makes all decisions and is in complete control of the company (could also be a disadvantage)
- Easiest and least expensive form of ownership to organize.
- proprietor will have *complete* control *of the entire business.* Thus this will facilitate quick decisions and freedom to do business.
- **SOLE PROPRIETORSHIP DISADVANTAGES**
- One of the biggest limitations of a sole proprietorship is the *unlimited personal liability of the owner*. If the business fails it can wipe out the personal wealth of the owner as well as affect his future business prospects too.
- Another problem is that a sole proprietor has access to *limited capital*. The money he can borrow from his own personal savings may not be enough to expand the business.
- A sole proprietor also has *limited managerial ability*. He cannot be an expert in all the fields of the business. As a result, the business may suffer from mismanagement and poor decision.

B)Partnership

In a Partnership, two or more people share ownership of a single business.

Features The essential features and characteristics of a partnership are:

1. **Agreement**: The partnership arises out of an agreement between two or more persons.
2. **Profit sharing**: There should be an agreement among the partners to share the profits of the business.
3. **Lawful business**: The business to be carried on by a partnership must always be lawful.
4. **Membership**: There must be at least two persons to form a partnership. The maximum number

is 20. But in case of banking business the maximum is 10 members.

5. **Unlimited liability**: The liability of every partner is unlimited, joint and several.

6. **Principal-agent relationship**: Every partner is an agent of the firm. He can act on behalf of the firm. He is responsible for his own acts and also for the acts done on behalf of the other partners.

7. **Collective management**: The firm and the partners are one. When a contract is made in the name of the firm all the partners are responsible for it individually and collectively.

8. **Non-transferability of shares**: A partner cannot transfer his share of interest to others without the consent of the other partners.

Advantages

1. Ease of Formation:

It is easy to form a partnership. No elaborate legal procedures are needed to bring a firm into existence. There is no need for registering a firm. Even when required, a firm can be registered quite easily. Likewise, one can close down a firm relatively easily.

2. Financial Resources:

Partners can pool their resources and expand the financial base of a firm. Creditors would be more willing to extend credit facility to a firm based on the reputation of partners and the soundness of business carried out by the partners.

3. Talent can be Pooled:

Partners can divide work among themselves, depending on their individual skills, and talents. This helps the firm to grow quickly.

4. Flexibility:

Partners can carry out day-today activities in a flexible way. The nature and place of business can be altered at will. New partners can join a firm when required. Partners can change hats depending on situational requirements. Capital infusion, profit sharing, pricing policies, etc., can be altered in sync with market demands.

. **5. Reward for Effort:**

Partners can work jointly and severally for improving business and get adequately rewarded.. Since there is no separation of ownership from management, everyone can work hard, and take the firm to commanding heights.

6.Informed, Balanced and Careful Decisions:

Partners can bring their skills, knowledge, and expertise to the table. Since they are jointly held responsible for losses, they are compelled to take a careful, cautious path. They are forced to take all the necessary steps for the benefit of the enterprise.

7. Secrecy:

Partners can keep business secrets close to their chest. They need not reveal them to anyone. The firm need not even get its accounts published and audited.

Disadvantages

1. Unlimited liability – The liability of partners in a firm is unlimited. Partners are said to be individually and jointly liable. This means that in case, the assets of the firm are insufficient to settle the claims against it, the personal assets of the partners may be utilized for the same.

2.imited resources – The Partnership Act places a restriction on the number of partners that may run a firm. Consequently, it may be difficult for a firm to raise capital beyond a certain limit in order to finance its expansion plans.

3.Possibility of conflicts – In a partnership firm the right to decision making and control is shared among all the partners. Sometimes, there may be difference of opinions among them which may not only lead to delay in decision making but also result in conflicts.

1.Lack of continuity – Partnership is not considered to be a very stable form of business organization. This is because the death, retirement, insolvency or insanity of any partner can bring the business to an end.

2.Lack of public confidence – It is generally believed that a partnership firm does not enjoying confidence of public in its working. This outlook is based on the fact, that a firm is not expected to publish its books of account. Hence, that can very easily hide its true financial status from general public.

3.Uncertain Future:

The firm may be closed down in case of death, failure, madness of any one of the partners. New partners can be inducted into a firm, only when all existing partners agree unanimously.

4.Not a Legal Entity:

A partnership firm has no legal entity separate from the members. It dies upon the death of a partner or upon separation between them. Partners are responsible for all the debts of the firm.

Types of partners

1.Active Partner

This type of partner is found in all partnerships. Such partners not only contribute capital but also takes part in the day-to-day running of the business and also takes active participation in the conduct and management of the business firm.

2.Sleeping partner

This type of partner is also known as “Dormant partner”. Such a partner contributes capital to the partnership firm but does not take active part in the management of partnership. Such a partner has no voice in the management. But the liability of such partner is unlimited.

3.Nominal partner

Such a partner neither contributes capital to the firm nor takes active part in the management of the partnership firm. This type of partner does not get any direct profit from the partnership.

4.Partners in profit only

There are some partners who may be interested in the profits of the partnership only but they are not share the losses. Such partner usually contribute capital but are not allowed to take active part in the management of the partnership firm.

5. Partner by Estoppel

A partner by estoppel is a partner who displays by his words, actions or conduct that he is the partner of the firm. In simple words, even though he is not the partner in the firm but he has represented himself in such a manner which shows that he has become a partner by estoppel .

6. Minor Partner

A person below 18 years of age is treated as minor. Hence a minor person can be admitted to partnership. He can contribute s capital to the partnership firm but can not take active part in the day to day management of the firm. He shares the profit and loss of the firm.

C)Joint Hindu Family

The Joint Hindu Family Business or the Hindu Undivided Family (HUF) is a unique type of business entity. It is governed and dictated by the Hindu Law, which is one of the several religious laws prevalent in India. The business of Joint Hindu Family is controlled under the Hindu Law instead of Partnership Act. The membership in this form of business organization can be acquired only by birth or by marriage to a male person who is already a member of Joint Hindu Family. The business of the Joint Hindu Family is controlled and managed by one person who is called ‘Karta’ or ‘Manager’. The Karta or manager works in consultation with other members of the family but ultimately he has a final say. The liability of Karta is unlimited while the liability of other members is limited to their shares in the business. It refers to a form of business organization which is owned and carried on jointly by the members of the Hindu Undivided Family (HUF).It is also known as Hindu Undivided Family Business.

Features:

Formation

- There should be at least two male members in the family to form a HUF.
- Ancestral property should have been inherited by members of HUF.
- All of the members enjoy this property and have an equal share in that Property.
- Thus, any child taking birth in that family becomes a member of the HUF.
- There is no requirement for an agreement to become a member.

Liability

- There is limited liability of all the members or co-parceners in the Hindu Undivided Family business.
- All the co-parceners have equal rights and shares in the property of Hindu Undivided Family business
- The Karta has unlimited liability.

Control

- Karta is the person who has full control over the Hindu Undivided Family business.
- Karta can take advice from all the members but he is not bound to accept their decisions.

Continuity

- After the "Karta" is deceased, the very next eldest member takes up the position of Karta in Hindu Undivided Family business.
- The business can be divided and ended up by the mutual consent of the members.
- Minor Members
- The person who has taken birth in Hindu Undivided Family can be a member of the family business.
- Therefore, a minor can also be a member of the family.

Advantages

Effective Control

- The Karta has full control over the business activities and takes a decision quickly.
- No one can interfere in the decision of Karta as every member is bound to accept his decision.
- Hence, it avoids clashes among the members and results in very speedy decision making.

Continued Business Existence

- After the death of Karta, the next eldest member takes up his position. So, it does not affect the activities of the business.

- Hence, all the business activities are done smoothly, continuously without any threat.

Limited Liability of Members

- As all the liability of the members is restricted to the extent of their share in the business.
- But the Karta has unlimited liability due to his complete hold on the business.
- Hence, in case of dissolution of the business, Karta's personal assets and his share will be liable.

Expanded Loyalty and Cooperation

- All the business operations are carried on by the members of a family jointly.
- So, this increases loyalty and cooperation with each other without any hindrance.
- Therefore, all the targets of the business can be achieved by the cooperation among the members and the Karta.

Disadvantages

Limited Resources

- All the members of Joint Hindu Family Business totally depend upon the ancestral property due to their limited liability.
- Many commercial banks resist extending the credit limit due to the weak financial position of the business.
- Hence, this will result in limited expansion and growth of the business.

Unlimited Liability of Karta

- All the important decision regarding management of various business activities are taken by Karta.
- But there is a disadvantage with the Karta that he has unlimited liability.
- Hence, all the business debts are paid by using the personal assets of the Karta.

Dominance of Karta

- The Karta takes all the decisions individually and manages the business
- He also involves other members in decision making.
- But Karta is not bound to accept the decisions of the members which may create conflicts between the Karta and the other members.
- Hence, due to clashes in decision making, lack of cooperation between Karta and other members occurs.

Limited Managerial Skills

- Sometimes the members suffer due to unfair decisions taken by the Karta in respect of business operations.
- Unfair decisions are taken due to the lack of managerial skills.
- So, the Karta cannot be knowledgeable or proficient in all managerial functions.

- Nowadays the joint Hindu family business is declining due to the decreasing number of joint Hindu families in the nation.

D) Cooperative Society

A cooperative society is a voluntary association of persons who join together with the motive of welfare of the members. A **cooperative** is a private business **organization** that is owned and controlled by the people who use its products, supplies or services. In other words it may be defined as Co-operative organization is a voluntary association of usually economically weaker sections of society; who join together to achieve a common objective by fighting against some social evil- through working collectively according to established principles of co-operation or in other words it may be defined as " when a group of persons belonging to a particular class or category or group associate themselves and start a business for their mutual benefit, it is called **Cooperative society**".

Features:

1.Registration:

A co-operative society must be registered under the Co-operative Societies Act, 1912 or under a State Co-operative Societies Act. On registration, the society becomes a body corporate, having a separate legal entity of its own, with perpetual succession and limited liability of its members.

2.Voluntary Association : A co-operative organization is a voluntary association of persons. Everyone having a common interest is free to join a co-operative society; irrespective of caste, c religion. No person can be forced to become the member of a co-operative society or continue as a member. A member after giving proper notice can leave the society; and will get back his capital according to the rules of the co-operative. But no member can transfer his shares to another person.

3.Minimum Ten Persons Needed:

A minimum of ten adult persons are needed to form a cooperative organization. Maximum number of members is 100, in a co-operative credit society; with no such limit in non-credit co-operative societies.

4.Service-Motive:

The primary aim of a co-operative society is to provide some service or benefit to its members (or even general public's) by fighting against some social evil.

5.Finance:

The capital of a co-operative is raised from members through issue of shares. A co-operative can also obtain loans from the Central or State Co-operative Banks.

6.Limited Liability:

The liability of each member of a co-operative is limited to the extent of the value of shares held by him, in the share capital of the co-operative.

7.Democratic Management*:*

Business of a co-operative society is managed by a managing committee; which is elected by the members. The members lay down the broad policy guidelines within which the managing committee manages the affairs of the co-operative society. The managing committee usually consists of the following office-bearers: 1. President 2. Vice-president. 3. Secretary 4. Joint Secretary 5. Treasurer.

8.State Control

Government exercises control over co-operatives to protect the interests of members of co-operatives; who, otherwise, are economically quite weak. Every co-operative society must furnish annual accounts and reports to the Registrar of Co-operatives. Further, accounts of all co-operatives are subject to compulsory audit.

Advantages

1.Easy to Form:

A co-operative society is easy to form. Its registration is very simple and does not involve many legal formalities.

2. Universal Brotherhood*:*

Membership of a co-operative is open to all having a common interest; irrespective of caste and religion. Any member may leave the society, after giving proper notice. There is no compulsion to stick to the co-operative against one's will.

3. Fully Democratic Management:

Managing committee of a co-operative is elected, by members. Further, 'one-man one-vote' principle is followed in all co-operatives. As such, each member has equal rights and equal voice in the management of the co-operative.

4.Perpetual Succession

After registration, a co-operative society acquires a separate legal status with perpetual succession. Its life is not affected by the death, insolvency or lunacy of members. Co-operatives exist for long periods-benefiting members and the community.

5.Limited Liability*:*

Liability of members of a co-operative society is limited to the extent of the value of their shares. Members do not run personal risk; while being members of the co-operative. This fact encourages even poor people to join co-operatives.

6. Governmental Patronage:

As a matter of social welfare policy, Government extends all support to co-operatives e.g. loans at low rates of interest, relief in taxation etc.

7.Internal Financing:

A large part of the profits of a co-operative is transferred to general reserve every year. Through ploughing back of profits, a co-operative can undertake schemes for its growth and expansion.

8.Lower Operating Costs:

Operating costs of a co-operative are quite low; because:

1. Office bearers offer honorary services.
2. There is no expenditure incurred on advertising and marketing activities.

9.Social Welfare Aspect*:*

Co-operatives are non-business organizations. They spread ideals of co-operation in society. They promote feelings of equality, independence, hard work among people in a society and help them morally upgrade themselves.

Disadvantages

1.Limited Capital:

Co-operative organizations have very limited capital; because of the following reasons:

(a) Members of a co-operative are economically backward, in most of the cases.

(b) Co-operatives do not give more than 10% interest on capital invested. This provides not much incentive to invest huge amounts in co-operatives.

(c) The principle of 'one-man one-vote' discourages people to buy a large number of shares in a co-operative organization.

All told, limited finances stand in the way of growth of activities indulged in by a co-operative.

2. Inefficient Management:

Management of a co-operative organization is called inefficient. In fact, members of managing committee are part-time and inexperienced people. They usually possess no specialized knowledge of modern management principles and techniques. Because of limited financial capacity, a co-operative is unable to hire the services of professional managers; who charge very high for their services, in the present-day-times.

3.Rift among Members:

Co-operatives are started with a sense of lot of enthusiasm about co-operation; Over a period of time, differences develop among members as to how to run the society. Selfish interests of dominating members prevail upon the genuine interests of poor members. Differences among members usually lead to a decline of co-operative activities

4.Rigid Rules and Regulations:

Co-operatives have to function according to rigid rules and regulations. They are subject to excessive Governmental control over their functioning. The result is lack of flexibility of operations in the functioning of co-operatives; which does not permit their growth in view of environmental opportunities.

5.Political Interference*:*

Government also invests in co-operative organizations. There are, then, members in managing committee, who represent interests of political parties. In fact, members of political parties dominate the working of the co-operative; and the co-operative organization very often turns into a political organization. Thus the very purpose and philosophy of co-operation, which is the basis of a co-operative organization meets with frustration.

6.Lack of Motivation:

The office-bearers of a co-operative are honorary officials. They have no incentive to work hard for the co-operative. In the absence of remuneration, they just work minimum and justify their status, in the eyes of the members.

E)Joint Stock Company:

When many persons start a business, it may be a joint stock company. Joint-stock companies are most popular form of business organization not only in India but also world wide. It is governed and regulated by an Act in the Parliament known as "The Indian Companies Act, 1956". It is owned by its investors, with each investor owning a share based on the amount of stock purchased. In other words a joint stock company is a voluntary association formed for the purpose of carrying on some business. Legally, it is an artificial person and having a distinctive name and a common seal. Lord Justice Lindley of England has defined joint-stock company as "an association of many persons who contribute money or moneys' worth to a common stock and employ it for a common purpose.

Features:

1.Flexible:

A joint stock company is treated as an independent and separate body apart from its members. It enjoys separate legal status. It is treated as an individual in the eye of law. It can enter into agreement with anybody. It can purchase properties in its name. Any one can file case in the name of joint stock company and the joint stock company can also file case in the name of any individual. Even the owner of the company can file case in the name of joint stock company and vice versa. A joint stock company enjoys all the privileges. A joint stock company can be penalized or rewarded as needed.

2.Perpetual succession : Once a joint stock company formed, it continues to carry on its activities for an unlimited period of time. No events like the death or insolvency of any or all members can lead to the closure of joint stock company. This is known as perpetual succession.

3.Limited Liability:

The liabilities of all members of a joint stock company are limited to the extent of their share in the company. If they have paid the full value of shares they can not be called upon to pay any further amount.

4.Minimum Number of Members:

Forming a public company minimum 7 persons are required and maximum is unlimited and for forming a private company at least 2 persons are required and maximum is fifty. If not registered it would be treated as illegal association.

5.Transferability of shares*:*

The shares of a joint stock company are freely transferable and any one can become a member of a joint stock company by purchasing the shares of that company.

6.Artificial legal person*:*

The share holders of a company are the members, who are the owners of that company. But the owners do not take active part in the management of the company. They elect a group of persons among themselves who manage the company on behalf of all the members.

7.Govt. control:

A joint stock company collects a large amount of money from the general public, so the Government usually puts more control over the working of the joint stock company.

8.Certificate for registration: The promoter of joint stock company have to get certificate of registration from the Registrar of companies and they have to apply for certificate for commencement of business when the company becomes ready to start its business.

Private Limited Company

Private limited company is held by few individuals privately having a separate legal entity. In this, the shareholders cannot trade publicly shares. It restricts its number of shares to 50. Shareholders cannot sell their shares without the approval of other shareholders. It is a company which restricts the right of its members to transfer its shares and it doesn't send the invitation to the public for subscription of its shares.

Features:

1.Members– To start a company, a minimum number of 2 members are required and a maximum number of 200 members as per the provisions of the **companies act 2013**.

2.Limited Liability– The liability of each member or shareholders is limited. It means that if a company faces loss under any circumstances then its shareholders are liable to sell their own assets for payment. The personal, individual assets of the shareholders are not at risk.

3.Perpetual succession– The company keeps on existing in the eyes of law even in the case of death, insolvency, the bankruptcy of any of its members. This leads to the perpetual succession of the company. The life of the company keeps on existing forever.

4.A number of directors– When it comes to directors a private company needs to have only two directors. With the existence of 2 directors, a private company can come into operations.

5.Prospectus– Prospectus is a detailed statement of the company affairs which is issued by a company for its public. However, in the case of **a private limited company**, there is no such need to issue a prospectus because in this public is not invited to subscribe for the shares of the company.

6.Name– It is mandatory for all the private companies to use the word private limited after its name.

Public Limited Company

According to the Companies Act 2013, a public limited company is a separate legal entity. Further, the members of such a company have limited liability. Also, a public company offers shares to the general public.

Features

1.Paid-up Capital – There is no requirement of a minimum paid-up capital. Hence, you can incorporate a public company with any amount of capital.

2.Minimum number of Directors – You need a minimum of 3 directors to incorporate a public company with a maximum of 15 directors. However, no. of directors can exceed 15 after obtaining Special Resolution.

3.Minimum number of Shareholders – You need a minimum of 7 members to incorporate a public company.

4.Name of the company – Every public company must have the word "Limited" at the end of the company name.

5.Transfer of shares – There are no restrictions on the transfer of shares in a public company.

6.Liability – The liability of each member of a public company cannot exceed the amount of investment in shares of the member. This limit is non-extendable.

7.Issue of securities – There is no restriction on the issue of securities to the public. The company can issue the same via an initial public offer (IPO) or a bonus issue through private placement. Also, the company needs to issue the securities in the Dematerialized format.

8.Quorum – Every public company must have at least five members personally present to form a quorum to constitute the meeting.

9.Managerial Remuneration – In a public company, the managerial remuneration paid to the director and manager and that should not exceed 11% of the net profits of the company subject to other provisions of the law.

Types of Industries

Depending on the nature of industrial activities, industries can be classified in to five categories such as :

- Manufacturing Industries,

- Extractive Industries,
- Genetic Industries,
- Construction Industries and
- Service Industries.

Manufacturing Industries

Manufacturing industries are understood to be the factories and mills where raw materials are introduced and finished product are found out through the help of men and machines.

Examples are Toyota, Yamaha, Panasonic, LG, Samsung and Tata Motors.

Extractive Industries

Extractive industry can be defined as a processes that involve different activities that lead to the extraction of raw materials from the earth and nature such as mining of ore, metals, mineral, collection of forest products etc. This type of industries directly depend on nature and their activities are directed towards exploitation the nature to collect something useful for their business activities.

Genetic Industries

Genetic industries are those industries which are engaged in re-production and multiplication of species of plants and animals with the sole objective of sale.

These industries are engaged in activities such as animal breeding, cattle breeding, etc.

Dairying and poultry are the example of genetic industry.

Construction Industries

This type of industries are engaged in the construction of various infrastructure like road, dam, bridge, canal, flyover, building, factory etc. Such types of industries carry on their activities at the sites where the structure is required.

Service Industry

This type of industries provide services of various types to the people, to the industries and to the other organizations. Such industries do not produce any commodities but produce or create services for the needy. Examples are service stations, garage for automobiles, hotels, hospitals, internet, telephone service, courier service etc.

Concept of Start-ups

The term startup refers to a company in the first stage of its operations. Startups are founded by one or more entrepreneurs who want to develop a product or service for which they believe there is a demand.

Features:

- Risk taking is the first and foremost trait of entrepreneurship. Starting any business involves a considerable amount of risk of failure. Therefore, the courage and capacity to take the said risk are essential for an entrepreneur.
- An innovation plays an essential role in the success of a startup, so entrepreneurs should seriously consider this aspect.
- An entrepreneur should be flexible and open to change according to the situation.
- Another quality of successful startups is their ability to adjust to feedback. Whether the feedback comes from investors, advisors, mentors, or customers, successful startups extract value from feedback to help improve their product, service, or business model.
- When starting from the ground up, especially with a small team, they should concentrate on a limited product according to market demand instead of introducing many products.
- Now a days in the present competition market work culture plays a vital role for the existing of the enterprise. So, the entrepreneurs put emphasis on work culture.
- In a long term a start-up company may turn into a bigger one.

Entrepreneurial support agencies at National, State and District level (Source)

Industrialization plays a significant role in the economic development of any country.

The industrial structure of a country consists of large, medium, and small scale industries. Of these three types of industrialization, the role of small scale industries in the industrial development of a country is of paramount importance.

The following institutions or agencies are the principal financial institution for the promotion, financing and development of industry in the small, tiny and cottage sectors such as DIC, NSIC, OSIC, SIDBI, NABARD, Commercial Banks and KVIC.

District Industries Centre (DIC)

A District Industries Center is an institution established at the district level so as to provide them to set up small and village industries there. Before the setting up of DIC, a prospective entrepreneur has to go to several agencies, many of them far from his district, in order to get the necessary assistance and facilities. This caused considerable delay, waste of time and money. Now suitable powers have been delegated by several departments of the State

Government to the District Industries Center. Thus an entrepreneur can get all the assistance he needs from a single agency itself i.e. DIC.

Functions of DIC

- The District Industries Center conducts survey of the existing traditional and new industries and raw materials and human resources.
- It makes market forecasts of various products.
- The District Industries Center also conducts training courses for the entrepreneurs of small and tiny units.
- It acts as an intermediary between the entrepreneurs and the small industries in order to introduce new and quality product developed by the latter to the former.
- The District Industries Center indicates the locations where from machinery and equipment can be acquired and also arrange for supply of machinery on hire purchase basis.
- The District Industries Center obtains the details regarding the materials required by various units and arrange for purchase of the same in bulk.
- Thereby it enables the small units to get their raw materials at reasonable prices.
- It makes the necessary arrangements with Lead Banks and other Financial Institutions in order to provide financial assistance to the entrepreneurs.
- The District Industries Center conducts market surveys and market development programs.
- It also organizes marketing outlets, contact with Government procurement agencies and make the entrepreneurs well informed of the market intelligence.
- District Industries Centers gives special attention to the development of khadi and village industries and other cottage industries.
- It also keeps close contact with the State Khadi Board and organize training programs for rural artisans.

National Small Industries Corporation (NSIC)

The National Small Industries Corporation Ltd (NSIC) was set up in 1955 as a central government undertaking, the main aim of which is to fulfill the requirement of machinery and equipment for the development of the small entrepreneurs. It is observed that the main constraint faced by the entrepreneurs is the dearth or shortage of investible funds to purchase machinery and equipment. Non-availability of finance deprives many new entrepreneurs from availing entrepreneurial opportunities.

Functions of NSIC

- The National Small Industries Corporation Ltd (NSIC) was set up in 1955 as a central government undertaking, the main aim of which is to fulfill the requirement of machinery and equipment for the development of the small entrepreneurs.
- Assists in marketing of the products of SSIs.
- Helps in exporting the product of SSIs.
- Provides training to workers of SSIs in various trades.
- Helps in the development and up gradation of technology and modernization of the industries.
- Undertakes construction of industrial estates.
- Purchases huge quantity of important raw materials and distribute the same to SSIs at reasonable rates.
- Develops prototype machines and equipments to pass on to SSIs for commercial production.
- Sets up small scale industries in other developing countries on turn-key basis.

Odisha Small Industries Corporation (OSIC)

OSIC was established on 3rd April, 1972 as a wholly owned Corporation of Government of Odisha. The basic objective of the Corporation is to assist and promote the MSMEs in the State for their sustained growth and development to gear up the industrialization process in the State.

Functions of OSIC

- This is the only corporation in the state exclusively engaged in the development of MSMES which form the back bone of industrial sector in the state.
- The basic objective of the Corporation is to assist and promote the MSMEs in the State.
- It acts as the facilitator for the industrial growth of the MSMES of the state.

- To provide quality raw material to MSMEs of the state.
- To provide quality building material to MSMEs sector of the state.
- To assist in marketing the product of the MSMEs sector.
- To market the MSMES produces by creating common brand name with quality assurance.
- Examples of MSME are napkins, tissues, chocolates, toothpick, water bottles, small toys, pens(Micro and Small scale), cotton, textile, jute textile, iron & steel industry etc.(Medium scale)

Small industrial Development Bank of India (**SIDBI**) is a development financial institution in India, headquartered at Lucknow and having its offices all over the country. Its purpose is to provide refinance facilities and short term lending to industries, and serves as the principal financial institution in the Micro, Small and Medium Enterprises (MSME) sector. SIDBI also coordinates the functions of institutions engaged in similar activities. It was established on April 2, 1990, through an Act of Parliament. It is headquartered in Lucknow. SIDBI operates under the Department of Financial Services, Government of India.

Functions of SIDBI

- SIDBI offers indirect assistance by providing Refinance to PLIs (Primary Lending Institutions), comprising of banks, State Level Financial Institutions, etc. with an extensive branch network across the country.
- The key objective of the refinancing scheme is to raise the resource position of Primary Lending Institutions that would ultimately enable the flow of credit to the MSME sector.
- Small Industries Development Bank of India offers microfinance to small businessmen and entrepreneurs for establishing their business.
- Small Industries Development Bank of India refinances loans that are extended by the PLIs to the small-scale industrial units and also offers resources assistance to them
- It also helps in expanding marketing channels for the products of SSI (Small Scale Industries) sector both in the domestic as well as international markets.
- It offers services like factoring, leasing etc. to the industrial concerns in the small-scale sector.

- It promotes employment oriented industries particularly in semi-urban areas for creating employment opportunities and thus checking relocation of people to the urban areas
- It also initiates steps for modernization and technological up-gradation of current units
- It also enables the timely flow of credit for working capital as well as term loans to Small Scale Industries in cooperation with commercial banks

National Bank for Agriculture and Rural Development (NABARD)

NABARD stands for National Bank for Agriculture and Rural Development. It was established on 12 July 1982 by an act of parliament to implement the National Bank for Agriculture and Rural Development Act 1981.

It is an apex development bank that provides a facility to credit flow for development of small industries, agriculture, cottage industries and other small businesses in rural areas. NABARD is headquartered in Mumbai, Maharashtra and its branches are located all over the country.

Functions of NABARD

- It refines and regulates the financial institutions which finance the rural sector.
- It regulates the cooperative banks .
- It provides training facility to the institutions which work for rural development.
- It also promotes research in rural banking and agriculture and rural development.
- It provide financial support for the commercial banks and Regional Rural Banks, and the training institutes of cooperative banks.
- It communicates and consults the RBI in matters such as issuing of licenses for new banks and to open the branches of rural banks.
- Help banks to improve their MIS System, modernize their technology, and develop human resources.
- It promotes rural industries, small scale and cottage industries by providing loans to commercial and Co-operative banks.
- During natural calamities, such as droughts, crop failure and floods, the bank helps by refinancing commercial and cooperative banks, so that the farmers are tied over their tough period.

- NABARD gives foremost priority to projects formed under the Integrated Rural Development Program (IRDP).
- NABARD is an apex institution which has the power to deal with various matters concerning policy, planning and operation in providing credit for agriculture and other economic activities in the rural areas.

Commercial Bank

The term commercial bank refers to a financial institution that accepts deposits, offers checking account services, makes various loans, and offers basic financial products like certificates of deposit (CDs) and savings accounts to individuals and small businesses. A commercial bank is where most people do their banking. Commercial banks make money by providing and earning interest from loans such as mortgages, auto loans, business loans, and personal loans. Customer deposits provide banks with the capital to make these loans.

Few examples of commercial bank in India are.

- State Bank of India (SBI)
- Housing Development Finance Corporation (HDFC) Bank
- Industrial Credit and Investment Corporation of India (ICICI) Bank
- Dena Bank
- Corporation Bank

Functions of Commercial Bank

- The bank takes deposits in the form of saving, current, and fixed deposits.
- Another critical function of this bank is to offer loans and advances to the entrepreneurs and business people and collect interest.
- The bank offers you with the facility of selling and buying the securities.
- Bank provides lockers facility to the customers to keep their valuable belonging or documents safely. Banks charge a minimum of an annual fee for this service.
- Collection and payment of rent, interest and dividend.
- Collection and payment of cheques and bills.
- Payment of insurance premium and subscriptions.
- ATM card, credit card and debit card facility.
- Issue of demand draft, pay order and traveler’s cheque.

- Internet and mobile banking
- Sale of application forms of competitive exams.
- Banks assist in the transfer of funds from one person to another or from one place to another through its credit instruments.

Khadi and Village Industries Commission (KVIC)

The Khadi and Village Industries Commission (**KVIC**) is a statutory body formed in April by the Government of India, under the Act of Parliament, 'Khadi and Village Industries Commission Act of 1956' with the objective to plan, promote, organize and implement the programs for development of khadi and village industries in rural areas. Examples are dhoti, kurta, handloom sarees, tussar silk etc.

Functions of KVIC

- To plan, promote, organize and implement the programs for development of Khadi and village industries in rural areas.
- Creating and managing reserves of raw materials and supplying them to producers, creating common service facilities for processing of raw material and semi-finished goods.
- To promote sales and marketing of Khadi Products.
- To encourage and promote research in the production techniques and equipments in Khadi Industries.
- To plan and organize training of persons employed or desirous of seeking employment in Khadi and village industries.
- To promote the sale of marketing of Khadi or products of Village Industries or handicrafts and for this purpose and keep links with established marketing agencies wherever necessary and feasible.
- To build up reserves of raw materials and supply them to persons engaged or likely to be engaged in production of handspun yarn or Khadi or Village Industries at such rates as the Commission may decide.
- To undertake experiments or pilot projects which in the opinion of the Commission are necessary for the development of Khadi and Village Industries.

- To encourage and promote research in the technology used in Khadi and Village Industries, including the use of non-conventional energy and electric power with a view to increasing productivity.

Department of science and technology has set up many technology business incubators(TBI) and science and technology entrepreneurship parks(STEPS) across the country in premier academic institutions to nurture entrepreneurs in various knowledge and technology field. These incubators and parks provide modern infrastructure, facilities and useful guidelines to the entrepreneurs.

Technology Business Incubation (TBI)

Technology Business Incubation (TBI) is one of the strategies identified by Department of Science and Technology (DOST) to promote innovation and techno-entrepreneurship for the Country's socio-economic development. TBI involves an ecosystem where innovation is promoted and supported towards commercialization. It aims to help startup technology based businesses by providing a range of resources, , services and facilities, furnished office space, mentoring support in developing stage of entrepreneurs.

Objective of TBI

- To promote new technology/knowledge/innovation based startups.
- To provide cost effective, value added services to startups like mentoring, legal, financial, technical services.
- It also provides office space, business meeting or conference room, training room and storage room.
- They provide Networking activities
- They provide Marketing assistance.
- Incubators help in Market Research.
- They provide High-speed Internet access.
- Incubators Help with accounting/financial management.
- They help in providing Access to bank loans.
- Incubators help with presentation skills.
- They organize Comprehensive business training programs.
- They act as Advisory boards and mentors.
- They provide Technology commercialization assistance.

Science & Technology Entrepreneurship Parks (STEPs)

The Science Parks and similar initiatives help in creating an atmosphere for innovation and entrepreneurship; for active interaction between academic institutions and industries for sharing ideas, knowledge, experience and facilities for the development of new technologies and their rapid transfer to the end user or entrepreneur.

A STEP creates the necessary climate for innovation, information exchange, sharing of experience and facilities and opening new avenues for students, teachers, researchers and industrial managers to grow for starting a successful economic venture. The major objectives of STEP are to establish linkages among academic and R & D institutions on one hand and the industry on the other and also promote innovative enterprise through S &T persons. Some of the examples of STEP are Amity Business Incubator, Noida, Society for innovation and entrepreneurship, Mumbai, Technology Business Incubator, Chenai etc.

Objectives

- To build a close linkage between universities, academic and R&D institutions on one hand and industry on the other.
- To promote entrepreneurship among Science and Technology persons.
- To provide R&D support to the small-scale industry mostly through interaction with research institutions.
- To promote innovation based enterprises.
- It offers facilities such as nursery sheds, testing and calibration facilities, central workshop, prototype development, business facilitation, computing, library and documentation, communication, seminar hall/conference room.
- It also provides common facilities such as phone, telex, fax, photocopying.
- It offers services like testing and calibration, consultancy.
- It also provides Training, technical support services, business facilitation services, database and documentation services and quality assurance services.

UNIT 2

MARKET SURVEY AND OPPORTUNITY IDENTIFICATION (BUSINESS PLANNING)

What is Business planning? A business plan is a blue print of the step by step procedure that would be followed in order to convert a business idea into a successful venture. It involves the following tasks :

- Identifying business opportunities and an innovative idea.
- Researching the external environment opportunities and threats.
- Identifying the internal strengths and weakness.
- Assessing the feasibility of that idea.
- Allocating resources in the best possible manner.
- Process of Business planning

Objectives of Business Planning:

- **Dedicating enough time for planning**

  A workable business plan cannot be created overnight. It is bound to take its own time to develop. So, a perfect business plan will attempt to spend enough time and hard work to achieve successful implementation. This should be one of the crucial stages in a business plan.

- **Create goals and objectives**

  An organization depends heavily on the business plan to arrive at the description of business it performs. There are several areas that a company will focus on if it wants to realize its objectives, understand the market that it is planned to operate in and the strategy to achieve the goals.

- **Evaluating Performance**

  A business needs proper planning and control over the activities for enhanced performance. It will be an essential step towards achieving the long term survival of the organization as a whole. The business plan also comes with a financial part to it and used for comparing the actual performance with the estimated one.

- **Gauging business strategy and applying due correction**

  A Business plan does assist entrepreneur in assessing the efficiency of his strategies for achieving business goals. In an ideal condition, a business needs to have the planned results with which the actual results can be compared, and the way forward is decided. If any of the strategies are found to be unsuccessful in achieving the relevant results, it may be a perfect idea to modify the strategy or take corrective actions. It is wise to have a good business plan so that the management does have a reference with which it can have a healthy comparison of the actual result achieved.

- **Arranging financial resources**

  A business plan can be much helpful and instrumental in acquiring adequate business financing. Banks and lenders look for a proper business plan before giving any sort of finance to the entrepreneur. A business plan should be prepared in such a manner that the banks will have a clear understanding of the business perspective before giving any finance.
- **Stay Consistent**

  This should be yet another objective that a business plan needs to be focused with is being consistent. A good business plan should place proper value on the exact process and its adherence to the planned goals. Through consistent schedule the enterprise can achieve the goals effectively. This will also help the employees and other staff to fall into a proper routine. This will help the concept of planning to be a part of the business culture.
- **Keep the goals 'SMART'**

  The goals in the business plan should be SMART(Specific, Measurable, Actionable, Realistic, and Time-Bound) to achieve success. This will help the entrepreneurs to achieve the business goals as laid out in the business plan effectively and efficiently. It would be practical to have the team member of the enterprise to analyze the goals set so that the entrepreneur will get back to a realistic approach.
- **Performing SWOT analysis**

  SWOT Analysis is one of the best options you would want to go with when it comes to focus on an effective business plan. Having perfect knowledge of the strengths and weaknesses of your organization helps you come up with a better insight into the realistic goals. The SWOT analysis also takes into account the opportunities and threats that the organization can come to face to face. This will assist you to focus on the positive factor and take corrective actions against the negatives.
- **Marketing analysis**

  Marketing analysis is an integral part of a business and so does with the business plan. This part of the business plan should be focused on determining the potential of the product or service. The marketing analysis part of the business plan should ideally provide the entrepreneur with a means of understanding their industry as a whole.

Process of Business Planning:

1. Recognizing Need for Action

An important part of the planning process is to be aware of the business opportunities in the firm's external environment as well as within the firm. Once such opportunities get recognized the managers can recognize the actions that need to be taken to realize them. A realistic look must be taken at the prospect of these new opportunities and SWOT analysis **should be done.**

***2.* Setting Objectives**

- This is the second and perhaps the most important step of the planning process. Here we establish the objectives for the whole organization and also individual departments. Organizational objectives provide a general direction, objectives of departments will be more planned and detailed.
- Objectives can be long term and short term as well. They indicate the end result the company wishes to achieve. So objectives will percolate down from the managers and will also guide and push the employees in the correct direction.

3. Developing Premises

Planning is always done keeping the future in mind, however, the future is always uncertain. So in the function of management certain assumptions will have to be made. These assumptions are the premises. Such assumptions are made in the form of forecasts, existing plans, past policies, etc.
These planning premises are also of two types – internal and external. External assumptions deal with Factors such as political environment, social environment, the advancement of technology, competition, government policies, etc. Internal assumptions deal with policies, availability of resources, quality of management, etc. These assumptions being made should be uniform across the organization. All managers should be aware of these premises and should agree with them.

4. Identifying Alternatives

The fourth step of the planning process is to identify the alternatives available to the managers. There is None way to achieve the objectives of the firm, there is a multitude of choices. All of these alternative Courses should be identified. There must be options available to the manager.

***5.* Examining Alternate Course of Action**

The next step of the planning process is to evaluate and closely examine each of the alternative plans. Every option will go through an examination where all there pros and cons will be weighed. The alternative plans need to be evaluated in light of the organizational objectives. For example, if it is a financial plan. Then it that case its risk-return evaluation will be done. Detailed calculation and analysis are done to ensure that the plan is capable of achieving the objectives in the best and most efficient manner possible.

***6.* Selecting the Alternative**

Finally, we reach the decision making stage of the planning process. Now the best and most feasible plan Will be chosen to be implemented. The ideal plan is the most profitable one with the least amount of negative consequences and is also adaptable to dynamic situations. The choice is obviously based on scientific analysis and mathematical equations. But a managers intuition and experience should also play a big part in this decision. Sometimes a few different aspects of different plans are combined to come up with the one ideal plan.

7. Formulating Supporting Plan

Once you have chosen the plan to be implemented, managers will have to come up with one or more supporting plans. These secondary plans help with the implementation of the main plan. For example plans to hire more people, train personnel, expand the office etc are supporting plans for the main plan of launching a new product. So all these secondary plans are in fact part of the main plan.

8. Implementation of the Plan

And finally, we come to the last step of the planning process, implementation of the plan. This is when all the other functions of management come into play and the plan is put into action to achieve the objectives of the organization. The tools required for such implementation involve the types of plans- procedures, policies, budgets, rules, standards etc.

Advantages of Business Planning

- It makes an entrepreneur consider every aspect of the start up so they can try to eliminate failures.
- It makes the entrepreneur aware of what skills they are missing so that they can hire experts in that particular field.
- Venture capital may be available to the business if investors like the business plans..

Disadvantages of Business planning

- The business plan is only a plan and does not guarantee success. For example, sales may be lower than predicted as they can be affected by a range of issues.
- If the plan is too rigid some problems may arise, it must be flexible to adapt to market changed.
- High sales expectations may cause overspending in other areas such as stock and staffing.

Small Scale Industries(SSI)

Small scale industries are those industries in which the manufacturing, production and rendering of services are done on a small or micro scale. These industries make a one-time investment in machinery, plants, and industries, but it does not exceed Rs 1 Crore. **Examples and Ideas of Small Scale Industries are** Bakeries, School stationeries, Water bottles, Leather belt, Small toys, Paper Bags, Photography, Beauty parlours.

Characteristics of SSI

- **Ownership**: SSI 's generally are under single ownership. So it can either be a sole proprietorship or sometimes a partnership.
- **Management**: Generally both the management and the control is with the owner/owners. Hence the owner is actively involved in the day-to-day activities of the business.
- **Labor Intensive**: SSI's dependence on technology is pretty limited. Hence they tend to use labor and manpower for their production activities.
- **Flexibility**: SSI's are more adaptable to their changing business environment. So in case of amendments or unexpected developments, they are flexible enough to adapt and carry on, unlike large industries.
- **Limited Reach**: Small scale industries have a restricted zone of operations. Hence, they can meet their local and regional demand.
- **Resources utilization**: They use local and readily available resources which helps the economy fully utilize natural resources with minimum wastage.

Role in the Indian economy

- **Employment**: SSI's are a major source of employment for developing countries like India. Because of the limited technology and resource availability, they tend to use labor and manpower for their production activities.
- **Total Production**: These enterprises account for almost 40% of the total production of goods and services in India. They are one of the main reasons for the growth and strengthening of the economy.
- **Make in India**: SSI's are the best examples for the Make in India initiative. They focus on the mission to manufacture in India and sell the products worldwide. This also helps create more demands from all over the world.
- **Export contribution**: India's export industry majorly relies on these small industries for their growth and development. Nearly half of the goods that are exported from India are manufactured or produced by these industries.
- **Public Welfare**: These industries have an opportunity to earn wealth and create employment. SSI's are also important for the social growth and development of our country.

Objectives of SSI

The objectives of the small scale industries are:

- To create more employment opportunities.
- To help develop the rural and less developed regions of the economy.
- To reduce regional imbalances.
- To ensure optimum utilization of unexploited resources of the country.
- To improve the standard of living of people.
- To ensure equal distribution of income and wealth.
- To solve the unemployment problem.
- To attain self-reliance.
- To adopt the latest technology aimed at producing better quality products at lower costs.

Advantages of small scale industries

1.Equitable distribution

Large scale industries lead to inequalities in income distribution and concentration of economic power. But small scale industries distribute resources and wealth more equitably. It is because income is distributed among more number of workers since it is labor intensive. This results in both economic and social welfare.

2. Use of domestic resources

Small Scale Industries use locally available resources in a productive manner which would have otherwise gone waste. Small amounts of savings which would have remained idle is channelized into setting up of small enterprises. This increases capital formation and investment in the economy.

3. Opportunities for entrepreneurship

Small Scale Industries provide opportunities for entrepreneurs with limited capital. Setting up of an SSI requires less capital and lower investment in technology and machines when compared to large scale enterprises. Therefore small entrepreneurs car start Small Scale Industries easily and succeed. Japan which was devastated by the Second World War became a major economic power because of many small entrepreneurs, who contributed greatly to the nation’s development.

4. Cost efficiency

Small scale units can adopt lean production method. which offer better quality and more variety at a lower cost. They can bi more cost efficient when compared to large scale units because their expenses are lower.

5. Requirement of less capital: Small Scale Industries require less capital when compared to large scale industries. India is a capital scarce country and therefore Small Scale Industries are more suitable in the Indian context. They can be started and run by small entrepreneurs who have limited capital resources

6. Potential for large employment

Small Scale Industries have potential to create employment opportunities on a massive scale. They are labor intensive in character. They use more labor than other factors of production. They can be set up in short time and can provide employment opportunities to more number of people. This is important for a labor abundant country like India.

8. Contribution to industrial output

Products manufactured by Small Scale Industries form a significant portion of the industrial output of the country. They produce a number of consumer goods as well as industrial components in large quantities and satisfy the needs of consumers. The consumer goods produced by Small Scale Industries are cheaper and satisfy the requirements of the poorer sections.

9. Contribution to exports

Small Scale Industries contribute nearly 40 per cent to the industrial exports of the country. Products such as hosiery, knitwear, hand loom, gems and jewellery, handicrafts, coir products, textiles, sports goods, finished leather, leather products, woolen garments, processed food, chemicals and allied products and a large number of engineering goods produced by the SSI sector contribute substantially to India's exports. Further products produced by Small Scale Industries are used in the manufacture of products manufactured and exported by large scale industries. Therefore they contribute both directly and indirectly to exports and earn valuable foreign exchange.

10. Cost efficiency

Small scale units can adopt lean production method. which offer better quality and more variety at a lower cost. They can bi more cost efficient when compared to large scale units because their expenses are lower.

11. Suitable for non-standardized products

Large scale enterprises are suitable for manufacturing standardized products on a large scale whereas Small Scale Industries are more suitable for manufacturing non-standardized products

12. Flexibility in operation

Small scale enterprises are more flexible. They can adapt themselves to changing market requirements very fast and benefit from new opportunities.

13. Quick decisions

Since the enterprise is small and there is not much hierarchy, quick decisions. can be taken. Quick decisions are helpful in solving problems in the initial stages and also to exploit market opportunities.

14. Adaptability to change

Small Scale Industries can understand the changing requirements of the customers and adapt themselves much quickly. They can change their procedures, methods and techniques faster and cater to new requirements of their customers.

15. Small market size

In case the market size is small, producing products on a large scale would not be feasible. In such cases, Small Scale Industries are more suitable since they produce limited quantities.

Disadvantages of small scale industries

1. Difficulty with meeting demand: When products are in high demand, small scale industries can often struggle to increase their output sufficiently to meet that demand.

2. Geographically restricted: Small scale industries may be concentrated in a particular town or even in one single building. This can limit their ability to become household names across the globe.

3. Less financial power: Small scale industries usually deal with less money (both in terms of ingoing's and outgoings) than larger factories and so have less financial weight.

4. Access to machinery: Small scale industries usually do not have the space or the money to use large scale machinery. However, they may have access to expensive, specialized equipment.

5. A niche business: What makes the products of small scale industries attractive to some – i.e. their niceness and uniqueness – may make them less attractive to others. Small scale industries often do not have the capacity to please all tastes.

Ancillary Unit:

An **ancillary unit** is the **unit** which supplies not less than 50% of its production to the parent **unit**. That means an ancillary unit providing necessary support to the primary unit. The examples are manufacturing automobiles, railway engines, tractors, etc.

A tiny unit is the business enterprise whose investment in plant and machinery is not more than Rs. 25 lakh. Investment limit in such **unit** is Rs. 25 lacs. The examples are small shops, STD booths, photocopy centres etc.

Difference between Tiny Unit and Ancillary Unit:

Tiny Unit

1. It is that type in which machinery and investment of plant is not more than 25 lac.
2. Its investment limit is almost 25 lac.
3. There is no assistance required.
4. It cannot do its business by itself.
5. It is of large scale.

Ancillary Unit:

1. It is that type in which its supplies its 50 % production to the parent unit.
2. Its investment limit is almost one crore.
3. There is assistance required from parents by providing technical and financial support.
4. It can do its business by itself.
5. It is of small scale.

Service Sector Unit: The **Service Sector**, also called **tertiary sector**, is the third of the three traditional economic **sectors**. Activities in the **service sector** include retail, banks, hotels, real estate, education, health, social work, computer **services**, recreation, media, communications, electricity, gas and water supply.

Time Schedule Plan: Time scheduling is the art of planning the activities. So that he entrepreneur can achieve his/her goals. In other words Scheduling is the process by which the entrepreneur can make plan to complete his assignments within that time schedule.(Daily/weekly)

Follow this six-step process to prepare the schedule :

- **Identify the time**: Start by establishing the time the entrepreneur wants to make available for his/her work. How much time they spend at work should reflect the design of their job.
- **Block in the essential task:** Next, block in the actions the entrepreneur must take to do a good job. These will often be the things they are assessed against. For example, if they manage people, make sure that they have enough time available to deal with team members' personal issues, coaching, and supervision activities.
- **Schedule high-priority urgent tasks:** In the time schedule the entrepreneur should keep some time for urgent activities like schedule meeting to discuss different issues related to their business.
- **Block in appropriate contingency time to handle unpredictable events and interruptions:** The entrepreneur should keep some time for emergency activities like sudden policies changes and strike by employees etc.
- **Schedule the activities that address the priorities and personal goals in the time that remains:** The entrepreneur should keep some time for any types of personal work like attend marriage or birthday party or any other activities.
- **Analyze your activities to identify tasks that can be delegated, outsourced or cut altogether**: In this the entrepreneur has to analyze the entire activities if necessary they can modify the time schedule according to the priority of their assignments.

Project Implementation Unit is a technical **project** management **unit** that serves as the technical secretariat for the GPC. PIU reports directly to GPC and is tasked to **implement** daily tasks, and manage and oversee the **project** development.

Some of the agencies contacted for project implementation are given below :

- Don Bosco Tech Society, Nangoli Road, Najafgarh-110043, New Delhi.
- Orion Edutech, Orion House, 28, Chinar Park, Rajarhat Road, Kolkata-700157.
- Shriram New Horizons Ltd., A-12, Sector-59, Noida, 201301.
- Human Welfare Organization, 344, !st Floor, BDA Complex, Shivagi Nagar, Bhopal, MP.
- National Institute for Entrepreneurship and Small Business Development, A-23, Institutional Area, Noida.
- Indian Institute of Natural Resource Management, C-29, Acharya Niketan, Mayur Vihar-1, New Delhi-110091.
- Indian Institute of Skill Development , B-13, Infocity, Sector-34Gurgaon-122002, Hayyana.
- National Institute for Technical Training, 3-A, Private Oppesite Church, Gandhi Nagar, Jammu-180004.
- Asia Pacific Institute of Management , 3 and 4, Institutional Area, Jasola, New Delhi.
- NIC Institute of Technology, Kalaberia, Rajarhat, Kolkata-700135.

Assessing the demand and supply

What is demand? Demand is the amount of goods or services that consumers are willing to pay at each price point. It is based on wants and needs and the ability to pay. If consumers are unable to pay for goods and services, demand does not exist. When the price of a good or service rises, demand decreases. Conversely, if the price of a good or service falls, demand goes up. This law of demand represents an inverse relationship between price and quantity demanded.

What is supply? Supply is the amount of goods or services available or produced, based on a number of factors such as input resources, labor, technology and regulations**.**

The following factors are to be considered for assessing the demand and supply:

Price Fluctuations

Price fluctuations are a strong factor affecting supply and demand. When a product gets expensive enough that the average consumer no longer feels it is worth it to buy the product, then the demand declines. This leads to cuts in production that will hopefully stabilize the product’s value. Lowering the price of a product may increase demand, indicating that the public feels the product is suddenly a great value. This may also cause changes in production to increase to keep up with the demand.

Income and Credit

Changes in income level and credit availability can affect supply and demand in a major way. The housing market is a prime example of this type of impact. During a recession when there are fewer jobs available and there is less money to spend, the price of homes tends to drop. Also, the availability of credit may be less because of the average person's inability to qualify for a loan. To help encourage those who can afford to buy, prices fall which can boost sales, and even more so if interest rates decrease. When there is an economic boom, unemployment is very low and people are spending money readily, the price of homes and other major purchases tends to rise and so do interest rates.

Availability of Alternatives or Competition

When an alternative product hits the market, the competition between the existing product and the new one can cause demand to drop for the existing product. Just as many people may be buying the product, a large portion of them may elect to buy the alternative brand. This leads to price wars that ultimately lower the price of the product and may require a cut in supply to fall in line with the decrease in demand.

Trends or Tastes and preferences

Demand rises and falls on trends in many cases**.** Consumer tastes are constantly changing, and demand for products rises and falls as a result. For example If the customers are interested to wear jeans, the demands for jeans will increase.

Prices of substitutes.

An increase in the price of one product can increase the demand for its substitute. Coca-Cola and Pepsi are excellent examples of this effect. If Pepsi increases its price, consumers will quickly switch to buying more Coke.

Commercial Advertising

Commercials on television, internet and radio have an effect on supply and demand in that they make more people aware of the availability of a product. People do not buy what they don't know is for sale. If it is an appealing ad, there is a good chance of both demand and supply will increase.

Seasons

The seasons can affect supply and demand drastically. The supply and demand for toys peaks around Christmas and Fireworks boom during Dewali. etc.

Potential areas of growth

Growth potential is an organization's future ability to generate larger profits, expand its workforce and increase production. In the business sense, an organization's growth potential depends heavily upon its leadership's expectations for success, and the quantitative and qualitative measures used to determine expansion readiness. Growth potential can be gauged from an organization's planned movement into new markets, the development of new product lines, the adaptability of more effective marketing techniques, or other methods that grow a business from a niche market to a more volume operation.

The following are the potential area to be developed:

1. Keep Financial Score: The businesses organization should keep their financial status daily, weekly, and monthly and that should be maintained regularly. . It's vital that to spend the necessary time keeping current on cash flow. If necessary the entrepreneur should appoint an accountant for this activities.

2. Set Goals

Setting goals and objectives is an essential part of the business success. So in this regard the entrepreneur should gather all the information related to the business and apply appropriate methodology to fulfill the objective for the organization.

3. Use High-Impact Marketing

Wasting money on ineffective marketing is easy. The entrepreneurs should implement low-budget, high-impact marketing strategies to improve their small business. Test one or two new tactics and see which perform best before adding them to their marketing strategy. Social media is an excellent low-cost and low-risk way to promote your business. LinkedIn, Facebook, Twitter, and Instagram are a few good tools to build a social presence and attract attention to the business.

4. Sharpen the Selling Skills A high-return area for business improvement is the sales function. In this regard the entrepreneur should implement different methods for sales improvement by appointing efficient sales team along with sales Manager.

5. Find Best Practices

Keeping everything transparent is an important activities. That means, communicating effectively, testing, and monitoring and approving the processes in order to keep everything running smoothly. Example is documenting the processes to avoid any miscommunication

6. Motivate Staff

Talented and motivated staff members can bring on big improvements in business. So, the entrepreneur should apply different strategies to motivate the potential employees by giving some bonus or incentives so that the employees will think that the organization is ours.

7. **Customer satisfaction**

Employee satisfaction is key for a business' success, but customer satisfaction is critical. The customer's satisfaction with the product / service or company is another strong indicator of the business performance. The entrepreneur should Conduct regular customer satisfaction surveys as part of his customer relationship management program, and determine of customer satisfaction changes over time.

Identify the business opportunity:

There are a lot of opportunities available in the world of business, but they are not visible to everybody. They are visible only to those who constantly remain in search of them. Opportunity does not come to any one by chance, but the entrepreneur has to struggle for it. The entrepreneur has to collect necessary resources to convert the opportunity into a successful business venture. Business opportunity can be described as an economic idea through which the entrepreneur can make a business and earn profits. He has to collect the information from external environment and analyze them so that he will be able to select best opportunity related to his business.

A business opportunity will be considered on the following factors:

1. A good market scope for the product he is going to produce: The entrepreneur has to analyze the gap between demand and supply of the product in which he is going to make business. The demand must be higher than the supply. He should consider not only the present demand and supply of the product but also he should put emphasis on the future forecast demand and supply. In this regard the entrepreneur has to establish new units and inter regional flow of commodities to analyze the demand and supply.

2. An attractive, acceptable and adequate rate of return on the investment: The next opportunity is the rate of return. If the rate of return on the investment is not attractive the entrepreneur can not move forward. So, the rate of return must be higher which can cover the remuneration of the entrepreneur, salary of employees, maintenance, loan payment along with other payments and also receives some extra money so that that can be used for expansion, modernization and for launching new projects and products.

3. Feasibility or practicability of the idea: The idea adopted by the entrepreneur must be feasible and practicable. If a business opportunity has all the ingredients but the idea is not feasible or can not be put into practice, it is useless. If permission or license is not available due to some reasons the entrepreneur may abandon the idea..

4. Competence of the entrepreneur to convert the idea Into real business practice. : The entrepreneur is the main element of an enterprise. So, the entrepreneur must be capable of turning the ideas into economic activities. Different business activities require different levels of skill, knowledge, ideas etc. He must have the competence to overcome the hurdles.

5. Assurance for future growth: Lastly there must be an assurance for a prosperous future and steady growth of the activities of the entrepreneur and enterprise. If all the components discussed above are there but there is a lot of uncertainties about the future prospects of the enterprise the entrepreneur can not consider it to be a good business opportunity. Apart from an attractive and acceptable rate of return on investment and a good market scope the entrepreneur has to study several other factors for the project relating to technical, production, managerial and feasibility point of view. These factors are so interlinked that a decision about one affects the others. So, the identification of a business opportunity for an entrepreneur requires intensive efforts and special skill. To collect all the information necessary to select an appropriate business opportunity, the entrepreneur has to remain in close touch with a number of entrepreneurs, institutions, and business publications so that he acquires a lot of knowledge and gain exposures on his projects.

Major criteria for final selection of a business opportunity

Before arriving at a conclusion on a business opportunity, an entrepreneur has to collect a lot of information on various business opportunities and examine all the opportunities minutely. He has to examine the business environment, present scenario and trend in a business, impact of changes in technology and behavior of the target group for whom the product is going to made. To make a final decision on business opportunities, various types of products and services available in the market, their merits and demerits, the expectation of the consumers should be studied. He should see if he can make a product best suited to the market, consumers, dealers and environment.

Although the amount of investment and nature of technology play an important role in the final selection of a business opportunity, yet the entrepreneur has to first select the **enterprise, product** and **project.**

Selection of Enterprise

After collecting all the required information and analyzing the information, the entrepreneur has to select the industry he may establish. He may select industry relating to consumer goods, producer goods or intermediate goods. While deciding the industry, the entrepreneur has to study the present business environment and industrial climate for the particular industry. What would be the expected future of the industry must be examined? While deciding the industry, he has to think for diversification, modernization and flexibility of the industry in future. While deciding the industry the entrepreneur may take into account his preferences, technical capabilities, familiarizes and support from others in the same line. He has also to take into account Government policies for the industry. He has to see the present position of such industry in the country as well as abroad forecast the future. On the basis of the above information, the entrepreneur may decide the industry.

Selection of product or Final Product Selection

After the selection of an industry, the entrepreneur has to select the product to be manufactured by him. While doing so, he has to make a comparison of all the products he has thought in mind. Producing a product is less important than marketing the product. So he has to select a product keeping on eye on the market. Market survey plays an important role in the selection of a product. Entry point into the market is important for the entrepreneur. For a new entrepreneur it is always better to enter the market with an essential commodity of daily use, so that he finds a ready market for his product and entry will also be easier. However, he may select any product which may be classified as essential items, luxury or comfort items. But, before making a selection, the entrepreneur has to study the behavior of the competitors and consumers for a new entrants. Similarly, the entrepreneur has also to take into account all the probable factors which may influence the future business activities. He has to analyze the market scope of the product and the rate of return on the investment before finally selecting a product.

Selection of Project

After the selection of an industry and product, the next problem for the entrepreneur is to select the project. The selection of a project depends upon the personal preferences of the entrepreneur, earnings of the entrepreneur, returns on investment and future prospects of the product. How much cash the entrepreneur can invest in his enterprise also plays an important role in the selection of a project. He should also study the Govt. policies for the particular project. All the formalities, licenses or permissions needed for the project should be examined by entrepreneur. Whether such licenses or permissions are available easily or not should also be examines. The entrepreneur has also to see if any restriction or control is there for the raw materials, finished products, the price of raw materials and finished product and their movements etc. which may affect the prospects of the project. He should also examine the possibility of restrictions on such matters in future. The project should be viable and acceptable to all the agencies. Again the entrepreneur has to examine the future prospects of his project. Examine the future includes study of the technology, possibilities of changes in technology, changes in the taste, fashion and custom of people. These factors will influence the future demand and prospects of the product and project.

UNIT 3
PROJECT REPORT PREPARATION

Project Report: After the selection of the industry and product, the entrepreneur should prepare the project report on his project. This project report is necessary to get registration, license, permission and loans from financial institutions for his project. Project report is the mirror through which one can see the entire picture of an organization in advance. Project report can be of two types i.e. Preliminary Project Report(PPT) and Detailed Project Report(DPR).

Preliminary Project Report : A preliminary project report is a brief summary of a project describing the expected inputs and outputs like finance , manpower, materials, machinery, technology, expenses, production, profits, sales etc. of a project before the project is actually implemented. A preliminary project report justifies the techno-economic feasibility of a project. An entrepreneur may make few preliminary project report on different products to see which one is more suitable to be accepted. So, a PPR is a rough estimate of the project through which the entrepreneur make a detailed project report and start working on it. A PPR may be the picture of a project in the mind of the entrepreneur which has been put into paper in a desired manner to convince others regarding its viability. It is a short description of the project by the entrepreneur.

A Performa of a Preliminary Project Report is given below :

PRELIMINARY PROJECT REPORT

1. Introduction

   A. Information about the Entrepreneur:

      Name:

      Date of birth:

      Address:

      Age:

      Sex:

Presently monthly income: RS.____________

Educational Qualification: _____________

Special training, if any: _____________

Work experience: _____________

Category : SC/ST/ Ex-military/NRI/Physically handicapped/General: ____________

B. Information about the proposed product/project

Product : ___________

Location of the project: _______

Type of organization: _______

Name of the firm: ________

2. Financial Details:

A. Land and Building

	Area	Value
i) land		
ii) Building		

B. Details of Machinery and Equipments

Sl No	Description of machinery	No required	Price	Total value	Name & address of suppliers
1.	_____	______	___	___	_____
2.	______	______	_____	___	______

Total value in Rs. ________

C. Miscellaneous Fixed Assets

1. Tools RS. ______
2. Furniture Rs. ______
3. Office Equipments Rs. ______

   Total Rs. ______

D. Preliminary and Preparative Expenses : This includes the amount to be spent by the entrepreneur to get registration, license, permission, security deposits along with travelling expenses and also mention the total expenses

a) Raw materials RS. ______

b) Salaries and wages of labor/staff per month Rs. ______

c) Utilities:

Electricity, water, coal, oil, LPG Rs. ______

d) Other Contingent Expenses:

Repair and Maintenance, Transport, postage and stationary, telephone, rent, Advertising Rs. ______

Importance of Preliminary Project Report

- A Project Report represents what the business is all about or what it intends to be over the time. It offers guideline to start-ups and existing businesses too.
- A Project Report is essential for those, who are seeking financial assistance from different financial institutions and banks, for their business.
- It acts as a guide in the all business operations, taking all financial decisions related to the business.
- It gives full visibility of every activity related to that particular business, and it will give full insights of the business.

Benefits:

Tracking : Through tracking the entrepreneur **can** track the current progress of the project against the original plan. Which include Tasks, Issues, Risks, budget, schedule, and overall project activities.

Identifies risks: Identifying risks is a key step to better projects. With the right reports, the entrepreneur can spot a risk early on and makes it easier for the team to work on the problem.

Cost management: Cost management is tricky. But with regular reporting, it's easy to view the expenditure clearly and manage the budget with full visibility.

Visibility :. Reporting increases the amount of visibility of the projects and will give full insight into how the project is performing, be it good or bad.

Control : Reporting puts the project under control.. It allows to see the progress, stagnation, or regress of certain elements, how team members are performing, and the quality of work completed.

Learning: Information provided by project reporting on completed tasks can inform future actions. For example, the entrepreneur may figure out that project communication was an issue and make changes to the communication plan for the next project.

Detailed Project Report (DPR)

Detailed project report is nothing but a detailed elaboration of each and every information and estimate mentioned in the Preliminary Project Report .While preparing a detailed project report the entrepreneur may take the help of experts to do the job. Preparation of the DPR requires a lot of time.

A DPR is a final, detailed appraisal report on the project and a blue print for its execution and eventual operation. It provide details of the basic program the roles and responsibilities, all the activities to be carried out and the resources required and possible risk with recommended measure to counter them.

Objectives of DPR

- The report should be with sufficient details to indicate the possible fate of the project when implemented.
- The report should meet the questions raised during the project appraisals, i.e. the various types of analyses—be it financial, economic, technical, social etc.—should also be taken care of in the DPR.

Contents of DPR:

The project report contains detailed information about Land and buildings required, Manufacturing Capacity per annum, Manufacturing Process, Machinery & **equipment** along with their prices and specifications, Requirements of raw materials, Requirements of Power & **Water**, Manpower needs, total Cost of the Project.

Difference between PPR and DPR

- PPR is a brief summary of each an every information related to business while DPR is a detailed elaboration of each and every information mentioned in the PPR.
- Preparation of PPR requires less time while it takes more time to prepare DPR.
- PPR can be easily prepared while it is a tedious task for preparing DPR.
- PPR can be prepared for getting license and permission to start a project while the status and future prospects depend on DPR.

Advantages:

- The entrepreneur can monitor operations procedures within the enterprise.
- Allowing managers to use the reports to review and corrective actions that are not effective.
- Supplying upper management important information to make decisions.
- Offering insight into the attitude and motivations of their employees.
- Providing employee performance evaluations to determine that work is being done properly and efficiently.
- Evaluating investment proposals.

Disadvantages:

- Reports are time-consuming to create.
- They are expensive to research and write.
- Technical reports can be difficult to understand.
- Implementing report recommendations can prove difficult.

Techno Economic Feasibility: It is a report which is determine the technical **feasibility** and financial viability of the project, assess the risks associated with the project and implement actions that are required to be taken.

It is a methodology framework to analyze the technical and economic performance of a process, product or or service. In other word s we can say that

- it refers to the estimation of project and choice of optimal technology.
- It is an analysis on the existing market and technology.
- It analyze the project on individual criteria on different aspects and set the stage for detailed design development.

Factors to be considered for Techno economic feasibility report

- Objective and scope of the **report**.
- Product characteristics.
- Market position and trends.
- Raw material requirement, prices, sources and properties of raw materials.
- Manufacturing processes, selection of process, production schedule and techniques.
- Plant and machinery.

Objectives:

- It determine the technical feasibility and financial viability of the project.
- It assess the risks associated with the project.
- It execute the action that are required to be taken for the betterment of the project.

Benefits:

- The entrepreneur can get the idea about the total costs associated with the project.
- The entrepreneur can execute the most appropriate technology to manufacture the products.
- The entrepreneur can analyze the existing market and technology.
- The entrepreneur can get a overall information about the project and then it will be easy for him to go for detailed design development.

Project viability:

Viability for a project refers to the assessment of whether the project has the capacity to meet the defined objectives and in addition to generate significant financial and economic gains to the stakeholders and to the economy in general.

Project viability depends on a number of factors which are given below :

Cost: A project is not typically considered viable if its value exceeds its costs. Sometimes the cost viability of a project can change over the course of the project's development or implementation. For example, if you have a particular amount of money designated for a project, and it appears actual costs will exceed the budget, the project is likely to lose its viability. Many factors can impact costs, such as an increase in the cost of supplies or materials or the scope of the project.

Time:

A project that is not on track from a deadline perspective can lose its viability. For example, if you have a project to design and print invitations for a grand opening event, if time delays result in the invitations going to print the day before the event, the project loses its viability. Invitations issued after an event has taken place are worthless, and continuing to pursue their production wastes time and money. Likewise, delays that result in additional fees -- such as rushed late printing fees -- may also render a project non-viable.

Manpower:

Losing key members or staff can cause a project to lose its viability. For example, if the entrepreneur has a graphic designer who is developing new logo, and that person quits without notice, the project may lose its viability, because the manpower anticipated for the role no longer exists. The project has the potential to regain its viability if someone else can take over the task or it can be effectively outsourced to another party.

Quality:

If the quality of a project is not attainable as anticipated, it can lose its viability. For example, if an entrepreneur own a small construction business and provide an estimate for building a custom home, that estimate is based largely on the current price of home-building materials. If the price goes up suddenly or the same quality of materials is no longer available, the project, as planned, loses its viability. It can regain its viability if materials of equal quality and similar price can be obtained.

UNIT 4

MANAGEMENT PRINCIPLE

Definition of Management:

- Management may be defined as the art of getting work done through people with satisfaction of employer, employees and the public.
- Management is a process for getting the work done through the efforts of other people , it is necessary to guide, direct, coordinate and control human efforts towards the fulfillment of the goals of the enterprise.
- Management is an art because management means coordinating and getting work done through others.

Principle of Management:

The fourteen principles of management created by Henri Fayol also known as "father of modern management theory" are explained below:

1. Division of Work - According to this principle the whole work is divided into small tasks and it is also based on the theory that if workers are given a specialized task to do, they will become skillful and more efficient in it which leads to specialization and specialization helps to increase efficiency and efficiency which results in improvements on the productivity and profitability of the organization.

2. Authority and Responsibility - Authority and responsibility should go together and must be related. Authority means the right of a superior to give enhance order to his subordinates and responsibility makes them responsible for the work done under their guidance or leadership. Responsibility without authority or vice versa is meaningless**.**

3. Discipline - Without discipline, nothing can be accomplished. It is the core value for any project or any management. Good performance and sensible interrelation make the management job easy and comprehensive. Employees good behavior also helps them smoothly build and progress in their professional careers. Discipline is absolutely necessary for efficient functioning of all enterprises.

4. Unity of Command - This principle states that each subordinate should receive orders and be accountable to one and only one superior. If an employee receives orders from more than one superior, it is likely to create confusion and conflict.

5. Unity of Direction. This means all the person working in a company should have one goal and motive which will make the work easier and achieve the set goal easily. It implies that there should be one plan and one head for each group of activities having the same objective. That means there should be one common plan for an enterprise as a whole.

6. Subordination of Individual Interest-This indicates a company should work unitedly towards the interest of a company rather than personal interest. That means the interests of an individual persons should not be permitted and this is necessary to maintain unity and to avoid friction among employees.

7. Remuneration - Remuneration is the price paid to the employees for the services rendered by them for the enterprise and this is also a chief motivation of employees and therefore it puts influences on productivity. The quantum and methods of remuneration payable should be fair, reasonable and bring maximum satisfaction to both employees and the employer.

8. The Degree of Centralization: Centralization implies that the decision making process should be taken at top management. In any company, the management or any authority responsible for the decision-making process should be neutral. However, this depends on the size of an organization. Henri Fayol stressed on the point that there should be a balance between the hierarchy and division of power.

9. Line of Authority/Scalar Chain - This refers to the chain of superiors ranging from top management to the lowest rank. The principle suggests that there should be a clear line of authority from top to bottom linking all managers at all levels. This is necessary so that every employee knows their immediate senior and also they should be able to contact any, if needed.

10. Order -. A company should maintain a well-defined work order to have a favorable work culture. The positive atmosphere in the workplace will boost more positive productivity. Material order ensures safety and efficiency in the workplace. Order should be acceptable under the rules of the company.

11. Equity - Employees must be treated kindly, and Managers should be fair and impartial when dealing with employees, giving equal attention towards all employees. This will make employees more loyal and devoted towards the management or enterprise.

12. Stability of Tenure of Personnel - Stable and secure work force is an asset to the enterprise because unnecessary labor turnover is costly. An employee delivers the best if they feel secure in their job. It is the duty of the management to offer job security to their potential employees.

13. Initiative - Initiative of employees can add strength and new ideas to an organization. Initiative on the part of employees is a source of strength for organization because it provides new and better ideas. Employees are likely to take greater interest in the functioning of the organization. In this regard manager should encourage his subordinates to take initiative.

14. Esprit de Corps/Team Spirit - It is the responsibility of the management to motivate their employees and be supportive of each other regularly. Developing trust and mutual understanding will lead to a positive outcome and work environment. This refers to the need of managers to ensure and develop morale in the workplace; individually and communally. Team spirit helps develop an atmosphere of mutual trust and understanding. Team spirit helps to finish the task on time.

Functions of Management: Broadly speaking, management includes everything which is necessary for the performance of work. All the activities performed by managers at various levels to get the desired result may be the functions of management**.** Usually, there are nine major functions of management such as **Forecasting**, **Planning, Organizing, Staffing, Coordination, Directing, Motivation, Communication and Control.**

1. Forecasting: Forecasting is the first thing in the management process through which plans are made and actions are taken. Forecasting forms the base for planning process. The efficiency of planning depends on the accuracy of forecasting. Forecasting is nothing but the prediction on the future or estimate the future events by comparative study and analysis of various factors and forces. Forecasting is based on the analysis of the past, study of the present and estimate of future. Forecasting helps to add certain level of to the future events and helps to meet the future challenges. Forecasting may be for short run or long run. A short run forecast is likely to be more accurate than the long run forecast. In case of long run forecast may be required for revision due to changes in different factors and forces. Result of forecast should be made available to all the planners to plan the activities suitably.

2. Planning: Planning is the most important among all the managerial functions. It is the function of management usually performed by all the managers at all the levels of work. If planning is wrong or defective, the entire work shall be defective and all the efforts shall be fruitless. Planning is considered to be the foundation of work. Planning means deciding a future course of action to be performed by all the employees in the management process. Planning involves study of future. It also includes selection of the best alternatives among the alternatives Available. Selection of the best alternative requires study, analysis and comparison of various alternatives. So, planning involves selection of the best alternative for the entire organization. Planning is deciding in advance the work to be performed in a desired manner in future. Planning also involves deciding what to do? When to do? Where to do? How to do? Planning aims at maximum result at minimum possible efforts.

3. Organizing: Organizing is the management process which helps to carry out the plans. Organizing Includes putting life to plans by bringing together the physical facilities, executives, personnel, workers, capital, machineries, materials, services to carry out the plans. When all these resources are assembled then the organization comes to life. Organizing provides for the establishment of relationship among posts, departments, section, units,, resources, , jobs etc. and creates routes for delegation of authority and responsibility. Organizing is a managerial process through which a manager groups his men to get the things done effectively and efficiently to achieve the best possible result. Organizing is an effective mechanism for management for achieving the plans. Organizing also defines the relationship among the persons and decides who will do what for the implementation of the plans and for the achievement of the goals.

4. Staffing: Organization creates a structure of duties and functions to be performed by various persons in the organization. So, staffing is nothing but filling up the positions created in the organization structure. Staffing functions include recruitment, selection, training, placement, transfer, promotion, etc. Staffing aims at optimum utilization of human resources of an organization**.** It is the duty of management to fill up the vacancies created in the organization by appointing competent, qualified, efficient and appropriate persons for each job.

5. Coordination: Coordination is the function of management which ensures that different departments and groups work in synchronization to achieve the common objectives of the organization. Therefore, there is unity of action among the employees, groups and departments. Unity of efforts can not be achieved automatically. So, a manager has to coordinate the activities of all the individuals to provide unity of action for the achievement of common goal. Coordination includes division of work and distribution of duties and responsibilities among various individuals and groups working in the Organization. Coordination ensure that all the individuals and groups work together effectively, economically and harmoniously to achieve common goal of the enterprise. Coordination is a function linking all the functions of management through unification of both human and other resources.

6. Directing: Simply appointing competent persons in different positions is not enough to get good results. They need direction that means proper orders and instructions as per requirement. So, directing is entirely a human functions which involves managing the managers and workers through motivation, proper leadership, effective communication and coordination. A manager with the help of leadership and motivational qualities has to direct and guide all his subordinates and get the work done through them. To direct and guide the subordinates a manager must develop his abilities to command people. A manager must know how to direct, how to issue orders and instructions to the subordinates without creating confusion. Directing helps the plans to converted into performance. It is the process through which people are made aware as to what and how they are expected to do.

7. Motivation: Without motivation things do not move smoothly. Motivation is nothing but creating an internal desire in the mind of a person to do something. In the management process motivation is a powerful tool to achieve the goal effectively. Motivation can set into motion a person to carry out some activities. To carryout the plans properly and smoothly a manager has to make use of motivation as a tool to motivate the subordinates to get the work done through them. Motivation' is the process of inspiring people in order to intensify their desire and willingness for executing their duties effectively and for co-operating to achieve the common objectives of an enterprise. The manager should adopt different methodology to motivate the subordinates in the form of adequate financial Incentive, proper working environment, provision for promotion, non monetary facilities like travelling, medical treatment, education etc.

8. Communication: Communication is the management process which refers to the transmission of messages, news, information, suggestion, instruction and ideas from one person to another. Through communication an effective link is created and maintained among all the employees of the organization. Communication is always objective oriented. There are various modes of communication but oral or verbal communication is the best form of communication. The communication may be from the bottom to top or top to bottom. The manager has to develop good communication skill and he should be a good communicator and should ensure that there is no communication gap. So, it is the duty of the manager to see that the information or messages are properly communicated to the appropriate persons or not.

9. Control: Control is a continuous process. Controlling is one of the important functions of a manager. In order to seek planned results from the subordinates, a manager needs to exercise effective control over the activities of the subordinates. In other words, the meaning of controlling function can be defined as ensuring that activities in an organization are performed as per the plans. Controlling also ensures that an organization's resources are being used effectively & efficiently for the achievement of predetermined goals. Managers at all levels of management top, middle & lower – need to perform controlling function to keep control over activities in their areas. Therefore, controlling is very much important in an educational institutions, military, hospital, or in any business organization. A good control system helps an organization in the form of accomplishing organizational goals, judging accuracy of standards, making efficient use of resources, improving employee motivation, ensuring order & discipline and facilitating coordination in action. Control helps realization of the plans as per expectation.

Level of management in an organization: According to duties and responsibilities the level of management in an organization is broadly classified into three categories as

1. Top-Level Management/ Administrative level,
2. Middle-Level Management/ Executory and
3. Low-level Management/ Supervisory.

1. Top Level of Management

It consists of board of directors, chief executive or managing director. The top management is the ultimate source of authority and it manages goals and policies for an enterprise. It devotes more time on planning and coordinating functions.

The role of the top management can be summarized as follows -

- Top management lays down the objectives and broad policies of the enterprise.
- It issues necessary instructions for preparation of department budgets, procedures, schedules etc.
- It prepares strategic plans & policies for the enterprise.

- It appoints the executive for middle level i.e. departmental managers.
- It controls & coordinates the activities of all the departments.
- It is also responsible for maintaining a contact with the outside world.
- It provides guidance and direction.
- The top management is also responsible towards the shareholders for the performance of the enterprise.

2. Middle Level of Management

The branch managers and departmental managers constitute middle level. They are responsible to the top management for the functioning of their department. They devote more time to organizational and directional functions. In small organization, there is only one layer of middle level of management but in big enterprises, there may be senior and junior middle level management.

Their role can be emphasized as -

- They execute the plans of the organization in accordance with the policies and directives of the top management.
- They make plans for the sub-units of the organization.
- They participate in employment & training of lower level management.
- They interpret and explain policies from top level management to lower level.
- They are responsible for coordinating the activities within the division or department.
- It also sends important reports and other important data to top level management.
- They evaluate performance of junior managers.
- They are also responsible for inspiring lower level managers towards better performance.

3. Lower Level of Management

Lower level is also known as supervisory / operative level of management. It consists of supervisors, foreman, section officers, superintendent etc. Their activities includes:

- Assigning of jobs and tasks to various workers.
- They guide and instruct workers for day to day activities.
- They are responsible for the quality as well as quantity of production.
- They are also entrusted with the responsibility of maintaining good relation in the organization.
- They communicate workers problems, suggestions, and recommendatory appeals etc to the higher level.
- They supervise & guide the sub-ordinates.
- They are responsible for providing training to the workers.
- They arrange necessary materials, machines, tools etc for getting the things done.
- They prepare periodical reports about the performance of the workers.

- They ensure discipline in the enterprise and motivate workers.
- They are the image builders of the enterprise because they are in direct contact with the workers.

UNIT 5

FUNCTIONAL AREAS OF MANAGEMENT

A)Production Management: Production management means planning, organizing, directing and controlling of production activities. Production management deals with converting raw materials into finished goods or products. It brings together the 6M's i.e. men, money, machines, materials, methods and markets to satisfy the wants of the people. Production management also deals with decision-making regarding the quality, quantity, cost, etc., of production. It applies management principles to production. Production management is a part of business management. It is also called "Production Function." Production management is slowly being replaced by operations management. The main objective of production management is to produce goods and services of the right quality, right quantity, at the right time and at minimum cost. It also tries to improve the efficiency. An efficient organization can face competition effectively. Production management ensures full or optimum utilization of available production capacity.

Functions:

1. Selection of Product and Design: Production management first selects the right product for production. Then it selects the right design for the product. Care must be taken while selecting the product and design because the survival and success of the company depend on it. The product must be selected only after detailed evaluation of all the other alternative products. After selecting the right product, the right design must be selected. The design must be according to the customers' requirements. It must give the customers maximum value at the lowest cost. So, production management must use techniques such as value engineering and value analysis.

2. Selection of Production Process: Production management must select the right production process. They must decide about the type of technology, machines, material handling system, etc.

3. Selecting Right Production Capacity: Production management must select the right production capacity to match the demand for the product. This is because more or less capacity will create problems. The production manager must plan the capacity for both short and long term's production. He must use break-even analysis for capacity planning.

4. Production Planning: Production management includes production planning. Here, the production manager decides about the routing and scheduling. Routing means deciding the path of work and the sequence of operations. The main objective of routing is to find out the best and most economical sequence of operations to be followed in the manufacturing process. Routing ensures a smooth flow of work. Scheduling means to decide when to start and when to complete a particular production activity.

5. Production Control: Production management also includes production control. The manager has to monitor and control the production. He has to find out whether the actual production is done as per plans or not. He has to compare actual production with the plans and finds out the deviations. He then takes necessary steps to correct these deviations.

6. Quality and Cost Control: Production management also includes quality and cost control. Quality and Cost Control are given a lot of importance in today's competitive world. Customers all over the world want good-quality products at cheapest prices. To satisfy this demand of consumers, the production manager must continuously improve the quality of his products. Along with this, he must also take essential steps to reduce the cost of his products.

7. Inventory control: Production management also includes inventory control. The production manager must monitor the level of inventories. There must be neither over stocking nor under stocking of inventories. If there is an overstocking, then the working capital will be blocked, and the materials may be spoiled, wasted or misused. If there is an under-stocking, then production will not take place as per schedule, and deliveries will be affected.

8. Maintenance and Replacement of Machines: Production management ensures proper maintenance and replacement of machines and equipments. The production manager must have an efficient system for continuous inspection (routine checks), cleaning, oiling, maintenance and replacement of machines, equipments, spare parts, etc. This prevents breakdown of machines and avoids production halts.

Activities:

1. Accomplishment of firm's objectives: Production management helps the business firm to achieve all its objectives. It produces products, which satisfy the customers' needs and wants. So, the firm will increase its sales. This will help it to achieve its objectives.

2. **Reputation, Goodwill and Image**: Production management helps the firm to satisfy its customers. This increases the firms reputation, goodwill and image. A good image helps the firm to expand and grow.

3. Helps to introduce new products: Production management helps to introduce new products in the market. It conducts Research and development (R&D). This helps the firm to develop newer and better quality products. These products are successful in the market because they give full satisfaction to the customers.

4. Supports other functional areas: Production management supports other functional areas in an organization, such as marketing, finance, and personnel. The marketing department will find it easier to sell good-quality products, and the finance department will get more funds due to increase in sales. It will also get more loans and share capital for expansion and modernization. The personnel department will be able to manage the human resources effectively due to the better performance of the production department.

5. Helps to face competition : Production management helps the firm to face competition in the market. This is because production management produces products of right quantity, right quality, right price and at the right time. These products are delivered to the customers as per their requirements.

6. Optimum utilization of resources : Production management facilitates optimum utilization of resources such as manpower, machines, etc. So, the firm can meet its capacity utilization objective. This will bring higher returns to the organization.

7. Minimizes cost of production : Production management helps to minimize the cost of production. It Tries to maximize the output and minimize the inputs. This helps the firm to achieve its cost reduction And efficiency objective.

8. **Expansion of the firm** : The Production management helps the firm to expand and grow. This is because it tries to improve quality and reduce costs. This helps the firm to earn higher profits. These profits help the firm to expand and grow.

Productivity:

Productivity is commonly defined as a ratio between the output volume and the volume of inputs. In other words, it measures how efficiently production inputs, such as labor and capital, are being used in an economy to produce a given level of output. **Productivity** is typically measured by comparing the amount of goods and services produced with the inputs used in production.

Benefits:

1. Higher profit : Higher productivity enables the company to produce more output. This results in more profit to it. This profit can be used for expansion and other activities.

2. Employees welfare : Higher productivity brings more profit to the company. This profit can be used to provide better facilities and working conditions to the employees. So, it results in welfare of the employees.

3. Better return : The company gets better return on investment due to higher productivity. So, they pay a better dividend (share of profit) to the shareholders. The market price of the share will also increase.

4.Nice relations : Higher productivity results in nice relations between the management and the employees. Good working conditions, facilities and incentives motivates employees to give their best to the organization.

5. **Customer satisfaction** : Higher productivity results in better customer satisfaction. This is because customers are provided with good-quality products at low prices. Satisfaction of customers will result in their loyalty towards the company.

6. **Good credit rating** : Higher productivity results in a good credit rating by financial institutions. This will enable the company to get cheap funds from the market to meet working and fixed capital requirements.

7. **Goodwill** : Due to higher productivity, the company will have a good corporate image (goodwill) in the minds of social entities. This includes: The shareholders, government, suppliers, financial institutions, customers, etc.

8. **Better credit terms** : Higher productivity helps the company to get better terms from the suppliers. The suppliers may give better credit terms due to its goodwill.

9. **Low turnover** : Higher productivity enables the company to provide better facilities and working conditions to the employees. This will make the employees loyal. Hence, employee turnover and absenteeism will reduce.

Quality Control:

Quality control (QC) is a process through which a business seeks to ensure that product quality is maintained or improved. Quality control requires the business to create an environment in which both management and employees strive for perfection. This is done by training personnel, creating benchmarks for product quality and testing products to check for statistically significant variations. Quality is a relative concept. It is related to certain predetermined characteristics such as shape, dimensions, composition, finish, color, weight, etc. In simple words, quality is the performance of the product as per the commitment made by the producer to the consumer. J. M. Juran (1970) who is considered the father of quality research has defined quality as “the performance of the product as per the commitment made by the producer to the consumer.”

Objectives of Quality Control

1. Establish the desired quality standards which are acceptable to the customers.
2. To discover flaws or variations in the raw materials and the manufacturing processes in order to ensure smooth and uninterrupted production.
3. To evaluate the methods and processes of production and suggest further improvements in their functioning.
4. To study and determine the extent of quality deviation in a product during the manufacturing process.
5. To analyze in detail the causes responsible for such deviation.
6. To undertake such steps which are helpful in achieving the desired quality of the product.

Advantages of Quality Control

1. The brand products build up goodwill or image which ultimately increases sales.

2. It helps the manufacturers/ entrepreneurs in fixing responsibility of workers in the production process.

3. Quality control also helps in minimizing the costs by increasing efficiency, standardization, working conditions, etc.

4. It also enables the entrepreneur to know the cost of his / her product quite in advance which helps him in determining competitive prices of his product.

5. Last but not the least; the entrepreneur can confirm whether the product manufactured by him / her is in accordance with the standard set by the Government. It further facilitates the entrepreneur to take necessary actions to comply with the standard set.

Methods of quality control:

Inspection:

Inspection means checking the product through visual or testing examination, at the input stage, transformation stage or output stage, against standards. The task of carrying out inspection is inspection function and the people who perform inspection are called inspectors. Inspectors measure quality of goods against standards and separate acceptable units from the non-acceptable ones. It is divided into two types i.e.

- **Product inspection** which relates to the final product sent into the market. The main purpose of product inspection is to ensure that the products sent into the market comply with the set standard for quality. In other words, it is to ensure that the product ready for sale is perfect and free of defects.
- **Process Inspection:** Process inspection proceeds to product inspection. It is aimed at ensuring that the raw material and machines and equipment's used in the production process are of prescribed quality and mark.

Statistical Quality Control:

It is an advanced method or technique used to control the quality of a product. This method is based on statistical techniques to determine and control the quality. Sampling, probability, and other statistical inferences are used in this method for controlling the quality of a product. It is widely used in process control in continuous process industries and in industries producing goods on a mass scale.

Production Planning and Control : Production planning and control is a predetermined process that plans, manages and controls the allocation of human resource, raw material, and machinery to achieve maximum efficiency. Production planning is a sequence of steps that empower manufacturers to work efficiently and optimize their production process in the best possible manner. Production planning and control programs involves the function of planning, directing and regulating the orderly movement of materials through the entire manufacturing cycle from the requisitioning of raw materials to the delivery of finished goods and ensure proper customer satisfaction by maintaining minimum inventory with maximum efficiency.

What is Production? Production is nothing but the conversion of raw materials into finished products. It is an organized activities of organization through which raw materials with the help of other inputs are transformed into finished products.

What is Planning? Planning is nothing but forecasting and deciding in advance a future course of action. Planning is essential to carry out certain activities in the best possible manner. It involves selection of desired course of action to achieve the goal of the enterprise. Planning makes uncertainties into certainties and makes the target achievable. Planning involves study of future and taking appropriate steps to ensure success. Planning involves the selection of best alternatives among the alternatives available.

Production Planning: Production planning can be defined as the forecasting or deciding in advance as to when, by whom and how the raw material shall be converted into finished product. Production planning ensures smooth flow of production programs to achieve economy and efficiency.

What is Control? Controlling involves checking and ensuring that the plans are carried on as per expectation. Control also includes checking and ensuring that the actual performance does nor deviate from the standard set earlier. Control helps the realization of the plans in the best possible manner. Without control things may not happen as per wish.

What is Production Control ? Production control guides the flow of production. So, that products of desired quality are produced at the appropriate time in the most economical manner. The main aim of production control is to facilitate the task of manufacturing and ensure that all the production activities are carried on as per plans.

Importance of Production Planning and Control: The following are the importance of production planning and Control:

1. Production planning and control program helps to increase productivity by means of planning production and Controlling production at each and every stage to ensure speedy , economical and efficient use of all available resources. An efficient production planning and control technique helps to reduce the idleness of men, machines, materials and money.

2. Production planning and control program arranges the production process in such sequences that production target is achieved in time.

3. Production planning and control is an important tool for the management in case of continuous industries where production is continuous and units produced are identical in nature. But it is not suitable in the industries where varieties of products are produces as per order however this tool ensures proper

utilization of all available resources to achieve efficiency, economy and performance of work as per plans.

4. Production planning and control program is highly essential for cost control purposes. A well organized production planning and control mechanism ensures optimum utilization of men, machines, materials and money so that they can work at their full capacity.

5. Production planning and control program helps in regulating production and maintain quality. It controls the production activities and ensure orderly flow of materials from one process to another and also ensures timely supply of tools and equipments to achieve full utilization of all the available resources . 6. Production planning and control program brings many benefits to many persons. The manufacturers achieve increased production, higher productivity, delivery of goods to customers in time, qualitative production, low cost production and higher profits. I will help the producer to have better control over the production activities. The customers get quality products at cheaper price and also in time. The workers get adequate wages, stable employment, job security, improved working condition and timely payment of wages . Similarly, the investors get an adequate rate of return on their investment and security of their investment.

Steps in production planning and control: The following steps are adopted for implementation of the production planning and control program such as **planning, routing, scheduling, loading, dispatching, follow up and inspection.**

1. Planning : It is the first step in production planning and control program. Under this the management has to prepare a broad plan for the production activities of the organization. At this stage the management decides the products to be produced. It will also decide the ingredients, raw materials, size, color, design, shape, quality, specification, quantity of production and cost of production**.** Planning also includes planning for the procurement of all the resources required to carry on the production plan.

2. Routing: Routing determines the way or the exact path through which all the raw materials will flow from one process to another until its completion as finished products. Routing decides in advance the path over which the work will flow from one stage to another. The main aim of routing is to find out the best and cheapest way of production. Routing also includes the selection of men, machines, and processes to carry out the work in desired manner.

3. Scheduling: After the exact route is decided, the next step is to make a schedule i.e. a list or time table for the production activities. Scheduling involves fixation of time and date for starting and completion of each operation. Determination of time for each operation is possible when the entire work is divided into many parts and assign each part of the work to a particular person by allocating responsibilities and accountabilities for the performance of the work. Scheduling provides a time table for manufacturing and all the other activities starting from the procurement of raw materials to the delivery of finished goods to the customers as per schedule.

4. Loading: It is associated with the quantity of works assigned to a machine or worker to be done or performed by that machine or individual. Loading of works to different machines , processes, sections, departments and individual is essential for proper distribution of duties as per the capacities of the departments or machine or individual. There should be neither be over load or under load of works to any one. There should be a perfect balance between the both. If there is overload it will lead to dissatisfaction and mismanagement. On the other hand under load will lead to idleness of resources which is loss. Under load or over load may be due to improper planning of activities and improper evaluation of load bearing capacity.

5. Dispatching : Dispatching involves actual execution of the plans in the manner prescribed and route decided. It also includes issue of order and instructions to carry on the work as per plans. Dispatching functions includes the following :

a. Issue of necessary materials to different individuals, jobs, process , departments or sections..
b. Allocation of appropriate labor force and required machinery for the performance of the work.
c. Issue necessary tools and equipments to individuals in time.
d. Maintenance of records for all the orders issued from time to time.

6. Follow up: It involves checking the progress of the work and see whether the work is being performed as per plans. Follow up ensures the progress of work according to plans. If there is any deviations at any stage it has been taken into account and corrective measures should be taken to ensures smooth performance of work as per plans. It also includes evaluation efficiency of men, machines and materials while the work is in progress.

7. Inspection: Inspection is the last stage of production planning and control. It involves checking the quality of goods produced and ensure that the quality of standard is up to mark. This can be done by comparing and testing the completed products with the help of the standards already established.

B) Inventory Management : Inventory management is a **systematic approach to sourcing, storing, and selling inventory**—both raw materials (components) and finished goods (products). In business terms, inventory management means the right stock, at the right levels, in the right place, at the right time, and at the right cost as well as price. In other words Inventory management is a systematic process to control and maintaining the storage of stock, controlling the amount of product for sale and order fulfillment. Today, inventory management has become vital for the survival of an organization. If entrepreneurs don’t have good control over their inventory, the day is not far when they will lose control of their profits.

Need for Inventory Management

1. Tracking Inventory

A good system will help the entrepreneurs keep track of their inventory and offer a centralized view of stock across sales channels – how much is in stock, and where. It will also allow allocating inventory to specific sales channels, which is important if they have warehouse and distribution centers at multiple locations, thus, enabling Warehouse management.

2. Control costs

Keeping reports about their inventory it helps them understand what stocks are doing well, versus which are just taking up shelf space. Lack of the right inventory at the right time can mean back orders, excess inventory, etc. which drive up costs.

3. Improve delivery

Late delivery due to stock-outs is bound to give them a bad reputation. For tracking, it is important for them to know when the vendor is shipping inventory and when it will arrive. This helps them manage customer expectations by delivery as, when and where they want.

4. Manage planning and forecasting

The software can help them improve demand forecasting by analyzing data trends from well-performing stocks. This minimizes their holding and handling costs, improves revenues and frees up cash flows. Also, by planning and forecasting – they can deliver on customer expectations better.

5. Reduce the time for managing inventory

With a good inventory management solution, the entrepreneurs can reduce the time taken to keep track of all the products they have on hand and on order. Additionally, the entrepreneur scan save the time taken up in inventory recounts if their records are in place.

6. Accurate: The entrepreneurs will always have accurate reports with a computerized inventory system. There is always that possibility that errors can occur when inventory is done by hand and it could easily be overlooked. Wrong calculation could mean losses or additional expenses.

7. Customer satisfaction

It is difficult to gain customer loyalty when the entrepreneurs cannot satisfy their needs when they want it. A good computerized inventory system allows them to quickly meet customer demands by having the right products as soon as their potential customer comes to order them.

8. Organize

Through proper inventory system the entrepreneurs cab able to organize their inventory activities. They can Keep or maintain all the products information that means they can find out which products enjoy the highest sales, so they can group them together for easier access. They can even categorize their stock for better identification and order processing.

Models/Techniques of Inventory Management

The following are the techniques of inventory management:

1.Economic Order Quantity: It is the order size that minimizes the sum of ordering and holding costs related to raw materials. In other words, it is the optimal inventory size that should be ordered with the supplier to minimize the total annual inventory cost of the business. The economic order quantity is computed by manufacturing companies . Manufacturing companies compute it to find the optimal order size of raw materials inventory. The two significant factors that are considered while determining the economic order quantity (EOQ) for any business are the *ordering costs* and the *holding costs*.

The **ordering costs** are the costs that are incurred every time an order for inventory is placed with the supplier. Examples of these costs include telephone charges, delivery charges, invoice verification expenses and payment processing expenses etc. The total ordering cost usually varies according to the frequency of placing orders. Mostly, it is directly proportional to the number of orders placed during the year which means If the number of orders placed during the year increases, the annual ordering cost will also increase and if, on the other hand, the number of orders placed during the year decreases, the annual ordering cost will also decrease.

The **holding costs** (also known as carrying costs) are the costs that are incurred to hold the inventory in a store or warehouse. Examples of costs associated with holding of inventory include occupancy of storage space, rent, shrinkage, deterioration, obsolescence, insurance and property tax etc. The total holding cost usually depends upon the size of the order placed for inventory. Mostly, the larger the order size, the higher the annual holding cost and vice versa.

The ECQ is a order qty that minimizes company's optimal its total costs related to ordering, receiving and holding inventory. ECQ formula : Q **= √(2SD/H)** where ,

Q = ECQ units, D = Demand in units annually, S = Order cost(per purchase order)

H = Holding cost(per unit per year) . For examples

- **For a company X, annual ordering costs are Rs. 10000 and annual quantity demanded is 2000 and holding cost is Rs.5000.** Economic Order Quantity is Calculated as: **√(2SD/H)**
- EOQ = √2(10000)(2000)/5000
- EOQ = √8000
- EOQ = **89.44**

So, the ideal order size is 89.44 to meet customer demands and minimize costs. It is also the reordering point at which new inventory should be ordered.

2. FIFO and LIFO.

FIFO, or First in, First out, assumes the older inventory is sold first. FIFO is a great way to keep inventory fresh. In other words A FIFO is a warehouse or inventory management system in which the first or oldest stock is first used and the stock or inventory most recently produced or received is only used or dispatched until all the oldest stock in the warehouse or store is used or dispatched. This system ensures a company that its oldest stock is used first and eventually minimizes the costs of obsolete inventory. FIFO inventory system is even considered as the ideal stock rotation system, and most commonly used in a variety of industries.

LIFO, or Last-in, First-out, assumes the newer inventory is typically sold first. LIFO helps prevent inventory from going bad. In other words it is an **inventory valuation method which assumes that the last items placed in inventory are the first sold during an account year.**

3. Just-in-time inventory management.

Just-in-time (JIT) inventory management is a technique that arranges raw material orders from suppliers in direct connection with production schedules.JIT is a great way to reduce inventory costs. Companies receive inventory on an as-needed basis instead of ordering too much and risking dead stock. Dead stock is inventory that was never sold or used by customers before being removed from sale status.

4. Demand forecasting.

Demand forecasting should become a familiar inventory management technique to retailers. Demand forecasting is based on historical sales data to formulate an estimate of the expected forecast of customer demand. Essentially, it's an estimate of the goods and services a company expects customers to purchase in the future.

5. **Safety Stock Inventory:** Safety stock inventory management is extra inventory being ordered beyond expected demand. This technique is used to prevent stock outs typically caused by incorrect forecasting or unforeseen changes in customer demand.

6. ABC analysis. In inventory management, *ABC analysis* is an inventory categorization technique. ABC analysis

divides an inventory into three categories—"A items" with more important and accurate records, "B items" with important and good records, and "C items" with less important and minimal record. Examples :**A**' items – 20% of the items accounts for 70% of the annual consumption value of the items(Laptop)

- '**B**' items – 30% of the items accounts for 25% of the annual consumption value of the items(Tablet)
- '**C**' items – 50% of the items accounts for 5% of the annual consumption value of the items(Desktop)

7. Minimum order quantity.

On the supplier side, minimum order quantity (MOQ) is the smallest amount of set stock a supplier is willing to sell. If retailers are unable to purchase the MOQ of a product, the supplier won't sell it to them. In other words we can say that minimum Order Quantity is the minimum amount or order quantity set by a supplier that can be ordered by a company. This means a retailer or business owner cannot order any given quantity they desire, but they have to adhere to the MOQ threshold or estimated value. For example , let us say, An entrepreneur of a company wants to buy 20 units of Toys. But as the MOQ is set at 50 units or for Rs. 5000/-, So, in this case the entrepreneur cannot order anything less than the set MOQ.

C) Financial Management: Financial management is all about planning, organizing, controlling, procurement , utilization and directing various activities of the organization related to finance. There are three elements of financial management required in an organization: investment decision, financial decision and dividend decision. These elements together ensure proper financial management of organizations. Financial management is the custodian of funds of an organization.

Objectives of Financial Management

- There must be a regular inflow and outflow of funds for the proper functioning of every activity in the organization.
- In the availability of the funds, the amount must be used in the best possible way with minimum wastage.
- An organization must ensure safe investment so that a high rate of return can be achieved in the invested amount.
- The shareholders who have invested in the organization must be given high return which eventually depends upon the share's market price, their expectations and earning capacity.
- An organization must ensure that there is an equal balance in the firm's debt and equity level.

Functions of Financial Management

1. Financial Planning and Forecasting

- It is the financial manager's responsibility to plan and estimate the business's financial needs. He needs to provide details regarding the amount of money that would be required to purchase different assets for the company.
- The management through the financial manager needs to know what they need to spend on working capital and fixed assets for the business too.

2. Determination of capital composition

Once the **Planning and Forecasting** have been made, the capital structure has to be decided. The mix of debt and equity used to finance the company's future profitable investment opportunities is referred to as capital structure.

3. Fund Investment

The financial manager has to ensure that funds made available to the business are used adequately to grow the business. The cost of acquiring the said fund and value of the returns need to be compared and balanced. The financial manager also needs to look into the channels of the business that is yielding higher returns and improve them.

4. Maintain Proper Liquidity

Cash is the best source for maintaining liquidity. The business requires it to buy raw materials, pay salaries, and tackle other financial needs of the company. However, the financial manager has to determine if there is a demand for liquid assets. He also has to arrange these assets in a manner that the business won't experience scarcity of funds.

5. Disposal of Surplus

Selling surplus assets and investing in more productive ways will increase profitability and therefore increase the ROCE.(Return on capital employed)

6. Financial Controls

Financial management monitors and controls the finances of business for maintaining a balance between risk and return. It exercises to minimize the risk and expenses associated with undergoing the required operations. Not only its plans, procures, and utilizes the funds efficiently but also monitors the overall finance of the business.

7. Estimates Capital Requirement

Financial management is concerned with the estimation of an adequate amount of funds required for an organization. The finance manager takes into account organization goals, objectives, and costs associated with them for determining the fund requirements. Future growth policies and programs of an organization are also considered by the finance manager. Proper estimation helps in procuring and utilizing required funds efficiently thereby improving the revenue of the business.

Management of Working Capital

What is Working Capital?

The amount of money invested by t he business in the current assets and to meet day to day expenses is known as working capital. Investment in working capital is made to meet the day to day expenses of the business. Working capital is utilized to purchase raw materials, pay salaries, wages, spent on transport, advertising, insurance premium, pay for telephone and postage. Working capital is a financial concept describing the difference between current assets and current liabilities of a business. If current liabilities are greater than current assets, a business has a deficit of working capital, which means it could not pay off its current liabilities using its current assets. Thus, a healthy business should have a surplus of working capital.

How to manage working capital?

The following are the management of working capital:

1.The management has to properly forecast the working capital needs of an organization and the working capital needs may be decided keeping in mind the budgets prepared for each and every element of working capital which includes cash budgets, production budgets, purchase budget, sales budget, maintenance budget, advertisement budget etc.

2. If there is a mismanagement of working capital the management may face difficulty to pay the payment to different parties like employees, advertisers, suppliers bankers , government and other agencies which leads the company may lost their goodwill or image. So, in this regard the entrepreneur should assess the working capital properly and arrange the funds accordingly.

3. The requirement of working capital fluctuated throughout the year. So, how much working capital will be required at different periods that have to be estimated in advance and that should be done properly.

4. If the organization labor oriented , working capital requirement is more because the workers have to be paid wages and salaries as well as incentives. If the production activities is computerized , the labor force will be reduced and as a result the working capital will be reduced.

5. The inventory policies puts direct affect on the working capital because if an organization wants to maintain huge stock of raw materials and finished products , it is required huge investment on working capital. If the stock will be maintained properly then the investment in working capital may be reduced.

6. Proper management of each and every steps of operating cycle which includes cash—raw materials—work-in-progress---finished goods---sales---debtors---cash is essential for ensuring smooth management of the working capital. All the activities of the operating cycle have to be performed with higher degree of accuracy and efficiency then the working capital can be properly managed.

7. If the time required to process the raw material to converted to finished product is more, the working capital will be considered high because a lot of raw material and other material shall be blocked for a long time and the machineries, tools, equipments , workers and employees shall be busy for along time and as a result it puts affect on working capital .So in this regard the management should make proper planning for processing the raw materials timely to manage the working capital properly.

8. Working capital requirement also depends upon the nature of products . If the products produced are small in size and low priced in nature, the working capital requirement shall be less.

9. Ensure high return on capital**:** To improve the funds of working capital the management or the entrepreneur should introduce different loan facility scheme and that they should provide loan to the debtors and ensure to collect the interest in time.

Advantages of working capital

1. Solvency of the Business:

Adequate working capital helps in maintaining solvency of the business by providing uninterrupted flow of production.

2. Goodwill:

Sufficient working capital enables a business concern to make prompt payments and hence helps in creating maintaining goodwill.

3. Easy Loans:

A concern having adequate working capital, high solvency and good credit standing can arrange loans from banks and others on easy and favorable terms.

4. Cash Discounts:

Adequate working capital also enables a concern to avail cash discounts on the purchases and hence it reduces costs.

5. Regular Supply of Raw Materials:

Sufficient working capital ensures regular supply of raw materials and continuous production.

6. Regular Payment of Salaries, Wages and Other Day-to-day Commitments:

A company which has ample working capital can make regular payment of salaries, wages and other day-to-day commitments which raises the morale of its employees, increases their efficiency, reduces wastages and costs and enhances production and profits.

7. Ability to Face Crisis:

Adequate working capital enables a concern to face business crisis in emergencies such as depression because during such periods, generally, there is much pressure on working capital .

Costing

- Costing is any system for assigning costs to an element of a business. Costing is typically used to develop costs for any or all of the following:
- Customers, employees, products, processes, entire companies, distribution channels etc.
- Costing may involve only the assignment of variable costs, which are those costs that vary with some form of activity (such as sales or the number of employees). This type of costing is called direct costing. For example, the cost of materials varies with the number of units produced, and so is a variable cost.
- Costing can also include the assignment of fixed costs, which are those costs that stay the same, irrespective of the level of activity. This type of costing is called absorption costing. Examples of fixed costs are rent, insurance, and property taxes.
- Costing is used for two purposes:

- Internal reporting. Management uses costing to learn about the cost of operations, so that it can work on refining operations to improve profitability. This information can also be used as the basis for developing product prices.
- *External reporting*. The various accounting frameworks require that costs be allocated to the inventory recorded in a company's balance sheet at the end of a reporting period. This calls for the use of a cost allocation system, consistently applied.
- **Break even analysis**
- A break-even analysis is an economic tool which is used to determine the cost structure of a company or the number of units needs to be sold to cover the cost. Break-even is a circumstance where a company neither makes a profit nor loss, but recovers all the money spent.
- Break-even analysis is used to examine the relation between the fixed cost, variable cost, and revenue. Usually, an organization with low fixed cost will have a low break-even point of sale.

Importance of Break-Even Analysis:

- **Manages the Size of Units to be Sold-** With the help of break-even analysis, the company or the owner comes to know how much units need to be sold to cover the cost. The variable cost and the selling price of an individual product and the total cost are required to evaluate the break-even analysis.
- **Budgeting and Setting Targets-** Since a company or the owner know at which point a company can break-even, it makes it easy for them to fix a goal and set a budget for the firm accordingly. This analysis can also be practiced in establishing a realistic target for a company.
- **Manage the Margin of Safety-** In financial breakdown, the sales of a company tends to decrease. The break-even analysis helps the company to decide the least number of sales required to make profits. With the margin of safety report, the management can execute a high business decision.
- **Monitors and Controls Cost-** Companies profit margin can be affected by the fixed and variable cost; therefore, with break-even analysis, the management can detect if any effects are changing the cost.
- **Helps Design Pricing Strategy-** Break-even point can be affected if there is any change in the pricing of a product. For example, if the selling price is raised, the quantity of the product to be sold to break -even will be reduced. Similarly, if the selling price is reduced, a company needs to sell extra to break-even.

Components of Break-Even Analysis:

- **Fixed Cost-** These costs are also known as an overhead cost. These costs materialize once the financial activity of a business starts. The fixed price includes taxes, salaries, rent, depreciation cost, labor cost, interest, energy cost etc.
- **Variable Cost-** This cost fluctuates, and will decrease or increase according to the volume of the production. This cost includes packaging cost, cost of raw material, fuel, and other material related to production

Uses of Break-Even Analysis:

- **New Business-** For a new venture, break-even analysis is essential. It guides the management with pricing strategy and be practical about the cost. This analysis also gives an idea if the new business is productive.
- **Manufacture New Product-** If an existing company is going to launch a new product, they still have to focus on break-even analysis before starting, and see if the product adds necessary expenditure to the company.
- **Change in Business Model-** Break-even analysis works even if there is a change in any business model, like shifting from retail business to wholesale business. This analysis will help the company to determine if the selling price of a product needs change.
- Break-Even Analysis Formula
- **Break-Even Point = Fixed Cost / Price Per Cost – Variable Cost**

Example of Break-Even Analysis

- Company X sells a pen. The company first determined that the fixed costs of Company X are a lease, property tax, salaries, which make a sum of Rs.1,00,000. The variable cost linked with manufacturing one pen is ₹2 per unit. So, the pen is sold at a premium price of RS.10.
- Therefore, to determine the break-even point of Company X premium pen will be:
- **Break-Even Point = Fixed Cost / Price Per Cost – Variable Cost**
- = RS.1,00,000 / (Rs.12 – Rs.2) = 10,000
- Therefore, given the variable costs, fixed costs, and the selling price of the pen, Company X would need to sell 10,000 units of pens to break even.

Book Keeping

Bookkeeping is the systematic recording and organizing of financial transaction in a Company.

Bookkeeping is the recording, on a day-to-day basis, of the financial transactions and information pertaining to a business. It ensures that records of the individual financial transactions are correct, up-to-date and comprehensive. Accuracy is therefore vital to the process of financial transactions in a company. Each transaction, whether it is a question of purchase or sale, must be recorded clearly. In other words we can say that the maintenance of all financial transaction record is known as book keeping. Book means record and keeping is maintaining.

Accounts

Almost all business organizations maintain their financial records under double entry system. To facilitate the maintenance of accounts under double entry system of book keeping. And all the accounts have two sides each. The left side of an account is known as the debit side shortly known as Dr. side and the right side is known as credit side shortly known as Cr. Side.

For personal account the rule is Debit the receiver and credit is giver: That means if any one is receiving anything, it will be recorded on debit side of his account and if someone is giving anything it would be recorded on the credit side of his account. For example , the business gives some goods to Mr. Ram on credit. It would be recorded in the debit side of Ram's account as Ram is the receiver of goods. And the goods are going out of business., so it would be recorded on the credit side of goods account. If later on Mr. Ram gives cash of Rs.5000/- to the business for the goods taken by him earlier , in this transaction ram is the giver, so his account shall be credited and the cash account shall be debited as cash is coming in to the business.

Dr.

Cr.

Date	Particulars	J.F.	Amount	Date	Particulars	J.F.	Amount
2.4.2020	**Ram's a/c**			**2.4.2020**	**Goods a/c**		
7.4.2020	**Cash A/c**		**Rs.5000/-**	**7.4.2020**	**Ram's a/c**		**Rs.5000/-**

For Nominal account the rule is Debit all expenses and losses and Credit all incomes and gains : That means all the expenses are written on the debit side of that expense a/c and all gains and profits shall be recorded on the credit side of that account. For example, suppose salary is paid of Rs. 5000/- .Here salary is an expense so it would be recorded on the debit side of salary account and the cash is going out so it would be recorded on the credit side of cash account. Similarly if interest of Rs.500 is received it would be recorded on the credit side of the interest account as interest here is an income and the cash is going out it would be recorded on the debit side of cash account**.**

Dr. **Cr.**

Date	Particulars	J.F.	Amount	Date	Particulars	J.F.	Amount

5.1.2020 Salary a/c Rs.5000/- 5.1.2020 Cash a/c Rs.5000/-

5.2.2020 Cash a/c Rs.500/- 5.2.2020 Interest a/c Rs.500/-

Journal Entry

Whenever a transaction takes place, it has to be recorded in the journal first which is known as the book of primary entry. Hence all the transactions are recorded in the journal and for that all the entries made in the journal are known as journal entry. The above rules of debit and credit are known as the rules of journalizing. All the journal entries have to be made as per the above rules. For example, suppose salary is paid of Rs. 5000/- .Here salary is an expense so it would be recorded on the debit side of salary account and the cash is going out so it would be recorded on the credit side of cash account. Similarly if interest of Rs.500 is received it would be recorded on the credit side of the interest account as interest here is an income and the cash is going out it would be recorded on the debit side of cash account.

Specimen of a Journal

Date	Particulars	L.F	Debit(Amount)	Credit(Amount)
5.1.2020.	**Salary A/c Dr**		**Rs.5000**	
	To cash A/c			**Rs.5000**
5.2.2020.	**Cash A/c Dr**		**Rs.500**	
	ToInterest A/c			**Rs.500**

Cash Book: The cash book is a register which contains two sides divided vertically from the middle of the register. The left side is the debit side also called the receipt side and the right side is the credit side called the payment side. All the cash receipts are recorded on the debit side or the receipt side of the cash book and all the payments are recorded on the credit side or the payment side of the cash book.

Petty Cash Book: The petty cash book is in addition to the main cash book which records all small or petty cash transactions below Rs.100/-. So, all cash transactions of Rs.100 and less are recorded in the petty cash book so that the main cash book is used only for big transaction only. In this petty cash book the petty cashier receives some amount of money from main cashier and goes on spending the amount. The amount received is recorded on the debit side of the petty cash book and all the expenses is recorded in the credit side of the petty cash book along with the voucher no.

Specimen format of petty cash book

Dr

Cr.

Amount Rs. Cash book Folio Date. Particulars. Voucher no. Amount Rs.

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35 2020

April.1.ByTelegramA/c Rs.7.00

ByPostage A/ c Rs.8.00

2.ByCarriage A/c. Rs.10.00

By Stationery Rs.10.00

35.00

Rs.35.00

Profit and Loss account : Profit and loss account has two sides i.e. the left side is the debit side and the right side is the credit side. If there is a gross profit it is written in the credit side of the profit and loss account. On the other hand if there is gross loss it is written on the debit side of the profit and loss account. All other expenses are written on the debit side of the profit and loss account. Similarly all other incomes are written on the credit side of the profit and loss account.

The items written on the debit side of the profit and loss account are gross loss(if any), salaries , rent , advertisement, interest paid, commission paid, telegrams, insurance premium, electricity charges, printing and stationary, repairs and maintenance of machineries. The items written on the credit side are gross profits, interest received, commission received and any other incomes related to business. The profit and loss account is always calculated for the year ending. If the total of the credit side is more than the totals of the debit side the difference is a “net profit” which is written on the debit side of the profit and loss account. On the other hand if the total of the debit side is more than the total of credit side the difference is a "net loss" which is written on the credit side of the profit and loss account. The net profit is transferred to the balance sheet and added to the capital or is shown separately in the liabilities side**.**

Specimen format of profit and loss account

Profit and loss account of X company for the year ending 31st March,2020

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	Rs.		**Rs.**
To salaries	**1,50,000**	**By gross. Profit. b/d.**	**450,000**
To wages	**80000**	**By Interest received.**	**50,000**
To insurance.	**50000**		
To commission	**20000**		
To Net profit Transferred to general reserve.	**2,00,000**		
	--------------		**------------**
	5,00,000		**5,00,000**

Balance Sheet : Balance sheet is prepared at the end of the year only after preparation of trading and profit and loss account**.** Balance sheet reflects the exact financial position of a business on a particular day. Balance sheet is a statement and not an account. It reflects how much belongs to the business, how much to the owners and how much to the outsiders on that particular day.

Balance sheet has two sides i.e. the left side is the liabilities side and the right side is the asset side. In the asset side of the balance sheet, all the assets of the business are recorded in a classified manner. All the assets are classified into three categories such as current assets, fixed assets and fictitious assets. Current assets includes cash in hand, cash at bank, sundry debtors, short term investments, rent receivable etc. Fixed assets include land, building, plant, machinery, tools and equipment's, furniture's, long term investments etc. Fictitious assets include preliminary expenses, extra losses, advertisement expenses etc.

On the liabilities side, besides the capitals all other liabilities are classified in to two categories such as long term liabilities and short term liabilities. The items recorded on the liabilities side are capital, reserves and surplus, long term loans, short term loan and advances, sundry creditors, bills payable, bank over draft, salary payable, rent payable, electricity bill payable, interest payable, commission payable etc. If there is a profit in the profit and loss account, it is added to the capital or added to the reserve. If there is a loss , it may be deducted from the capital.

Specimen of. Balance sheet :

Balance sheet of XYZ Co. Ltd as at March 31, 2020

Liabilities	Amount Rs.	Assets	Amount Rs.
Capital	**3,00,000**	**Cash in hand**	**10,000**
General. Reserve	**30,000**	**Cash in Bank**	**25,000**
Long term loan	**2,00,000**	**sundry debtors**	**20,000**
Short term loan	**40,000**	**Raw materials**	**10,000**
Bank overdraft	**10,000**	**Finished goods**	**8,000**
Sundry creditors	**45,000**	**Rent receivable**	**5,000**
Salary payable	**40,000**	**Commission receivable**	**5,000**
Rent payable	**10,000**	**Interest receivable**	**5,000**
Interest Payable.	**25,000**	**Short term Investment**	**12,000**
Commission payable	**5,000**	**Long term Investment**	**50,000**
Wages payable	**20,000**	**Plant and Machinery**	**2,40,000**
Electricity charges payable.	**15,000**	**Land and building**	**3,00,000**
		Furniture and fitting	**50,000**
	7,40,000		**7,40,000**

D) Marketing Management : Market is a place where buyers and sellers often meet together to decide the terms and conditions of purchase and sale. It is also the place where the actual exchange of goods and services takes place. So marketing involves the flow of goods and services from the producer to the consumers through the ps of exchange or distribution. It can also be defined as the process of exchange between buyer and seller. Marketing is the need of buyers and selling is the need of the sellers.

Marketing management can be described as a combination of marketing and management. Marketing management may be defines as the process of ascertaining consumer needs and wants and converting them into products and services and then moving the products and services to the final customers to satisfy such needs and wants.

Importance of Marketing Management:

1. Marketing management helps to create demand and needs in the minds of the people for the goods and services of the organization.
2. Marketing Management helps to identify markets and prospective markets.
3. A good marketing management helps to create customers and helps to maintain a cordial relation between the producers and consumers, customers and the middlemen, producer and middlemen, company and society etc.
4. Marketing management focuses on increased consumer's satisfaction.
5. Marketing management helps to achieve the goals of the organization.
6. Marketing management helps the sales management to achieve its objectives.
7. Marketing management focuses on the reduction in the cost of marketing thus reducing the total costs and increasing the profit margin.
8. Marketing management makes possible the forecasting of demand which is essential to decide marketing strategies and marketing plans.

Marketing Techniques: The marketing concept is the strategy that firms implement to satisfy customers' needs, increase sales, maximize profit, and beat the competition. There are 4 marketing concepts that organizations adopt and execute. These are; (1) production concept, (2) product concept, (3) selling concept (4) marketing concept.

1. **Production concept: The idea of production concept – "Consumers will favour products that are available and highly affordable."** This concept is one of the oldest Marketing management orientations that guide sellers.
2. **Product concept : The product concept holds that consumers will favour products that offer the most quality, performance, and innovative features.** Here. Marketing strategies are focused on making continuous product improvements. Product quality and improvement are important parts of marketing strategies, sometimes the only part.
3. **Selling concept: The selling concept holds the idea- "consumers will not buy enough of the firm's products unless it undertakes a large-scale selling and promotion effort."** Here the

management focuses on creating sales transactions rather than on building long-term, profitable customer relationships.

4. **Marketing concept:** T**he marketing concept holds- "achieving organizational goals depends on knowing the needs and wants of target markets and delivering the desired satisfactions better than competitors do."** Here marketing management takes a "customer first" approach. Under the marketing concept, customer focus and value are the routes to achieve sales and profits.

Concept of 4 Ps: The Four Ps (product, price, promotion and place) are four considerations known as a marketing mix. Attention to these four factors is necessary for maximizing the chance a product will be recognized and bought by customers.

- **Product:** The item or service being sold must satisfy a consumers need or desire.
- **Price:** An item should be sold at the correct price for consumer expectations; neither too low nor too high. Price refers to the real amount the end user is expected to pay for the product. The price of a product affects how it performs on the market.
- **Promotion:** The public needs to be informed about the product and its features in order to understand how it fills their needs or desires. The promotion plan comprises of the marketing communication strategies and techniques. These may entail advertising, sales promotions, special offers, as well as public relations. Regardless of the channel used, the promotion should be appropriate for the product, the price as well as the targeted end user.
- **Place:** The location where the product can be purchased is important for optimizing sales. That means how the product will be provided to the customer is what determines the place or its

placement. Thus, a product's distribution is a major element in determining a products placement. The placement strategy can be helpful when it comes to assessing the most suitable channel of distribution to be used.

E) Human Resource Management:

Functions of personnel management may be discussed under two broad categories:

- (A) Managerial Functions
- (B) Operative Functions
- **A. Managerial Functions:**
- Management aims at getting things done by others. Managerial functions deal with planning, organizing, directing, coordinating and controlling the activities of employees in an enterprise.

These functions are discussed as follows:

1. Planning:

Planning involves thinking in advance. It is the determination of strategies, programmes, policies, procedures to accomplish organizational objectives. Planning is a difficult task which involves ability to think, to predict, to analyse and to come to decisions. In the context of personnel management, it requires the determination of human resource needs.

2. Organizing:

Organization is a process of allocating the task among its members for achieving organizational objectives. This is done by designing the structure or relationship among jobs, personnel and physical factors. For achieving enterprise goals a number of plans, policies and programmes are decided upon. Organization is a channel for implementing them and achieving good results. The assignment of tasks and fixing of responsibilities will be the function of personnel management.

3. Directing:

It is the basic function of managerial personnel. Directing means telling people to do a particular work. It does not mean only issuing orders to employees but also ensures that they perform as per the directions. The employees are also given instructions for carrying out their task. The orders and instructions should be clear and precise so that these are obeyed properly.

4. Coordinating:

Organizational objectives will be achieved only if group activities in the enterprise are coordinated effectively. There may be a problem of each group or department trying to pursue its own goals without bothering about overall objectives. A coordinated approach will help in achieving common goals. Coordination of personnel is required at all levels of management.

5. Controlling:

Controlling is the act of checking, regulating and verifying whether everything occurs as per the standards set and plans adopted. The performance of persons is regularly reviewed to find out whether it is going according to the standards or not. In case, performance is low then steps are taken to improve it in future. Controlling function involves reviewing performance and taking corrective measures.

B. Operative Functions:

These functions are related to the procurement, developing, compensating, integrating and maintaining a work-force for attaining organizational goals. These functions are also known as service functions.

Various operative functions are discussed as follows:

1.Procurement:

This function relates to the procuring of sufficient and appropriate number of persons for carrying out business work. The needs of the organization should be assessed to find out the requirements of persons.

Besides number, the procurement of suitable persons is also essential. For this purpose, the requirements of various jobs should be studied for fixing the educational and technical experience of persons expected to man those jobs. Only the right type of persons will be able to give satisfactory results.

2. Development:

The development function is concerned with the development of employees by increasing their skill and proficiency in work. The persons are given proper training through various methods so that their performance is better in undertaking the jobs. Proper job description will enable the employees to know their weak points in performing various jobs. Training programmes are made suitable to cover up deficiencies in workers' performance.

3. Compensation:

It is concerned with securing adequate and equitable remuneration to persons working in the organization. Job analysis will enable in fixing the remuneration for various jobs. The needs of the jobs and qualifications of persons who will take up those jobs should be taken into consideration while fixing remuneration. If the employees are paid less than they should have got, they may leave the job at an earliest opportunity. So compensation should be fixed in such a way that it is able to attract and retain suitable persons in the organization.

4. Integration:

It involves infusing among employees a sense of belonging to the enterprise. The employees should identify their personal interest with that of the organization. They should have a feeling that everything good of the enterprise will also be in their interest. This will bring about harmony of interests both of employees and the organization. There should be proper communication channel at all levels.

5. Maintenance:

This function deals with sustaining and improving conditions that have been established. Better conditions of work should be maintained at all times. The employees will feel happy to work under such conditions. These conditions include establishment of health, sanitation and safety standards. If working conditions deteriorate, then employees will be prompted to leave the enterprise.

Manpower Planning: Manpower Planning which is also called as Human Resource Planning consists of putting right number of people, right kind of people at the right place, right time, doing the right things for which they are suited for the achievement of goals of the organization. Human Resource Planning has got an important place in the arena of industrialization. Human Resource Planning has to be a systems approach and is carried out in a set procedure.

Importance of Manpower Planning:

- **Key to managerial functions-** The four managerial functions, i.e., planning, organizing, directing and controlling are based upon the manpower. Human resources help in the implementation of all these managerial activities. Therefore, staffing becomes a key to all managerial functions.

- **Efficient utilization-** Efficient management of personnel's becomes an important function in the industrialization world of today. Setting of large scale enterprises require management of large scale manpower. It can be effectively done through staffing function.
- **Motivation-** Staffing function not only includes putting right men on right job, but it also comprises of motivational programmes, i.e., incentive plans to be framed for further participation and employment of employees in a concern. Therefore, all types of incentive plans becomes an integral part of staffing function.
- **Better human relations-** A concern can stabilize itself if human relations develop and are strong. Human relations become strong trough effective control, clear communication, effective supervision and leadership in a concern. Staffing function also looks after training and development of the work force which leads to co-operation and better human relations.
- **Higher productivity-** Productivity level increases when resources are utilized in best possible manner. higher productivity is a result of minimum wastage of time, money, efforts and energies. This is possible through the staffing and it's related activities (Performance appraisal, training and development, remuneration)

Need of manpower Planning:

Manpower Planning is a two-phased process because manpower planning not only analyses the current human resources but also makes manpower forecasts and thereby draw employment programmes. Manpower Planning is advantageous to firm in following manner:

- Shortages and surpluses can be identified so that quick action can be taken wherever required.
- All the recruitment and selection programmes are based on manpower planning.
- It also helps to reduce the labour cost as excess staff can be identified and thereby overstaffing can be avoided.
- It also helps to identify the available talents in a concern and accordingly training programmes can be chalked out to develop those talents.
- It helps in growth and diversification of business. Through manpower planning, human resources can be readily available and they can be utilized in best manner.
- It helps the organization to realize the importance of manpower management which ultimately helps in the stability of a concern**.**

Recruitment: In human resource management, “recruitment” is the process of finding and hiring the best and most qualified candidate for a job opening, in a timely and cost-effective manner. It can also be defined as the “process of searching for prospective employees and stimulating and encouraging them to apply for jobs in an organization.

Recruitment Process:

Recruitment is a process of finding and attracting the potential resources for filling up the vacant positions in an organization. It sources the candidates with the abilities and attitude, which are required for achieving the objectives of an organisation. Recruitment process is a process of identifying the jobs vacancy, analysing the job requirements, reviewing applications, screening, shortlisting and selecting the right candidate.

Steps of Recruitment Process:

1. Recruitment Planning: Recruitment planning is the first step of the recruitment process, where the vacant positions are analysed and described. It includes job specifications and its nature, experience, qualifications and skills required for the job, etc. A structured recruitment plan is mandatory to attract potential candidates from a pool of candidates. The potential candidates should be qualified, experienced with a capability to take the responsibilities required to achieve the objectives of the organisation.

2.**Recruitment Strategy:** Recruitment strategy is the second step of the recruitment process, where a strategy is prepared for hiring the resources. After completing the preparation of job descriptions and job specifications, the next step is to decide which strategy to adopt for recruiting the potential candidates for the organization. The steps involved in developing a recruitment strategy include −

- Setting up a board team
- Analysing HR strategy
- Collection of available data
- Analysing the collected data
- Setting the recruitment strategy

3. Searching the Right Candidates: Searching is the process of recruitment where the resources are sourced depending upon the requirement of the job. Searching involves attracting the job seekers to the vacancies.

Sources of Manpower: The sources are broadly divided into two categories: **Internal Sources** and **External Sources**.

Internal sources consists of Transfer, Promotion and own training centres.

Promotion: Under this system positions or posts are filled up by upgrading persons to higher status by offering them promotions to higher posts. It is a process of filling vacancies of higher posts by individuals from lower grade to higher grade within the organization**.**

Transfer: Transfer usually does not involve any extra financial benefits to an employee. Employees are simply shifted from one job to another or one place to another for administration convenience.

Own Training Centers: A large no of organizations have opened their own training centers where they take trainees on a regular basis to develop skilled manpower as per their own need so that they can be recruited as and when they are required.

External sources consists of the following:

1.Advertisement: Under this system applications are invited from eligible candidates for different posts through open advertisement in news papers, magazines, employment news, TVs etc. Such advertisements are drafted carefully to create interest in the eligible candidate. This type of advertisement reaches a large number of people spread over a large area.

2.Campus Interview: Now a days recruiters go to different technical, professional and management institutions for the purpose of selecting young and fresh talent for their manpower requirement. The placement cells of such institutions provide all necessary steps to conduct test, interviews in the institution itself. Such selected candidates are usually appointed as trainees for a define period and after successful completion of their training/probation, posted or appointed as regular employees.

3.Walk-in-Interview: Under this system the venue, date, eligibility criteria and other formalities are advertised in the local news papers earlier and the applicants come to the centers to face the selection process. There is no need of prior applications or information by the candidates. They simply bring their bio-data and submit just before the interview. Under this system urgent manpower requirement can be solved.

4.Employment fair/ Job Mela: A number of employers or consultants combined together to organize the fair in the important cities and towns giving wide publicity to the event to attract large no of job seekers. The employers/consultants open stall insides the mela where they display their requirement. Eligible interested candidates come and approach the stall to make queries about the vacancies. They submit their bio-data at the stall and after preliminary screening they may called for interview at a specified place and time.

5.Employment Consultant: Employment consultant remain in touch with number of organizations to collect their orders for manpower supply. They also remain in touch with various sources of different types of manpower. They advertise, conduct tests and interviews to select the appropriate candidate and submit the lists of selected candidates to the employers for issue of appointment letters.

6.Employment Exchange: This is very old sources of recruitment of manpower. Government employment exchange are there through out the country and employers take advantage of this source. Job seekers go to employment exchange and get their names registered and employers can readily get the information about various types of manpower. The employment exchange does not charge any fees to the employers or to the job seekers .

7.Unsolicited Applications: Many candidates submit applications for different posts at different times even if there is vacancy in the organization. Such applications can be called in for the purpose of recruitment whenever there is vacancy in the organization. The personal department usually maintain s record of such applications. This is a common practice in private sectors.

8.Recommendations: Sometimes appointments are made based on the recommendations made by committees, important persons, friends and relatives, employees, retired employees.

9.Labor Contractor: Large scale industries usually require a large no of unskilled workers but do not appoint them rather they hire their services through labor contractors. The labor contractors supply such unskilled workers in sufficient numbers as and when required. The contractors appoint them and make their pay roll. Such contractors make payments to the workers at their own rate agreed and collect the payment from the organizations at timely intervals. They are usually registered contractors with the organizations.

Selection Process:

The selection process can be defined as the process of selection and short listing of the right candidates with the necessary qualifications and skill set to fill the vacancies in an organisation. The selection process varies from industry to industry, company to company and even amongst departments of the same company.

The selection criteria has to be decided by the Personal manager. The selection process includes:

Inviting applications, screening the application received, conducting tests and interviews, conducting physical and medical fitness examination, collecting references and checking the antecedents, verifying the certificates and issue of selection letters after final selection.

1.Inviting Applications: The first step in the selection process is to invite applications from the eligible candidates. Application form may be designed and supplied to the applicants on the request or the Performa may be advertised according to which the applicants shall apply. The application format may be designed in such a manner that the applications have to give the details of their education, training, experience, age, family back ground, previous employment, previous salaries, hobbies etc.. The Performa may be designed depending on the post and the information required.

2.Screening the application: A number of applications may be received and all the applicants may not be called for tests or interviews. Some of the applications may be rejected at the application stage due to any reasons. Hence, there is the need of making a preliminary screening of the applications received. The main idea behind this sort of screening is to minimize the number of applicants to make the selection process easy and effective.

3.Conducting Tests/Interviews: After the preliminary screening is over, the short listed applicants may be called for employment tests which may include a written examination, interview, group-discussion etc.

to test the skill, intelligence, knowledge, aptitude, personality etc. There are a varieties of tests to examine the specific qualities and abilities of the applicants. Such tests may be designed depending on the type of persons required for specific posts. Usually the applicants found suitable in the written examinations are called for interviews because conducting interviews is a time taking affair. So, only a limited number of successful candidates of the written examination may be called for interview. Finally the interviewer shall make a list of suitable candidates for the posts in order of their merit.

4.Conducting medical/physical test: All the candidates qualified in the interviews should be called for a test of physical fitness to be conducted by a group of experts. The physical tests may include running, swimming, jumping, driving, cycling etc. The physical examination may depend on the nature of job to be handled by the individual. Apart from the physical test there may be a medical examination of the candidates to check the Eyesight, ears, heart, kidney etc. The purpose of the medical test is to handle the job efficiency and ensure that the candidate's fitness meets the job requirement.

5.Collecting References and Checking the Antecedents: After the medical and physical test is over, there is a need of making a collection of information about the candidates from the list of references. Usually, the applicants give the names of those persons who will give favorable report. Apart from that the employer may write to the former employer of the applicant, to the institutions where he was reading or to any other person who might be knowing the person well. There is also the need of checking the past records of the applicant including the report of the local police stations where he had been staying in the past.

6.Verifying the Certificates: After all the above processes are over, the applicant may be called once again with his original certificates for the purpose verification to see that the certificates furnished are authentic or not.

7.Issuing of Selection Letters after Final Selection: All the successful candidates are to be ranked in order of their merit and final selection may be made depending on the number of posts lying vacant. Appointment letters may be issued to the successful applicants in order of their rank and may be given a time limit to report for joining. If any candidates fails to turn up, the next rank-holder may be issued selection letter. So, the merit list prepared shall be helpful to issue selection letters to the next best candidates.

Method of Testing:

Tests are of twelve types. These tests are conducted by many organizations. It does not mean that every organization conducts all of these tests. Some organizations may not conduct a few tests. However, brief descriptions of these tests are mentioned below:

1.Written tests: Written tests are **tests** that are administered on paper or on a computer (as an eExam).

A **test** taker who takes a **written test** could respond to specific items by **writing** or typing within a given space of the **test** or on a separate form or document.

2. Achievement tests: To verify how he can achieve the target. Past experience can help the employees to satisfy the recruiters.

3. Intelligent tests: The employee's intelligent level is determined here.

4. Performance tests: Whether the employees perform well or not.

5. Honesty or polygraph (lie detector) tests: The use of lie detector for verifying information on the application form can only be used for specific jobs, such as police officer, finance managers etc.

6. Aptitude tests: Whether the employee is interested in the job or not can be determined by this test.

7. Psychological tests: The psychology of the employee is determined. The employees who are psychologically strong and do not get nervous do well.

8. Graphology (Handwriting analysis) tests: It has been said that an individual's handwriting can suggest the degree of energy, inhibitions, and spontaneity to be found in the writer, disclosing idiosyncrasies and elements of balance and control from which many personality- characteristics can be inferred.

9. Physical tests: To examine whether the candidate is physically fit for the job.

10. Personality tests: Through these tests a mental and behavioural quality i.e. personality level is measures.

11. Trainability Tests: For jobs in which training is necessary due to the skill level of the job applicants or the changing nature of the job, trainability tests are useful. Essentially, the goal is to determine the trainability of the candidate.

12. Work Sample: Work Sample tests measure the ability to do something rather than the ability to know something. These tests may measure motor skills or verbal skills, Motor skills include physically manipulating various job related equipment and verbal skills include problem solving and language skills.

Methods of Training and Development: Training is a learning process which imparts skill, knowledge, attitude, behavior etc. to an individual to make the performance of jobs as per plan. Training is also regards as the transfer of skill, knowledge, etc. from the trainers to the trainees with specific objectives. Training is a continuous process from the recruitment till retirement. Training is always object-oriented. Training helps the employees to cope up with the changing business environment and challenges of technology. Training is also essential for the old employees whenever they are put to new assignments due to promotion, transfer, change in the nature of job, changes in technology etc. There are different types of training adopted for executives, supervisors and workers. Different methods of training may also be recommended for different types of jobs handled by the executives, supervisors, workers and others.

The training can be classified into three categories such as a) on the job training, b) off the job training and c) vestibule training.

A.On-the-Job Training: This training consists of the following methods:

1.Under-studies: Under this method of training, the trainee is placed under an experiences person as an assistant or sub-ordinates who is to acquire skill, knowledge, experience, by doing the job under the direct supervision and guidance of the experienced person. Working under an experienced person will be a good learning process for a new person.

2.Coaching by Experts on the jobs: Under this method the trainees are taken to the spots where the works are being performed. Different expert trainers of different jobs train the trainees regarding the performing the jobs. They demonstrate the jobs by performing them in front of the trainees so that the trainees get the chance of learning on the spots. The trainees are also given chance to handle the jobs themselves.

3. Job Rotation: Under this system, the trainees get the opportunities of learning different jobs during their employment. They are not specifically trained only for one job but are trained on various jobs on rotation basis so that they get through knowledge on different jobs. After they are trained in one job, they are sent for training to another job and in this process they acquire good experiences of different jobs of the organization. This is known as job rotation in which the trainees are periodically rotated from one job to another.

B) Off-the- Job Training: This training consists of the following methods:

1. Classroom training: Under this type of training, training courses are organized for the employees either inside the organization or outside the organization. Lecturers or instructors act as trainers who teach the topics and give adequate technical and theoretical knowledge about the activities to be performed**. F**or such type of training the trainer may use the models, slides, overhead projectors, video, audio, films, computer etc. to train the employees.

2. Conference: Under this method of training, a small group of trainees are selected and they work together to train themselves. They make open discussion, exchange ideas and experiences and share the knowledge. They learn together to come to a conclusions or for solutions to different problems and develop new techniques, skill etc. in them**.**

3. Special courses and lectures: Special courses and lectures are either designed by the company itself or by the management or professional schools. Companies then sponsor their trainees to attend these courses or lectures. These are the quick and most simple ways to provide knowledge to a large group of trainees.

4. Selected reading: This is the self-improvement training technique. The persons acquire knowledge and awareness by reading various trade journals and magazines. Most of the companies have their own libraries. The employees become the members of the professional associations to keep abreast of latest developments in their respective fields.

5. Role Playing: In this method, the trainees are assigned a role, which they have to play in an artificially created situation. For example, a trainee is asked to play the role of a trade union leader and another trainee is required to perform the role of a HR manager. This technique results in better understanding of each other's situation.

6. Brainstorming: This is creativity-training technique, it helps people to solve problems in a new and different way. In this technique, the trainees are given the opportunity to generate ideas openly and without any fear of judgement. Criticism of any idea or any comments are not allowed. Once a lot of ideas are generated then they are evaluated.

C) Vestibule Training: Under this type of training, training is conducted neither on the job nor off the job. Under this method a similar situation to a working condition is created and training is given to the trainees under such conditions. As far as practicable, actual machineries, actual materials, actual raw materials are used and actual like working condition is created so that the trainers and the trainees feel like working in real working situations. This type of training is done without disrupting the actual activities of the organisation. This sort of training make the trainees capable to handle actual work situations. For example, firemen training for fire fighting.

Payment of Wages:

What is wages? Wages is money paid to a worker for work performed, or the price you pay for doing something . If you make Rs.100 per hour at work, this **is an example** of your **wage**.

Procedure for payment of wages: Pay slip is prepared on the basis of the payroll or wages sheet. Pay slip is prepared for each worker separately. Now, each worker is given his/her pay slip in advance so that he/she can check the calculations before the actual payment is made. The particulars of net amount for the wage payment are forwarded to the cashier who draws money from the bank and arranges payment. After drawing the amount from bank, pay pocket is prepared for each worker separately and sealed after checking. The pay pocket contains the details like the name of worker, his/her number, designation and the name of department under which he/she is working. The pay pocket is handed over to workers under the presence of responsible officer and the department head under which the worker is working. The signature or thumb impression of an employee is received in the Wage Payment Register.

UNIT 6

LEADERSHIP AND MOTIVATION

LEADERSHIP.

Definition: Leadership is the act of guiding a team or individual to achieve a certain goal through direction and motivation. **Leaders** encourage others to take the actions they need to succeed or in other words we can say that Leadership is the ability of an individual or a group of individuals to influence and guide followers or other members of an organization.

NEED OR IMPORTANCE:

1.Initiating Action: Leadership starts from the very beginning, even before the work actually starts. A leader is a person who communicates the policies and plans to the subordinates to start the work.

2.Providing Motivation: A leader motivates the employees by giving them financial and non-financial incentives and gets the work done efficiently. Motivation is the driving force in an individual's life.

3.Providing guidance: A leader not only supervises the employees but also guides them in their work. He instructs the subordinates on how to perform their work effectively so that their efforts don't get wasted.

4.Creating confidence: A leader acknowledges the efforts of the employees, explains to them their role clearly and guides themto achieve their goals. He also resolves the complaints and problems of the employees, thereby building confidence in them regarding the organization.

5.Building work environment: A good leader should maintain personal contacts with the employees and should clear their problems and solve them. He always listens to the point of view of the employees and in case of disagreement persuades them to agree with him by giving suitable clarifications. In case of conflicts, he handles them carefully and does not allow it to adversely affect the entity. A positive and efficient work environment helps in stable growth of the organization.

6.Co-ordination: A leader reconciles the personal interests of the employees with the organizational goals and achieves co- ordination in the entity.

7.Creating Successors: A leader trains his subordinates in such a manner that they can succeed him in future easily in his absence. He creates more leaders.

8.Induces change: A leader persuades, clarifies and inspires employees to accept any change in the organization without much resistance and discontentment. He makes sure that employees don't feel insecure about the changes.

QUALITIES OF LEADERS:

1. **Ethical and Corporate Social Responsibility (CSR):** Leadership sets the standards and culture for ethical behavior.

2. **A Leader is there to serve:** A truly successful leader understands that they are there to serve their team, not to be served.

3. **A vision of commitment to the organization:** Leadership is about creating a vision that inspires those who work for and around others to participate actively in key goals, objectives and the overall mission.

4. **From the top to the bottom:** Leaders must be able to quickly assess the gap between top management and all employees, and think of innovations of how to encourage the team to act and feel satisfied as winners or contributors to the success of the company.

5. **Excellent communication:** Leaders must have an astute clarity of expression, communicating thoughts entirely synchronized with the messages delivered AND received. A leader must have the ability to communicate effectively at every level in your organization.

6. **Ability to listen and debate:** Rather than simply 'delivering' ideas, prepare to engage in debate around ideas and really listen to every suggestion.

7. **Teamwork:** The ability to create and maintain trust and respect between team members quickly and effectively is vital. A leader should be able to spot key problems and empower management to iron out any issues.

8. **Delegation:** A senior executive leader must have confidence to delegate work to his or her team and step back - leaders are there to empower others to become leaders and managers themselves.

9. **Honesty and integrity:** Although leaders must be positive, when things are not going well, the truth must be communicated. Subsequently, leaders must provide the vision and encouragement to bring the organization forward.

10. **A Problem Solver:** Leaders must always find solutions or (at least) suggest alternatives to every problem.

11. **Focused:** Keep the team on the right track on goals and strategies – ask for reminders of projects / goals and maintain focus on critical objectives despite endless obstacles.

12. **Change Management:** Adapt quickly to changes in the marketplace and communicate these to all members of the organization. Get the entire company behind changes necessary through visionary leadership.

13. **Forward thinking:** Beyond adapting to external changes, a leader must enact their own – an executive leader should be able to see current and future trends, apply them to his or her organization and stay ahead of the competition.

14. **Visionary and Leadership quality-** To be successful, the leader should have a clear vision of his new venture. However, to turn the idea into reality a lot of resources and employees are required. Here, leadership quality is important because a leader can guide their employees towards the right path of success.

15. **Open-Minded-** In a business, every circumstance can be an opportunity and used for the benefit of a company.

16. **Flexible-** A leader should be flexible and open to change according to the situation. To be on the top, a businessperson should be equipped to embrace change in a product and service as and when needed.

17. **Creativity :** Leadership starts with an idea. To be successful, a person needs to always be thinking of new ideas and better ways of doing things.

FUNCTION OF A LEADER:

1.Setting Goals:

A leader is expected to perform creative function of laying out goals and policies to persuade the subordinates to work with zeal and confidence.

2.Organizing:

The second function of a leader is to create and shape the organization on scientific lines by assigning roles appropriate to individual abilities with the view to make its various components to operate sensitively towards the achievement of enterprise goals.

3.Initiating Action:

The next function of a leader is to take the initiative in all matters of interest to the group. He should not depend upon others for decision and judgment. He should float new ideas and his decisions should reflect original thinking.

4.Co-Ordination:

A leader has to reconcile the interests of the individual members of the group with that of the organization. He has to ensure voluntary co-operation from the group in realizing the common objectives.

5.Direction and Motivation:

It is the primary function of a leader to guide and direct his group and motivate people to do their best in the achievement of desired goals, he should build up confidence and zeal in the work group.

6.Link between Management and Workers:

A leader works as a necessary link between the management and the workers. He interprets the policies and Program of the management to his subordinates and represents the subordinates' interests before the management. He can prove effective only when he can act as the true guardian of the interests of his subordinates.

Manager vs Leader:

1.Leader creates a vision, manager creates goals.

Leaders inspire and engage their people in turning that vision into reality. They activate people to be part of something bigger. Managers focus on setting, measuring and achieving goals. They control situations to reach or exceed their objectives.

2.Leaders are change agents, managers maintain the status .

Leaders are proud disrupters. Innovation is their mantra. They understand and accept the fact that changes to the system often create opportunities. Managers stick with the works, refining systems, structures and processes to make them better.

3.Leaders are unique, managers copy.

Leaders are self-aware and work actively to build their unique and differentiated personal brand. They are comfortable in their own shoes and willing to stand out. They're authentic and transparent. Managers copy the competencies and behaviors they learn from others and adopt their leadership style rather than defining it.

4/Leaders take risks, managers control risk .

Leaders are willing to try new things even if they may fail miserably. They know that failure is often a step on the path to success. Managers work to minimize risk. They seek to avoid or control problems rather than accept them.

5.Leaders are in it for the long term , managers think for short-term.

Leaders have intentionality. They do what they say and stay worked toward a big and for a long term . They remain worked without receiving regular rewards. Managers work on shorter-term goals, seeking more regular acknowledgment or awards.

6.Leaders build relationships, managers build systems and processes.

Leaders focus on people – all the stakeholders they need to influence in order to realize their vision. They know who their stakeholders are and spend most of their time with them. They build loyalty and trust by consistently delivering on their promise. Managers focus on the structures necessary to set and achieve goals. They focus on the analytical and ensure systems are in place to attain desired outcomes. They work with individuals to fulfill their goals and objectives.

7.Leaders grow personally, managers rely on existing, proven skills.

Leaders know if they aren't learning something new every day, they aren't standing still, they're falling behind. They remain curious and seek to remain relevant in an ever-changing world of work. Managers rely on existing skills and adopting proven behaviors.

STYLE OF LEADERSHIP: Based on the behavior of leader, the leadership style is classified in to three categories i.e. Autocratic, Democratic or Participative and Delegative.

1.Autocratic: Authoritarian leaders, also known as autocratic leaders, provide clear expectations for what needs to be done, when it should be done, and how it should be done. This style of leadership is strongly focused on both command by the leader and control of the followers. There is also a clear division between the leader and the members. Authoritarian leaders make decisions independently, with little or no input from the rest of the group. Authoritarian leadership is best applied to situations where there is little time for group decision-making or where the leader is the most knowledgeable member of the group. The autocratic approach can be a good one when the situation calls for rapid decisions and decisive actions. However this type of leadership style can be damaging rather than rewarding in the long run as it resembles that of a dictator. It leads to low employee morale, which in turn may lead to attrition in many cases.

2.Democratic or Participative: Participative leaders encourage group members to participate. Group members feel engaged in the process and are more motivated and creative. Democratic leaders tend to make followers feel like they are an important part of the team, which helps foster commitment to the goals of the group. Democratic leadership, also known as participative leadership or shared leadership, is a type of leadership style in which members of the group take a more participative role in the decision-making process.

3.Delegative: In this style the leader allow members to take decisions. While this style can be useful in situations involving highly qualified experts, it often leads to poorly defined roles and a lack of motivation. This leadership style tended to result in groups that lacked direction and members who blamed each other for mistakes, refused to accept personal responsibility, made less progress, and produced less work.

Motivation:

Definition: Motivation is the word derived from the word 'motive' which means needs, desires, wants or drives within the individuals. It is the process of stimulating people to actions to accomplish the goals. In other words motivation is the processes that account for an individual's intensity, direction, and persistence of effort toward attaining a goal. The main features of motivation are a goal-oriented continuous process and a psychological phenomenon that converts abilities into performance.

Characteristics:

1.Motivation is need based – If there is no need for an individual, the process of motivation fails.

2.Motivation is a continuous process – Most of the human needs are of recurring nature, some of the needs of individuals shall always be found to be unfulfilled. Thus motivational process can be enforced on a continuous basis.

3.Motivation is a planned process-to produce a desired result by stimulating and influencing human behavior for the best realization of the common objective. Two individuals could not be motivated in exactly similar manner as people differ in this case of approach to respond to the process of motivation.

4.Motivation may be positive or negative - A positive motivation promises incentives to people (pay, rewards, bonus, etc), a negative motivation threatens the enforcement of disincentives (penalties, disciplinary action, threat of demotion, fear of loss of job, etc).

5.Motivation aims for best attainment of common objectives through best utilization of resources - Motivated employees make the best utilization of all resources – materials, machines, technology and other work facilities and put in their best effort towards the attainment of common objectives of the enterprise.

6.Motivation is an internal feeling - It is a psychological phenomenon, which generates within an individual.

Importance of Motivation:

1.Effective Use of Resources: Motivation activates human resources and compels employees to behave in a particular manner. In business, all physical resources need to be used through human force. Highly motivated employees greatly help in making optimum use of available resources.

2.Higher Efficiency of Employees:

Motivation is directly related to the level of efficiency. Motivated employees put in their maximum effort for achieving organizational goals. Motivation improves the work performance by bridging the gap between the ability and willingness to work. Better performance results in higher productivity and consequently lower cost of production.

3.Healthy Industrial Relation:

Motivation is considered as the backbone of good industrial relation. Motivation creates friendly and supportive relationships between the employer and the employees. When the industrial relation becomes better, industrial disputes are reduced. There will be an atmosphere of confidence between the employer and the employees.

4.Better Organizational Image:

Motivation helps in improving an image of the organization. Employees produce more when they are properly motivated. Highly motivated employees try to maintain a self- disciplined and productive internal environment in the organization. This creates a better impression to the outsiders dealing with the organization.

5.High Morale and Satisfaction:

Motivation is helpful in increasing the morale of employees. High degree of motivation may lead to high morale. Highly motivated employees will get higher satisfaction which may lead to higher efficiency. Motivation improves the quantity as well as the quality of production.

6.Reduced Labor Turnover and Absenteeism:

Motivation leads to job satisfaction of workers. Employees are punctual and regular in their work schedule, provided they get job satisfaction. Highly motivated employees are loyal and committed to the organization. They are sincere and prefer to stay on the job for longer period of time. As a result, labor absenteeism and turnover are low.

7.Accomplishment of Organizational Goals:

Motivation helps in shaping the working behavior of the employees. It channelizes energy of employees for achieving organizational-goals. Highly motivated employees are more committed and cooperative for seeking organizational objectives. Motivation ensures achievement of organizational goals by meeting individual needs through a satisfactory system of rewards.

8.Introducing Changes in the Organization:

Motivation helps the management in introducing changes in the organization. Normally, employees resist changes for fear of an adverse effect on their employment. When the employees are given various opportunities of development, they can easily adapt to new situations. Motivated employees support all changes that are in the interest of the organization.

Factors affecting motivation:

1.Reward and Recognition:

There are many ways to reward employees. The aim of rewarding and recognizing employees is to encourage and motivate them to exceed within their roles and promote positive behaviors.

2.Development

Development is very important for motivating employees; studies have shown that most of the employees prefer career development opportunities and training.. Development makes an employee self-dependent and allows them to contribute more effectively in the workplace, it also helps employees to enhance their input to the business.

3.Relationship with colleagues

As employees spend one-third of their day at work, relationships and interactions they have with their colleagues can significantly impact their mood and outlook. Negative experiences or attitudes will eventually lead to isolation and loneliness, making it more difficult to find satisfaction from work, which in turn will decrease motivation.

4.Company's Culture

A company's culture consists of 6 main elements: work environment, company mission, value, ethics, expectations and goals. In practice, the culture is just a set of rules or accepted behaviors that help employees make decisions everyday. While every company would have their own unique set of features, values and beliefs, culture is always about making sure that the employees have a productive and enjoyable working environment. If the company's culture is unstable, in that situation the employees can not work for a long time and that leads to low job satisfaction, negative attitude which affects motivation.

5.Processes within the company

The workload, division of responsibilities, access to resources and accountability all depends on the structure and efficiency of the processes on which the business runs. Efficient processes stimulate workers, allowing them to work effectively and efficiently. At each stage of the process an individual should be aware of what's expected from them and what resources are available. Making sure that an employee feels responsible for the outcomes of their work is crucial in building work engagement and stimulating higher performance.

Maslow theory of motivation: Abraham Maslow's motivation theory is based on the human needs. These needs are classified into a sequential hierarchy from the lower to higher order as five need clusters as given below:

1.Physiological Needs: These needs are of the lowest-order and most basic needs of human beings. These involve satisfying fundamental biological drives, such as the need for food, air, water, cloth, and shelter generally expressed in the names of roti, kapada aur makan. These needs exert tremendous influence on human behavior. Entrepreneur also being a human being has to meet his physiological needs for survival. Hence, he / she is motivated to work in the enterprise to have economic rewards to meet his / her basic needs.

2.Safety and Security Needs:

The second level of need in Maslow's hierarchy is emerged once physiological needs are met. Safety needs involve the need for a secure environment, free from threats of physical and psychological harm. These needs find expression in such desires as economic security and protection from physical dangers. Meeting these needs requires more money and, hence, the entrepreneur is prompted to work more in his/ her entrepreneurial pursuit. Like physical needs, these become inactive once they are also satisfied.

3.Social Needs:

Man is social animal. These needs, therefore, refer to belongingness or affiliation. All individuals want to be recognized and accepted by others. Likewise, an entrepreneur is motivated to interact with fellow entrepreneurs, his employees, and others.

4.Esteem needs: These needs refer to self-esteem and self-respect. These include such needs that indicate self-confidence, achievement, competence, knowledge, and independence. In case of entrepreneurs, the ownership and self- control over enterprise satisfies their esteem needs by providing them status, respect, reputation, and independence.

5.Self Actualization Needs:

At the top of the hierarchy is the need for self actualization or the need to fulfill what a person considers to be the mission in his life. After all his other needs are fulfilled, a man has the desire for personal achievement. He wants to do something which is challenging and since this challenge gives him enough push and initiative to work, it is beneficial to him and the society. The sense of achievement gives him a sense of psychological satisfaction.

Methods of improving Motivation: The following are the the methods for improving motivation:

1.Create a friendly working environment

The employees spend a large amount of time of their lives working in the office. So try to make the office look as friendly and appealing as possible. When the entrepreneur create a pleasant working atmosphere the employees will be more satisfy to go to work every day.

2.Acknowledge employees' achievement

Everyone wants to be recognized and acknowledged for something they have done. The acknowledgement of a job well done coming from upper management that increases the morale of the employees. The entrepreneurs always remember to give credit to their employees when credit is due.

3.Rewarding employees

It is the responsibility of the entrepreneur to give simple incentives as rewards to the employees through which they will be motivated. It does not have to be monetary rewards all the time, the entrepreneur may reward the employee by providing T- shirts or some sweets. Rewarding employees could also be a part of the company benefits.

4.Positive communication is the key

Positive communication is the best method for improving the motivation of the employees in an organization. The entrepreneurs spend a short period of time each day to have a word with the employees; discussing different ideas in a very friendly manner. This will not only make the employees happy but also the entrepreneur will get all types of support from the employees.

5.Create a career path

When employees will be provided through incentives ,they will become motivated. This will lead to increased commitment towards their employer. The members of the team will be more valuable to the organization, and to themselves, when they have opportunities to learn new skills. So It is the responsibility of the entrepreneurs to provide their employees with the training so that they can increase their potential, skill and also acquire new knowledge on latest technology as a result they can develop their career which the entrepreneurs can improve their motivation for the employees.

1.Welcome all ideas

Everyone employee is unique and they might have some good ideas and suggestions. So it is the duty of the entrepreneurs to allow the employees to participate in the decision making process and they should listen their suggestions and evaluated them. In this regard the entrepreneurs can improve the motivation.

2.Encourage creativity

Creativity does not have to be based on the work that the employees are doing. It could be simple task like giving ideas on different activities related to business or team building exercises.

Importance of communication in business: Communication is one of the most important functions of management. It may cement an organization or disrupt. It promotes managerial efficiency and induces the human elements in an organization to develop a spirit of cooperation. It has become one of the most vital factors in the efficient performance of management. The importance of communication are given below:

1.Efficient and Smooth Running of an Enterprise: The smooth and efficient functioning of an enterprise entirely depends upon the effectiveness of the system of communication. It provides the necessary basis of direction and leadership. It actuates people to action in accordance with the desires of the management. Without proper communication, performance and achievements of the goals may not be possible. It is essential to secure cooperation between any two persons.

2.Basis of Decision Making:

Communication is the basis of decision making. It helps the management to take essential decision and conduct vital operations. The quality of decisions made in an organization entirely depends on the amount and quality of information available to the management. The quality of information depends upon effective communication, and the quality of communication exercises considerable influence on the quality of decision making.

3.Proper Planning and Coordination:

Communication is very helpful in planning and coordinating the activities of business. If the system of communication is good, useful suggestions will come from the subordinates to the superiors. This would be helpful in the formation of plans. Participation of employees is now regarded essential for getting the task done, and this, can effectively be secured only through the media of communication.

4.For Higher Productivity at Minimum Cost:

Effective communication between employers and employees plays a vital role in obtaining maximum production with the minimum of cost. Effective communication will make the employee feel more secure and more interested in his work. It will increase the understanding of the employees and secure their willing acceptance of the business plans. It will increase the productivity on the part of workers.

5.Morale Building:

Communication in industry is the basis for morale building. Under an effective system of communication, it is quite convenient for the employees to bring their grievances to the notice of the management and get a proper adjustment. It creates mutual trust and faith, and that ultimately ensures job satisfaction amongst the employees, creates confidence in the ability of managers and promotes their loyalty towards the enterprise.

2.Democratic Management:

Effective communication is the basis for democratic management. It ensures co-operation through understanding. The management has been forced to recognize the maintenance of sound system in democracy which necessitates understanding and support of workers. Adequacy and clarity of communication facilitates effective leadership and maintenance of man to man relationship.

1.Binds People Together:

Effective communication induces the human elements in an organization to develop a spirit of cooperation and produces the will to do work before actually doing it. In this way, effective communication binds the people of an organization together.

2.Create mutual trust and confidence:

Effective communication creates mutual trust and confidence between the management and the labour. It gives job satisfaction to the workers. It is essential for healthy industrial relations. Sharing ideas and experiences with workers eliminates their fears and misunderstanding and helps in winning over their trust and confidence.

What is communication? Communication is the the act of sharing or transferring information between two or more individuals or a group of people. Technically, each communication process requires a sender, a recipient, a message and a medium.

Barriers of communication: The following are the barriers of communication:-

1.Physical Barriers

A communication is a two-way process, distance between the sender and the receiver of the message is an important barrier to communication. Noise and environmental factors also block communication.

2.Personal Barriers:

Personal factors like difference in judgment, inferiority complex, attitude, pressure of time, inability to communicate, etc. widen the psychological distance between the communicator and the communicate. Credibility gap i.e., inconsistency between what one says and what one does, also, acts as a barrier to communication.

3.Status Barriers (Superior-Subordinate Relationship):

Status or position in the hierarchy of an organization is one of the fundamental barriers that obstructs free flow of information. A superior may give only selected information to his subordinates so as to maintain status differences. Subordinates, usually, tend to convey only those things which the superiors would appreciate.

4.Organizational structure Barriers:

Effective communication largely depends upon sound organizational structure. If the structure is complex involving several layers of management, the breakdown or distortion in communication wall arise. Moreover, information travelling through formal structure introduces rigidity and causes-delay because of long lines of communication. Similarly, lack of instructions for further conveying information to the subordinates and heavy pressure of work at certain levels of authority also act as barriers to effective communication.

5.Barriers Due to Inadequate Attention:

Listening is the most neglected skill of communication. Inadequate attention to the message makes communication less effective and the message is likely to be misunderstood. Inattention may arise because of over business of the communicate or because of the message being contrary to his expectations and beliefs. Whatever be the reason, communication remains only a one-way process and there is no understanding of the message, if the receiver pays little attention to the message.

6.Resistance to Change:

It is a general tendency of human beings to stick to old and customary patterns of life. They may resist change to maintain status quo. Thus, when new ideas are being communicated to introduce a change, it is likely to be overlooked or even opposed. This resistance to change creates an important obstacle to effective communication.

7.Barriers Due to Lack of Mutual Trust:

Communication means sharing of ideas in common. "When we communicate, we are trying to establish a commonness." Thus, one will freely transfer information and understanding with another only when there is mutual trust between the two. When there is a lack of mutual trust between the communicator and the communicate, the message is not followed. Credibility gaps, i.e., inconsistency in saying and doing, also causes lack of mutual trust which acts as a basic obstacle to effective communication.

8.Emotional Attitude:

Barriers may also arise due to emotional attitude because when emotions are strong, it is difficult to know the frame of mind of other person or group. Emotional attitudes of both, the communicator as well as the communicate, obstruct free flow of transmission and understanding of messages.

UNIT 7

WORK CULTURE, TQM AND SAFETY

Human relationship and performance in organization:

Four Factors Influencing Human Relations in an Organizations are: (I) work environment (II) work-group (III) individual (Iv) leader. Organization should be viewed as a social system. Human relations in the organization are determined by work environment, workgroup, individuals & leader i.

1.Work Environment: Human relations promoted the creation of a positive work environment where organizational goals are achieved through satisfaction of employees. In general, when employee needs are satisfied, the work environment is termed positive and when employee needs are not satisfied, the work environment is termed negative. Positive work environments are characterizing by such factors like: goals are clearly stated, incentives are properly used to improve performance, feedback is available on performance, decisions are timely and participative.

2.Work Group: The work group is the centre of focus of human relations studies. It has an important role in determining the attitudes and performance of individual workers. Studies showed that the informal groups apply tremendous influence over the behavior patterns of workers. The informal groups cancelled official orders quite frequently and played a decisive role in determining production standards. Work is a social experience and most workers find satisfaction in membership in social groups. Unless managers recognize the human relations at work productivity will not improve.

3. Individual: The human being is an important segment of the organization. Behavior of an individual is affected by his feelings sentiments and attitudes. Motivation of employees should give due consideration to their economic, social and psychological needs. Thus, motivation is a complex process.

4.Leader: The human relationships gave great importance to leadership. The leader must ensure full and effective utilization of all organizational resources to achieve organizational goals. He must be able to adjust to various personalities and situations. He must behave in a way that generates respect. A supervisor can contribute significantly in increasing productivity by providing a free, happy and pleasant work environment where bossism is totally absent and where members are allowed to participate in decision-making processes. Authoritative tendencies must give way to democratic values.

Relations with Peers, Superiors and Subordinates:

It is always an experience to interact with the peer, superior and subordinate groups. All the three groups of people give a different feel and learning, when we interact with them. All the three groups are important and very much existent in all areas of life. Whether it is family, office, friends, mentors, teachers, bosses, acquaintances, etc, all of them are typically divided into three- categories.

Peers:

The first category will always be peers because we respond them very easily and very firstly. They are typically the same level as us either in intelligent quotient or status or family structure or in any other way at par with us. We normally tend to be comfortable with them in terms of talking and interacting. One more reason of a person being comfortable with peers is they have similar problems and they empathize very well with each other. For example colleagues in office, friends, cousins etc.

Superiors:

The second category is superiors. The teachers, mentors, bosses, family, etc generally fall in this category. They are the ones who are higher than us as far as the knowledge or experience or intellect quotient or relationship goes. They expect a certain kind of respectful treatment from us, while we deal with them. We normally tend to take time to interact with them directly; more so, particularly because they also have an expectation barrier to break first with us. They are the ones from whom you learn effortlessly because we know that they know more than us. For example uncles, aunts, bosses, mentors, aged consultants, senior- positions-in-anyway,etc.

Subordinates:

The third category opens up the scope of being a mentor to others, as well as taking work from them or helping them to cope up. They are lesser either by age, experience, knowledge or relationship and that's why we feel good dealing with them and sometimes even show them off our seniority. They are the ones who need our help for their growth but still our responses to them are important;

TQM Definitions: Total Quality management is defined as a continuous effort by the management as well as employees of a particular organization to ensure long term customer loyalty and customer satisfaction. Remember, one happy and satisfied customer brings ten new customers along with him whereas one disappointed individual will spread bad word of mouth and spoil several of the existing as well as potential customers.

TQM Concepts:

1.Continuous improvement of quality

Foremost among TQM concepts is the idea of continuous improvement of quality. The underlying aim of total quality management is to improve the quality of products and services in any organization. By so doing, productivity, employability and customer service are improved. When an organization focuses on this concept of total quality management, they are able to achieve the best.

1. Focus on the customer

Another TQM concept is a central focus on the customer. The customers are the internal and external recipients of an

organization's products. Therefore, the needs of customers and their desires define quality for the organization.

2. Operations improvement

Furthermore, systematic improvement of operations is another concept of total quality management. Every work done in an organization follows a chain or process. These processes account for 80-85% of the quality of work and productivity of employees. This concept establishes that work processes should be studied, through individuals or teams, to identify lapses or complexities.

3.Human resources.

The concept of human resources development is one of the concepts of total quality management. Organizations that employ total quality management principles are committed to employee learning and development. These principles require that management trust that well-trained staff can do the jobs assigned to them properly.

4.TQM leadership

Similarly, another concept of TQM is about management responsibility for TQM leadership. Managers are responsible to lead the transformation of an organization to imbibe the culture of quality. They must accept the responsibility for continuous quality improvements and be dedicated to empowering others.

Quality policy:

A quality policy drives the function of the entire QMS. A brief statement that aligns the **purpose** and strategic direction of the company, the policy lays the framework for all future quality objectives. In addition, it states the **commitment** to meeting requirements of customers. The Directors, Management and Staff are **responsible for Quality** Control through the **Quality** Management System seeking improvement by constant review, with suppliers and sub-contractors being encouraged to co-operate.

Important of quality policy:

a) It is important because it expresses management commitment to ensure customer satisfaction through product quality.

b) It is important because it expresses management commitment to ensure customer satisfaction through product quality and is a basis for quality communication inside the company.

Quality Management:

Quality management: Quality management is focused not only on product and service quality, but also on the means to achieve it. Quality management, therefore, uses quality assurance and control of processes as well as products to achieve more consistent quality. Quality management is the act of overseeing all activities and tasks that must be accomplished to maintain a desired level of excellence. This includes the determination of a quality policy, creating and implementing quality planning and assurance, and quality control and quality improvement. It is also referred to as total quality management (TQM). . It has four main components: quality planning, quality assurance, quality control and quality improvement.

Principles of Quality Management:

1.Customer Focus

The primary focus of quality management is to meet customer requirements and to strive to exceed customer expectations. Success is achieved when an organization attracts and retains the confidence of customers. Every aspect of customer interaction provides an opportunity to create more value for the customer. Understanding the current and future needs of customers contributes to the sustained success of an organization

2.Leadership

Leaders at all levels establish unity of purpose and direction and create conditions in which people are engaged in achieving the quality objectives of the organization. Creation of unity of purpose, direction, and engagement enable an organization to align its strategies, policies, processes, and resources to achieve its objectives.

3.Engagement of People

It is essential for the organization that all people are competent, empowered and engaged in delivering value. Competent, empowered and engaged people throughout the organization enhance its capability to create value. To manage an organization effectively and efficiently, it is important to involve all people at all levels and to respect them as individuals. Recognition, empowerment, and enhancement of skills and knowledge facilitate the engagement of people in achieving the objectives of the organization.

4.Process Approach:

The quality management system is composed of interrelated processes. Understanding how results are produced by this system, including all its processes, resources, controls and interactions, allows the organization to optimize its performance.

5.Improvement:

Improvement is essential for an organization to maintain current levels of performance, to react to changes in its internal and external conditions and to create new opportunities.

6.Relationship Management

For sustained success, organizations manage their relationships with interested parties, such as suppliers and partners**.** Benefits:

- greater efficiency and less waste
- better and consistent control of major business processes
- a better understanding of customer needs
- regulation of successful working practices
- improved risk management
- increased customer satisfaction
- improved participation of employees
- better internal communication
- greater consistency in the quality of products and services
- increased profits
- managing growth more effectively

Quality System:

A quality management system (QMS) is defined as a formalized system that documents processes, procedures, and responsibilities for achieving quality policies and objectives. A QMS helps coordinate and direct an organization's activities to meet customer and regulatory requirements and improve its effectiveness and efficiency on a continuous basis

Accident and safety:

Causes: There are a number of factors that can lead to industrial accidents, including everything from improper lifting techniques to mishandling hazardous materials. Below are some common causes of accidents in the workplace.

Environmental Causes of Accidents

- Accidents which occur from environmental causes refer to those workplace accidents that happen because of the working environment. The environmental factors can be both natural and man-made such as workplace design. Common environmental causes of accidents include:
- **Poor-lighting**

  Low visibility is a common cause of slips, trips, and falls.

- **Ambient-temperature** –

  If a workplace is too hot, overheating can occur. If the workplace is too cold, frostbite or hypothermia can occur.
- **Air-pollution** –

  Breathing issues can develop if a workplace has poor ventilation and/or air pollution.
- **Sound-pollution** –

  The sound in a workplace can cause injury to a worker's hearing.

Mechanical Causes of Industrial Accidents

- Mechanical causes of industrial accidents are factors that refer to machine or equipment failure or breakdown. Generally, with proper maintenance and safety processes in place, these types of accidents are preventable. Common mechanical causes of accidents include:
- **Broken-or-damaged-machine –** Parts can be easily broken or damaged if made of poor-quality metal.
- **Power-failure –**

  Total or partial power failure can lead to serious injury.
- **Fire-or-explosion –**

  Cooling failure or a small spark can lead to a mechanical fire or explosion.
- **Fair-wear-and-tear –**

  The older machine, the more wear and tear on the parts which can lead to a higher risk of mechanical accident.

Human Factors That Cause Accidents

- Accidents caused by human factors refers to incidents in which the accident is directly attributed to the worker involved in the accident. Common human factors that cause industrial accidents include:
- **Poor-housekeeping** –

  An unkempt work space can lead to slips, trips, and falls.
- **Fatigue**

  When a body is tired, injury is more likely to occur.
- **Overexertion** –

  Overexertion injuries are the most common type of workplace injury.
- **Stress** –

  Workers who are stressed are often more distracted and of greater risk of injury.
- **Dehydration** –

It is important to consume enough water to ensure you body functions properly.

- **Improper-Lifting**

  Lower back strains and shoulder injuries are common among workers who use improper lifting techniques.

Preventive-measures:

Some of the steps for preventing industrial accidents are as follows : 1. Proper safety measures 2. Proper selection 3. Safety conscious 4. Enforcement of discipline 5. Incentives 6. Safety committees 7. Proper maintenance of machines, equipment and infrastructural facilities 8. Safety training.

1.Proper safety measures:

The proper safety measures should be adopted to avoid accidents Government also provides guidelines for enacting measures for checking accidents, these should be properly followed.

2.Proper selection:

Any wrong selection of workers will create problems later on. Sometime employees are accident prone, they may not be properly suitable for the particular jobs. So the selection of employees should be on the basis of properly devised tests so that their suitability for jobs is determined.

3.Safety conscious:

The employees should be made conscious of various safety measures to be followed. There should be proper working slogans and advises to the worker for making them conscious.

4.Enforcement of discipline:

Disciplinary action should be taken against those who flout safety measures. There may be negative punishments like warnings, lay off, terminations of workers.

5.Incentives:

Workers should be given various incentives for maintaining safety. There may also be safety contrasts among workers. Those who follow safety instructions properly should be given monetary and nonmonetary incentives.

6.Safety committees:

Safety measures are in the interest of both employers and workers. There should be committees consisting of representatives of workers and employees for devising and enforcing safety programs.

7.Proper maintenance of machines, equipment and infrastructural facilities:

Accidents may occur on account of the fault in machines or equipment. There should be proper maintenance of machines. These should be regularly checked and frequently inspected the machines.

8.Safety training:

The workers should be given training regarding safety measures. They should know the hazards of the machines, the areas of accident proneness and the good working possible precautions in case of some accident.

General safety rules:

- Be sure you know how to perform the job and perform it safely.
- Report all near misses, incidents, injuries and illnesses immediately.
- Wear the required personal protective equipment necessary for the job. Safety glasses are required as minimum eye protection on all jobsites.
- Never conduct work, unless trained.
- Obey all warning signs and barricades.
- Inspect all equipment, scaffolds, ladders, lifts, etc. before using. If found to be defective remove from service.
- Report any unsafe tools, equipment or hazardous conditions to your supervisor.
- See that good housekeeping is maintained in your work area.
- Exercise proper lifting techniques..
- Do not perform work under unsafe conditions. Any employee has the right to stop work if they feel it is unsafe.
- Only authorized personnel shall repair company furnished tools or equipment.
- Firearms on the job are prohibited.
- Always keep a positive attitude. This will make the day go better and make you a safer worker.
- Do not use ladders as scaffolds and never climb so high that it is impossible to hold the top step for support.
- **Personal Protection Equipment(PPE):**
- Information on specific components of PPE. Including gloves, gowns, shoe covers, head covers, masks, respirators, eye protection, face shields, and goggles.
- Gloves: Gloves help protect workers when directly handling potentially infectious materials or contaminated surfaces.
- Gowns: Gowns help protect workers from the contamination of clothing with potentially infectious material.
- Shoe and Head Covers: Shoe and head covers provide a barrier against possible exposure

within a contaminated environment.

- Masks : Surgical masks help protect nose and mouth of workers from poisonous smell before inhale it.

UNIT 8

LEGISLATION

Intellectual Property Rights(IPR): **Intellectual property rights** are the **rights** given to persons over the creations of their minds. They usually give the creator an exclusive **right** over the use of his/her creation for a certain period of time. Intellectual property (IP) refers to creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce. Or in other words Intellectual property is the product of the human intellect including creativity concepts, inventions, industrial models, trademarks, songs, literature, symbols, names, brands,....etc.. They also entitle him/her to prevent others from using, dealing or tampering with his/her product without prior permission from him/her. He/she can in fact legally sue them and force them to stop and compensate for any damages.

What is Patents? Patent is an exclusive right granted by law to an inventor or assignee to prevent others from commercially benefiting from his/her patented invention without permission or in other words we can say that anyone who invents or discovers “any new and useful process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof” can apply for society use. Example computer, telephone and Bluetooth.

What is a Trademark? A trademark is a unique symbol or word(s) used to represent a business or its products

A trademark is a sign that individualizes the goods or services of a given enterprise and distinguishes them from those of competitors. Examples are Maruti Suzuki symbol, audi factory symbol, adidas, cocacola etc.

What is copy right? Copyright refers to the legal right of the owner of intellectual property. A copyright is a formal declaration that the owner is the only one with the right to publish, reproduce, or sell a particular artistic work. In **simpler** terms, **copyright** is the right to copy. This means that the original creators of products and they give authorization to others to reproduce the work. **Copyright** is a legal means of protecting an author's work. It is a type of intellectual property that provides exclusive publication, distribution, and usage rights for the author. Many different types of content can be protected by **copyright**. **Examples** include books, poems, plays, songs, films, and artwork.

Feature of factories Act, 1948: The Factories Act, 1948 consolidating and amending the law relating to labour in factories, was passed by the Constituent Assembly on August 28, 1948. The Act received the assent of Governor General of India on 23 September 1948 and came into force on April 1, 1949.

Objective of Factories Act ,1948

The main objectives of the Indian Factories Act, 1948are to regulate the working conditions in factories, to regulate health, safety welfare, and annual leave and enact special provision in respect of young persons, women and children who work in the factories.

1.Working Hours:

According to the provision of working hours of adults, no adult worker shall be required or allowed to work in a factory for more than 48 hours in a week. There should be a weekly holiday.

2.Health:

For protecting the health of workers, the Act lays down that every factory shall be kept clean and all necessary precautions shall be taken in this regard. The factories should have proper drainage system, adequate lighting, ventilation, temperature etc. Adequate arrangements for drinking water should be made. Sufficient latrine and urinals should be provided at convenient places. These should be easily accessible to workers and must be kept cleaned.

3. Safety:

In order to provide safety to the workers, the Act provides that the machinery should be fenced, no young person shall work at any dangerous machine, in confined spaces, there should be provision for manholes of adequate size so that in case of emergency the workers can escape.

4. Welfare:

For the welfare of the workers, the Act provides that in every factory adequate and suitable facilities for washing should be provided and maintained for the use of workers. Facilities for storing and drying clothing, facilities for sitting, first-aid appliances, shelters, rest rooms and lunch rooms should be there.

5.Penalties:-

The provisions of The Factories Act, 1948, or any rules made under the Act, or any order given in writing under the Act is violated, it is treated as an offence. The following penalties can be imposed:-

(a) Imprisonment for a term which may extend to one year;

(b) Fine which may extend to one lakh rupees; or

(c) Both fine and imprisonment.

If a worker misuses an appliance related to welfare, safety and health of workers, or in relation to discharge of his duties, he can be imposed a penalty of Rs. 500/-.

Cleanliness {Section 11}

Every **factory should be kept clean and free** from effluvia arising from any drain, privy or other nuisance.

Disposal of wastes and effluents {Section12}

Effective arrangements should be made in every factory for the **treatment and effluents due to the manufacturing process** carried on therein, so as to render them innocuous, and for their disposal.

Ventilation and temperature {Section 13}

Effective and suitable provisions should be made in every factory for securing and maintaining in every workroom; **adequate ventilation by the circulation of fresh air**; and such a temperatures will secure to workers therein reasonable conditions of comfort and prevent injury to health

Dust and fume {Section 14}

Effective measures should be taken **to prevent inhalation of dust and fume** that may produce in the course of manufacturing process.

Artificial humidification {Section 15}

In any factory where the humidity of air is artificially increased, the State Government may make rules prescribing standards of humidification; regulating the methods used for artificially increasing humidity of the air; and directing prescribed test for determining the humidity of the air to be correctly carried out and recorded; and prescribing methods to be adopted for securing adequate ventilation and cooling of the air in the workrooms.

Overcrowding {Section 16}

No room in any factory should lie overcrowded to an extent injurious to the health of the workers employed therein.

Lighting {Section 17}

In every part of a factory where workers are working or passing, there should be provided and maintained sufficient and suitable lighting, natural or artificial, or both.

Drinking water {Section 18}

In every factory effective arrangements should be made to provide and maintain at suitable points conveniently' situated for all workers employed therein a sufficient supply of wholesome drinking wate

Latrines and urinals {Section 19}

In every factory sufficient latrine and urinal accommodation of prescribed types should be provided conveniently situated and accessible to workers, separately for male and female workers, at all times while they are at the factory.

Spittoons {Section 20}

- In every factory there should be provided a sufficient number of spittoons in convenient places and they shall be maintained in a clean and hygienic condition.

Employee Safety

- The machinery in every factory should be properly fenced. **{Section 21}**
- Only the trained adult male worker, wearing tight fitting clothing which should be supplied by the Occupier, should be allowed to work near the machinery in motion. **{Section 22}**
- No young person shall be employed on **dangerous machinery, unless he is fully instructed** as to the danger arising in connection with the machine and the precautions to be observed and he has received sufficient training in work at the machine. **{Section 23}**
- Suitable arrangements should be made to provide striking gear and devices for cutting off power in case of emergencies. **{Section 24}**
- Sufficient precautions should be taken with regard to self-acting machines to avoid accidents. **{Section 25}**
- To prevent danger, all machinery driven by power should be encased and effectively guarded. **{Section 26}**
- Woman worker and children should not be employed in any part of the factory for pressing cotton in which a cotton-opener is at work. **{Section 27}**
- Hoists and Lifts in a factory should be periodically inspected by the Competent Person. **{Section 28}**
- Lifting Machines, Chains, Ropes and Lifting Tackles in a factory should be periodically inspected by the Competent Person. **{Section 29}**
- Where process of grinding is carried on, a notice indicating the maximum safe working peripheral speed of every grind-stone or abrasive wheel etc., should be fixed to the revolving machinery.**{Section 30}**

- Where any plant or machinery or any part thereof is operated at a pressure above atmospheric pressure, effective measures should be taken to ensure that the safe working pressure of such plant of machinery or part is not exceeded.**{Section 31}**

- Floors, stairs and means of access should be soundly constructed and properly maintained. **{Section 32}**

- Pits, sumps opening in floor etc., should be either securely covered or fenced. **{Section 33}**

- No workman shall be employed in any factory to lift, carry or move any load so heavy as to be likely to cause him injury. **{Section 34}**

- Necessary protective equipment should be provided to protect the eyes of the workman, where the working involves risk of injury to the eyes. **{Section 35}**

- Suitable precautionary arrangements should be taken against dangerous fumes, gases etc. **{Section 36}**

- Every practicable measures should be taken to prevent any explosion where the manufacturing process produces dust, gas, fume or vapour etc. **{Section 37}**

- Every practicable measures should be taken to prevent the outbreak of fire and its spread, both internally and externally. **{Section 38}**

- The Inspector of Factories can ask the Occupier or the Manager of the Factory to furnish drawings, specification etc., of any building, machinery or a plant, in case he feels that condition of such building, machinery or the plant may likely to cause danger to human life. **{Section 39}**

- The Inspector of Factories can suggest suitable measures of steps to take by the Occupier or Manager for implementation, when he feels the condition of any building, machinery or a plant may likely to cause danger to human life. **{Section 40}**

- Wherein **1000 or more workmen are employed in a factory**, the Occupier **should appoint a Safety Office**r to look after the safety aspects of the factory. **{Section 40-B}**

- Adequate and suitable '**washing facilities**' should be provided in every factory. **{Section 42}**

- Provision should be made to provide suitable places for keeping clothing not worn during working hours and for the drying of wet clothing.**{Section 43}**

- In every factory, suitable arrangements for sitting should be provided and maintained for all workers obliged to work in a standing position, in order that they may take advantage of any **opportunities for rest** which may occur in the course of their work.**{Section 44}**

- **First-Aid Boxes** with the prescribed contents should be provided and maintained so as to be readily accessible during all working hours at the rate of at least one Box **for every 150 workmen. {Section 45}**

- The Occupier should provide a **canteen for the use of workers in every factory, where the number of workmen employed is more than 250**.**{Section 46}**
- In every factory wherein more than **150 workers are employed adequate and suitable shelters or rest rooms and a suitable lunch room, with provision for drinking water,** where workers can eat meals brought by them, should be provided and maintained for the use of the workers. **{Section 47}**
- In every factory wherein more than **30 women workers** are ordinarily employed there should be provided and maintained a **suitable room for the use of children** under the age of six years of such women. **{Section 48}**

Ordinarily, a worker should not be allowed to work in a factory for more than **48 hours in any week**. **{Section 51}**

The workman should have one holiday for a whole day in a week. Where he was asked to work on his scheduled **weekly holiday**, he should be given compensatory holiday within three days of his scheduled weekly holiday. **{Section 52}**

Features of payment of wages Act, 1936: The **Payment of Wages Act**, **1936** regulates **payment of wages** to employees (direct and indirect). The **act** is intended to be a remedy against unauthorized deductions made by employer and/or unjustified delay in **payment of wages**.

The **Payment Of Wages Act 1936** was come in to the force on 23rd April **1936**. This **Act** was passed to regulate the **payment of wages** for certain classes of persons employed in industry. It ensures **payment of wages** in a particular form and at regular intervals without unauthorized deductions.

The **salient features** of the payment of wages act 1936 are as follows:

a) The Act was formed with the intention to regulate timely payment of wages to specific class of workers employed in industry without any wrongful deductions apart from what is mentioned in the Act.

b) The Act ensures that the salary be paid by **7th of each month** in factories/establishments having a workforce of less than 1000 workers and by **10th of each month** in other cases.

c) The Act ensures fixing of wage period, time and mode of payment of wages

d) The Act does not cover those whose wage is **Rs. 24,000/-** or more per month.

e) The Act provides a worker with its duly right as covered under the Act.

f) The Act empowers a worker to file a claim directly or through a Trade Union or through an Inspector, before with the Authority appointed under the Payment of Wages Act in case there is a delay in wages or in case of an unauthorized deduction.

UNIT 9

SMART TECHNOLOGY

The **Internet of Things** (**IOT**) refers to a system of interrelated, internet-connected objects that are able to collect and transfer data over a wireless network without human intervention.

Concept of IOT: The **Internet of things** (**IOT**) describes the network of physical objects—"things"— **IOT** devices are a part of the larger **concept** of home automation, which can include lighting, heating and air conditioning, media and security systems ...

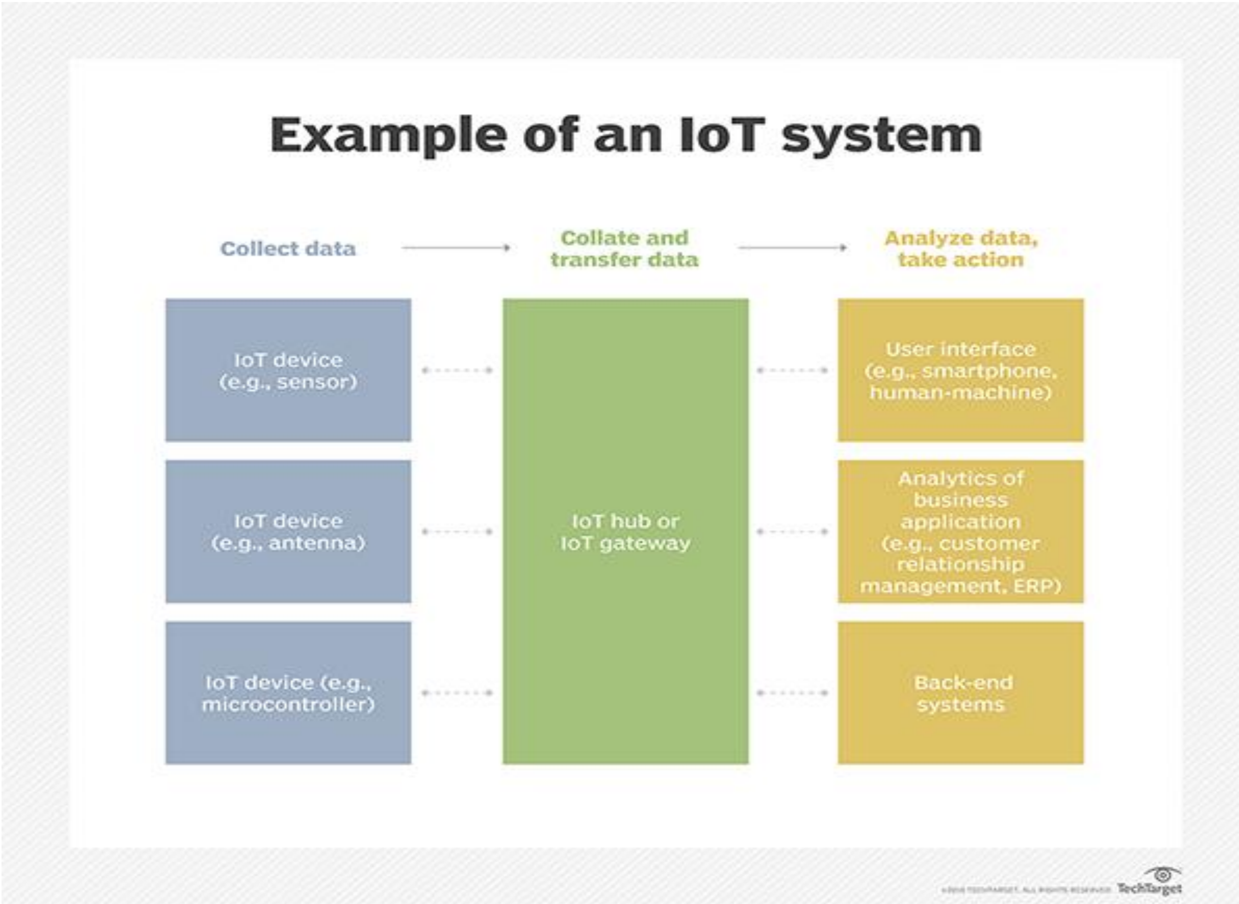
In other words we can say that The Internet of Things, or IOT, refers to the billions of physical devices around the world that are now connected to the internet, all collecting and sharing data. The Internet of Things is making the fabric of the world around us more smarter and more responsive, merging the digital and physical universes.

How IOT works

An IOT ecosystem consists of web-enabled smart devices that use embedded systems, such as processors, sensors and communication hardware, to collect, send and act on data they acquire from their environments. IOT devices share the sensor data they collect by connecting to an IOT gateway or other edge device where data is either sent to the cloud to be analysed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data.

The connectivity, networking and communication protocols used with these web-enabled devices largely depend on the specific IOT applications deployed.

IOT can also make use of artificial intelligence (AI) and machine learning to aid in making data collecting processes easier and more dynamic.



COMPONENTS OF IOT :

1. Smart devices and sensors – Device connectivity

Devices and sensors are the components of the device connectivity layer. These smart sensors are continuously collecting data from the environment and transmit the information to the next layer.

Latest techniques in the semiconductor technology is capable of producing micro smart sensors for various applications.

Common sensors are:

- Temperature sensors and thermostats
- Pressure sensors
- Humidity / Moisture level

- Light intensity detectors
- Moisture sensors
- Proximity detection

2. Gateway: IOT Gateway manages the bidirectional data traffic between different networks and protocols. Another function of gateway is to translate different network protocols and make sure interoperability of the connected devices and sensors.

Gateways can be configured to perform pre-processing of the collected data from thousands of sensors locally before transmitting it to the next stage. In some scenarios, it would be necessary due to compatibility of TCP/IP protocol. IOT gateway offers certain level of security for the network and transmitted data with higher order encryption techniques. It acts as a middle layer between devices and cloud to protect the system from malicious attacks and unauthorized access.

3. Cloud:

Internet of things creates massive data from devices, applications and users which has to be managed in an efficient way. IOT cloud offers tools to collect, process, manage and store huge amount of data in real time. Industries and services can easily access these data remotely and make critical decisions when necessary.

Basically, IOT cloud is a sophisticated high performance network of servers optimized to perform high speed data processing of billions of devices, traffic management and deliver accurate analytics. Distributed database management systems are one of the most important components of IOT cloud.

Cloud system integrates billions of devices, sensors, gateways, protocols, data storage and provides predictive analytics. Companies use these analytics data for improvement of products and services, preventive measures for certain steps and build their new business model accurately.

4. Analytics: Analytics is the process of converting analog data from billions of smart devices and sensors into useful insights which can be interpreted and used for detailed analysis. Smart analytics solutions are inevitable for IOT system for management and improvement of the entire system.

One of the major advantages of an efficient IOT system is real time smart analytics which helps engineers to find out irregularities in the collected data and act fast to prevent an undesired scenario. Service providers can prepare for further steps if the information is collected accurately at the right time.

5. User interface:

User interfaces are the visible, tangible part of the IOT system which can be accessible by users. Designers will have to make sure a well designed user interface for minimum effort for users and encourage more interactions.

Modern technology offers much interactive design to ease complex tasks into simple touch panels controls. Multicolour touch panels have replaced hard switches in our household appliances and the trend is increasing for almost every smart home devices.

Characteristics of IOT:

1. Connectivity

In the case of IOT, the most important feature one can consider is connectivity. Without seamless communication among the interrelated components of the IOT ecosystems (i.e sensors, compute engines, data hubs, etc.) it is not possible to execute any proper business use . IOT devices can be connected over Radio waves, Bluetooth, Wi-Fi, Li-Fi, etc. We can leverage various protocols of internet connectivity layers in order to maximize efficiency and establish generic connectivity across IOT ecosystems and Industry. There may be special cases where the IOT ecosystem is built on-premises or in an intranet

2. Dynamic Nature

For any IOT use case, the first and foremost step is to collecting and converting data in such a way that means business decisions can be made out of it. In this whole process, various components of IOT need to change their state dynamically. For example, the input of a temperature sensor will vary continuously based on weather conditions, locations, etc. IOT devices should be designed this keeping in mind.

3.Safety

One of the main features of the IOT ecosystem is security. In the whole flow of an IOT ecosystem, sensitive information is passed from endpoints to the analytics layer via connectivity components. While designing an IOT system we need to adhere to proper safety, security measures, and firewalls to keep the data away from misuse and manipulations. Compromising any component of an IOT ecosystem can eventually lead to failure of the whole pipeline.

4. Integration: IOT integrates various cross-domain models to enrich user experience. It also ensures proper trade-off between infrastructure and operational costs.

5. Heterogeneity: The devices in the IOT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.

6. Enormous scale: The number of devices that need to be managed and that communicate with each other will be at least an order of magnitude larger than the devices connected to the current Internet.

7. Security:

IOT devices are naturally vulnerable to security threats. As we gain efficiencies, novel experiences, and other benefits from the IOT, it would be a mistake to forget about security concerns associated with it. There is a high level of transparency and privacy issues with IOT. It is important to secure the endpoints, the networks, and the data that is transferred across all of it means creating a security paradigm.

Categories of IOT:

IOT can be divided into 3 categories based on usage and clients base:

- **Consumer IOT** includes the connected devices such as smart cars, phones, watches, laptops, connected appliances, and entertainment systems.
- **Commercial IOT** includes things like inventory controls, device trackers, and connected medical devices.
- **Industrial IOT** covers such things as connected electric meters, waste water systems, flow gauges, pipeline monitors, manufacturing robots, and other types of connected industrial devices and systems.

Applications of IOT: The following are the applications of IOT:

1. **Smart Cities**: **Smart cities** will promote the use of technology, information and data to enhance and improve its infrastructure and services. This includes access to resources like water and electricity. Providing homes that are affordable to all, provision of proper education and health services, and increase IT connectivity.

Characteristics of Smart City:

A. Smart cities will promote the use of technology, information and data to enhance and improve its infrastructure and services. This includes access to resources like water and electricity. Providing homes that are affordable to all, provision of proper education and health services, and increase IT connectivity.

B. A larger number of government services will be made more accessible to people. Services will be offered online and will provide more accountability, transparency and more involvement of the public.

Formation of E-groups will allow people to voice their opinions and receive feedback, monitor programs and activities with the help of cyber tour worksites.

C. An increase in access to public transportation and creative solutions such as smart parking, intelligent management, and integrated modal transport. Smart cities will be more pedestrian and cyclist friendly with key administrative services at shorter, walk able distances.

D. Smart cities will redevelop or develop unplanned and poorly planned areas such as slums, with a vision to make cities safer and less disaster-prone. With the use of video surveillance, criminal activity will be tracked, and drastic security measures will be taken to protect women, children, and senior citizen.

E.Urban hear effects will be reduced by creating and maintaining parks, playgrounds, and recreational spaces. Living spaces will be made to accommodate the growing population and also enhance its standard of living.

F. Infrastructure will be more sustainable and eco-friendly, by reducing the amount of waste generated and also through mindful consumption of natural resources.

- adequate water supply, assured electricity supply, sanitation, including solid waste management,
- efficient urban mobility and public transport,
- affordable housing, especially for the poor,
- robust IT connectivity and digitalization,
- good governance, especially e-Governance and citizen participation,
- sustainable environment,
- safety and security of citizens, particularly women, children and the elderly, and
- health and education.

2.Smart Transportation: Smart transportation, a key internet of things vertical application, refers to the integrated application of modern technologies and management strategies in transportation systems.

These technologies aim to provide innovative services relating to different modes of transport and traffic management and enable users to be better informed and make safer and 'smarter' use of transport networks.

Smart transportation includes the use of several technologies, from basic management systems such as car navigation; traffic signal control systems; container management systems; automatic number plate recognition or speed cameras to monitor applications, such as security CCTV systems; and to more advanced applications that integrate live data and feedback from a number of other sources.

According to the Intelligent Transportation Society of America , ITS technology makes it possible to:

- Use a navigation system to find the best route based on real-time conditions
- Alert drivers of potentially hazardous situations in time to avoid crashes
- Be guided to an empty parking space by a smart sign
- Ride a bus that turns traffic lights green on approach
- Detect and respond promptly to traffic incidents
- Reroute traffic in response to road conditions or weather emergencies
- Give travelers real-time traffic and weather reports
- Allow drivers to manage their fuel consumption
- Adjust speed limits and signal timing based on real-world conditions
- Improve freight tracking, inspection, safety and efficiency
- Make public transportation more convenient and reliable
- Monitor the structural integrity of bridges and other infrastructure

3.Smart Home: A **smart home** allows homeowners to control appliances, thermostats, lights, and other devices remotely using a smartphone or tablet through an internet connection. **Smart homes** can be set up through wireless or hardwired systems. **Smart home** technology provides homeowners with convenience and cost savings.

Features of Smart Home:

Light Control: As lighting is an integral part of a building. The user would be able to choose the time of activation, for example, in the home 7pm when it starts to get dark might be a sensible option.. This could include a specific room in the home or all the rooms. In a voice controlled format the user can change the colour of the light along with switch on or switch off the through Bluetooth headset.

Security: With the advancements of smart technology, it makes sense to include security features. The user would be able control the arming and disarming of the alarm, as well as edit specific settings of the alarm, such as the key code. The user could also have the option to configure intrusion detection settings. This system would warn the security personnel or house owner of any windows or doors being forced open, through the use of electronic sensors that are connected to the system.

Temperature: The user would be able to control the heating and cooling of the home, through the use of both time and parameter-based functions. The user may choose for the heating to come on when outside conditions drop below a certain temperature, there would be heat-sensitive sensors placed outside to detect varying conditions.

Appliances: The power supply to all appliances in the home could be controlled using the smart system. In a large home this would be a very convenient feature because there may be a lot of electrical appliances that are left on standby, hence the system should contain a feature, which searches all power supply links in the home to determine where energy can be saved.

Vehicle Detection: When a vehicle approaches the driveway of a home, the system should be able to alert the homeowner. This is only possible if certain types of smart home technologies are used. It would work very well with a Bluetooth headset because the system announce the arrival of the visitor to the homeowner.

Entertainment: For a fully capable smart home, entertainment features would be an innovative feature to include. The most widely used aspect of entertainment features is that the user can play his favourite or selected song at the time of requirement.

4.Smart Healthcare: Smart healthcare uses a new generation of information technologies, such as the internet of things (lOT), big data, cloud computing, and artificial intelligence, to transform the traditional medical system in an all-round way, making **healthcare** more efficient, more convenient, and more personalized.

In the healthcare, IOT plays a very important role in various applications. This criterion is divided into three phases, such as clinical care, remote monitoring and context awareness. During data collection, the risks of human error are reduced by means of automatic medical data collection method. This will improve the quality of the diagnosis and reduce the risk of human errors, who are involved in the collection or transmission of false information which is dangerous for the patients' health. There have been efforts for reviewing healthcare with different aspects. smart healthcare is defined by the technology that leads to better diagnostic tools, better treatment for patients, and devices that improve the quality of life for anyone and everyone." The key concept of smart health includes eHealth and mHealth services, electronic record management, smart home services and intelligent and connected medical devices.

Ehealth: As mentioned above, one of the key concepts for improving today's healthcare is eHealth, i.e. the usage of ICT in care. This is also how the World Health Organization defines the term: "eHealth is the use of information and communication technology (ICT) for health. Examples include treating patients, conducting research, educating the health workforce, tracking diseases and monitoring public health."

Mhealth: The term mHealth is short for mobile health. This terms has been defined by the WHO as "a component of eHealth". Since there is no standardized definition of mHealth, the Global Observatory of eHealth (GOe) has determined *mHealth* as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices." Mobile phones and other devices are used to support patients and improve healthcare. Besides using mobile phones to make calls and sent text messages, mHealth also includes more complex features and applications such as general packet radio service (GPRS), third and fourth generation mobile telecommunications (3G and 4G systems), GPS and Bluetooth technology.

Helping to Older people: As life expectancy keeps increasing, and more and more countries are confronted with an ageing society, smart health has to be applied to healthcare of older adults as well. Ambient Assisted Living, short AAL, is one new approach that aims at helping older people live as independently as possible.

5. Smart Industry: Smart Industry stands for radical digitalisation, connecting products, machines and people, and the use of new production technology. ... The optimisation of production through the application of ICT and new production technologies like 3D printing makes manufacturing more efficient, cheaper and boosts quality.

Features:

Security and safety: Security and safety for Industry includes protecting people from machinery-related hazards (safety) as well as the protection of production facilities and corporate IT from attacks and faults from the surrounding environment (security). This involves securing sensitive data as well as the prevention of intentional and unintentional malfunctions.

Digital life-cycle Management: The comprehensive networking of all automation components, machines, processes and product data — from development and production to recycling — decreases development time and therefore development costs, for both completely new smart manufacturing lines and upgrades to existing platforms. In addition, this also ensures the application-oriented design of all components.

Fast integration and flexible configuration: With Plug and Produce, people, machines, processes and the flow of goods are networked together on an ad hoc basis. Software tools simplify multiple smart manufacturing machine steps: commissioning, integration and (re)configuration, as well as preventive maintenance of all components, modules and machines.

Distributed Intelligence: intelligent automation components with integrated software perform their tasks independently, according to the specifications of higher-level systems, and make autonomous decisions.

People as key players: Digital assistant functions and intelligent workplace design support people with production-related information and improved ergonomics, thereby increasing the level of individualisation of the work environment.

Open standards: Open Standards that extend across manufacturers and are platform-independent form the basis for horizontal and vertical integration and thus for the seamless exchange of information in value-creation networks.

6. Smart Agriculture: The term **smart agriculture** refers to the usage of technologies like Internet of Things, sensors, location systems, robots and artificial intelligence on your farm. **The ultimate goal is increasing the quality and quantity of the crops while optimizing the human labor used**.

Technology used in smart agriculture is given below:

- **Irrigation control and precise plant nutrition**
- **Climate management and control** in greenhouses
- **Sensors** – for the soil, water, light, moisture, for temperature management
- **Location systems** – GPS, satellite, etc
- **Communication systems** – based on mobile connection, LoraWan, etc

- **Robots**

Features:

Pump Control – remote and automated turn-off control of most electric and diesel irrigation well pumps used on farms today.

Pump Monitoring – the essential information a farmer needs to know about the operation condition of his well pumps.

Pump Automation Features – easy-to-use, easy-to-understand automation features that have a tremendous positive impact on field operations like measuring the moisture level, water level.

Smart Farming : It is an emerging concept that refers to managing **farms** using modern Information and Communication Technologies to increase the quantity and quality of products while optimizing the human labour required.

- The goal of **smart agriculture** research is to ground a decision making support system for **farm** management. ... By providing them with the benefits of technological advancements, **smart agriculture aims** to reduce the heavy workload of the **farm** workers, hence improving their quality of life.
- Through IoT it increase the efficiency and helping the farmer to maximise crop production .
- Reduce emission from fertilizer manufacturing
- Through IOT the farmers can easily find out how much pesticide and water are required for the development of crops.

7. Smart Energy Management: Smart energy management systems allow the coordination among sensors and lights to automatically keep lights off when not required.. The **system** uses a combination of technologies to enable data-driven lighting automation. **Smart energy management** is a way to understand **smart energy** and how the systems work most efficiently. Some **smart energy** systems are basic like **energy** saving air conditioners or using **smart** appliances.

Features:

- Smart energy management will help you diagnose potential energy losses and existing problems in your residential, business or commercial premises.

- An **energy management feature** uses smart technology to identify hours of large energy usage, wasted electricity,.
- It turns off appliances, lights, and devices when they are not being used.
- **Smart Energy Management** can truly help the society to save money and reduce the impact on the environment.
- it makes easier for consumers to monitor their energy consumption and allowing them to make effective changes.
- Reduce cost : EMS allows the consumer to significantly reduce utility , including heating, cooling, lighting, and water.
- Improve staff well-being: Both consistent lighting and temperature control through smart energy management system, it will create energy-efficient workplaces for all, increasing employee happiness and performance.
- Improve facility performance: Not only EMS improve employee performance, but also it improves building performance. By reducing energy waste and operating costs, we can save more money and that can be utilised in other use like business, marketing, promotions, salaries, and product spends.

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

REFRIGERATION AND AIR CONDITIONING

5TH SEMESTER

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REFRIGERATION

The process of removing heat from an enclosed space or from a substance for the purpose of lowering the temperature.

UNIT OF REFRIGREATION

The unit of refrigeration is expressed in terms of ton of refrigeration (TR). One ton of refrigeration is defined as the amount of refrigeration effect (heat transfer rate) produced during uniform melting of one ton (1000kg) of ice at 0°C to the water at the 0°C in 24 hours.

Refrigeration effect and coefficient of performance

Refrigeration effect

A refrigeration machine can be called efficient only of it can create maximum refrigerating effect for the work allotted to it. Refrigeration effect means that cooling action should be done at the rate of heat absorption from any place in a cycle.

coefficient of performance

The rate of refrigerating effect to the heat equal to the supplied work is called coefficient of performance.

$$\text{C.O.P.} = \frac{\text{Refrigerating effect}}{\text{Input work}}$$

AIR REFRIGERATION SYSTEM

Air cycle refrigeration systems belong to the general class of gas cycle refrigeration systems, in which a gas is used as the working fluid. The gas does not undergo any phase change during the cycle, consequently, all the internal heat transfer processes are sensible heat transfer processes. Gas cycle refrigeration systems find applications in air craft cabin cooling and also in the liquefaction of various gases.

Air Standard Cycle analysis

Air cycle refrigeration system analysis is considerably simplified if one makes the following assumptions

i. The working fluid is a fixed mass of air that behaves as an ideal gas

ii. The cycle is assumed to be a closed loop cycle with all inlet and exhaust processes of open loop cycles being replaced by heat transfer processes to or from the environment

iii. All the processes within the cycle are reversible, i.e., the cycle is internally reversible

iv. The specific heat of air remains constant throughout the cycle An analysis with the above assumptions is called as cold Air Standard Cycle (ASC) analysis. This analysis yields reasonably accurate results for most of the cycles and processes encountered in air cycle refrigeration systems. However, the analysis fails when one considers a cycle consisting of a throttling process, as the temperature drop during throttling is zero for an ideal gas, whereas the actual cycles depend exclusively on the real gas behavior to produce refrigeration during throttling.

Air cycle refrigeration is one of the earliest methods used for cooling. The key features of this method is that, the refrigerant air remain gaseous state throughout the refrigeration cycle. Based on the operation, the air refrigeration system can be classified into

- Open air refrigeration cycle
- Closed refrigeration cycle

Open air refrigeration cycle

In an open refrigeration system, the air is directly passed over the space is to be cooled, and allowed to circulate through the cooler. The pressure of open refrigeration cycle is limited to the atmospheric pressure. A simple diagram of the open-air Refrigeration system is given below.

Advantages and application

- It eliminates the need of a heat exchanger.
- It is used in aircraft because it helps to achieve cabin pressurization and air conditioning at once

Disadvantages

One of the disadvantages of this system is that its large size. The air supplied to the refrigeration system is at atmospheric pressure, so the volume of air handled by the system is large. Thus the size of compressor and expander also should be large. Another disadvantage of the open cycle system is that the moisture is regularly carried away by the circulating air, this leads to the formation of frost at the end of the expansion process and clogs the line, and hence a use of dryer is preferable to the open air refrigeration system.

Closed refrigeration system / Dense air refrigeration cycle

In closed or dense air refrigeration cycle, air refrigerant is contained within pipes and component part of the system at all time. The circulated air does not have to direct contact with the space to be cooled. The air is used to cool another fluid (brine), and this fluid is circulated into the space to be cooled. So the disadvantages listed in open air refrigeration can be eliminated. The advantages of closed air refrigeration system are

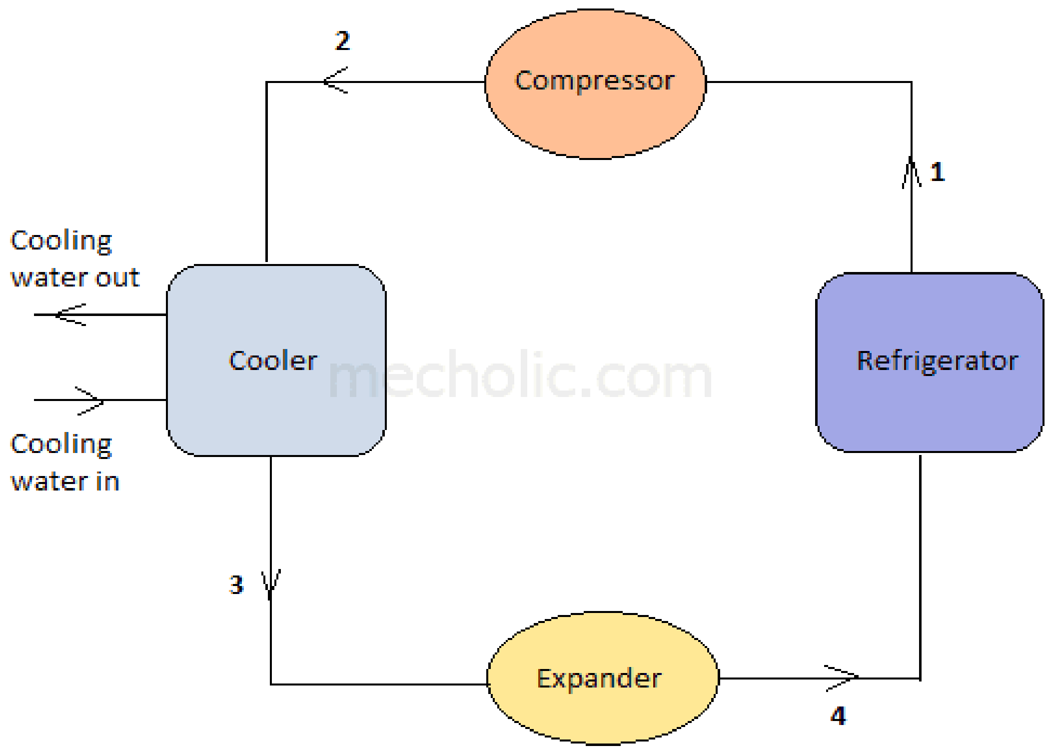
Advantages

- The suction to the compressor may be at high pressure, therefore the volume of air handled by the compressor and expander is low when compared to an open system. Hence the size of compressor and expander is small compared to the open air system.
- The chance of freezing of moister and choke the valve is eliminated.
- In this system, higher COP can be achieved by reducing operating pressure ratio.

Comparison Chart

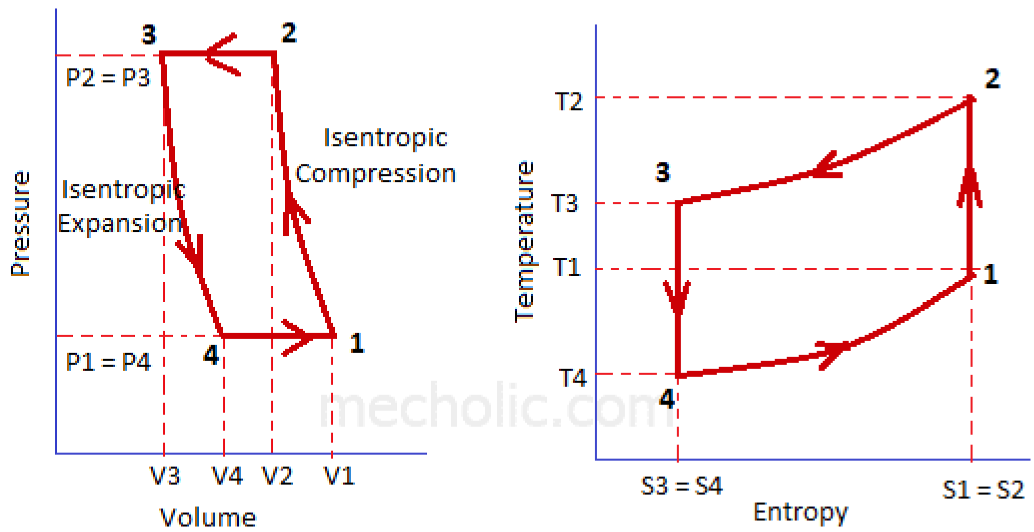
Open System	Closed System
Air is directly led to the space to be cooled.	Dense air passed through pipes all the time.
Since air is supplied to the refrigerator at atmospheric pressure, the volume of air handled by the compressor is large.	Suction pressure is higher than atmospheric pressure volume of air is to be handled by the compressor.
Moisture leads to the formation of frost at the end of expansion thus drier is used.	Pressure ratio can be reduced which results in higher

Air Refrigerator Working On Bell-Coleman Cycle with PV and TS Diagram (Reversed Brayton or Joule Cycle)



The above fig. shows a schematic diagram of Bell-Coleman refrigerator (reverse Brayton or joule cycle). This refrigeration system components consists of a compressor, cooler, Expander, and refrigerator. In this process, heat absorption and rejection follows at the constant pressure; the compression and expansion of process are isentropic.

Different process in Bell-Coleman refrigeration



(a) P-V Diagram (b) T-S Diagram

Fig show P-V and T-S diagram of bell coleman refrigerator. Here P_1, V_1, T_1, S_1 represents the pressure, volume, temperature, entropy of air respectively at point 1. And so on. It represents the corresponding condition of air when it passed through the component.

1-2: Isentropic Compression

The Air drawn from refrigerator to air compressor cylinder where it compressed isentropically (constant entropy). No heat transfer by the air. During compression, the volume decreases while the pressure and temperature of air increases.

2-3: Constant pressure cooling process.

The warm compressed air is then passed through cooler, where it cooled down at constant pressure.

The heat rejected per kg of air during this process is equal to

$q_{2-3} = Cp(T_2-T_3)$

3-4: isentropic expansion

No heat transfer takesplcae. The air expands isentropically in expander cylinder. During expansion, the volume increases, Pressure P3 reduces to P_4. (P_4 = atmospheric pressure). Temperature also falls during expansion from T_3-T_4.

4-1: Constant pressure expansion

Heat transfer from the refrigerator to air. The temperature increases from T_4 to T_1. Volume increases to V_4 due to heat transfer. Heat absorbed by air per kg during this process is equal to

$q_{4-1} = Cp(T_1-T_4)$

Equation of Coefficient of performance (COP) of Bell Coleman cycle

Heat absorbed during cycle per kg of air $q_{4-1} = Cp(T_1 - T_4)$
Heat rejected during cycle per kg of air $q_{2-3} = Cp(T_2 - T_3)$
Then the work done per kg of air during the cycle is = Heat rejected – Heat absorbed
$= Cp(T_2 - T_3) - Cp(T_1 - T_4)$
Coefficient of performance;

$$\text{C.O.P.} = \frac{\text{Heat absorbed}}{\text{Work done}} = \frac{C_p(T_1 - T_4)}{C_p(T_2 - T_3) - C_p(T_1 - T_4)}$$

$$= \frac{(T_1 - T_4)}{(T_2 - T_3) - (T_1 - T_4)}$$

$$C.O.P. = \frac{T_4\left(\frac{T_1}{T_4} - 1\right)}{T_3\left(\frac{T_2}{T_3} - 1\right) - T_4\left(\frac{T_1}{T_4} - 1\right)} \qquad \text{(i)}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \qquad \text{(ii)}$$

For isentropic expansion process 3-4

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \qquad \text{(iii)}$$

Since, P2 = P3 and P1 = P4, therefore from equation (ii) and (iii)

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} \quad or \quad \frac{T_2}{T_3} = \frac{T_1}{T_4} \qquad \text{(iv)}$$

Substitute equation (iv) in (i)

$$C.O.P. = \frac{T_4}{T_3 - T_4} = \frac{1}{\frac{T_3}{T_4} - 1}$$

$$= \frac{1}{\left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} - 1} = \frac{1}{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1}$$

$$C.O.P. = \frac{1}{\left(r_p\right)^{\frac{\gamma-1}{\gamma}} - 1}$$

$$r_p = Compression\ or Expansion\ ratio = \frac{P_2}{P_1} = \frac{P_3}{P_4}$$

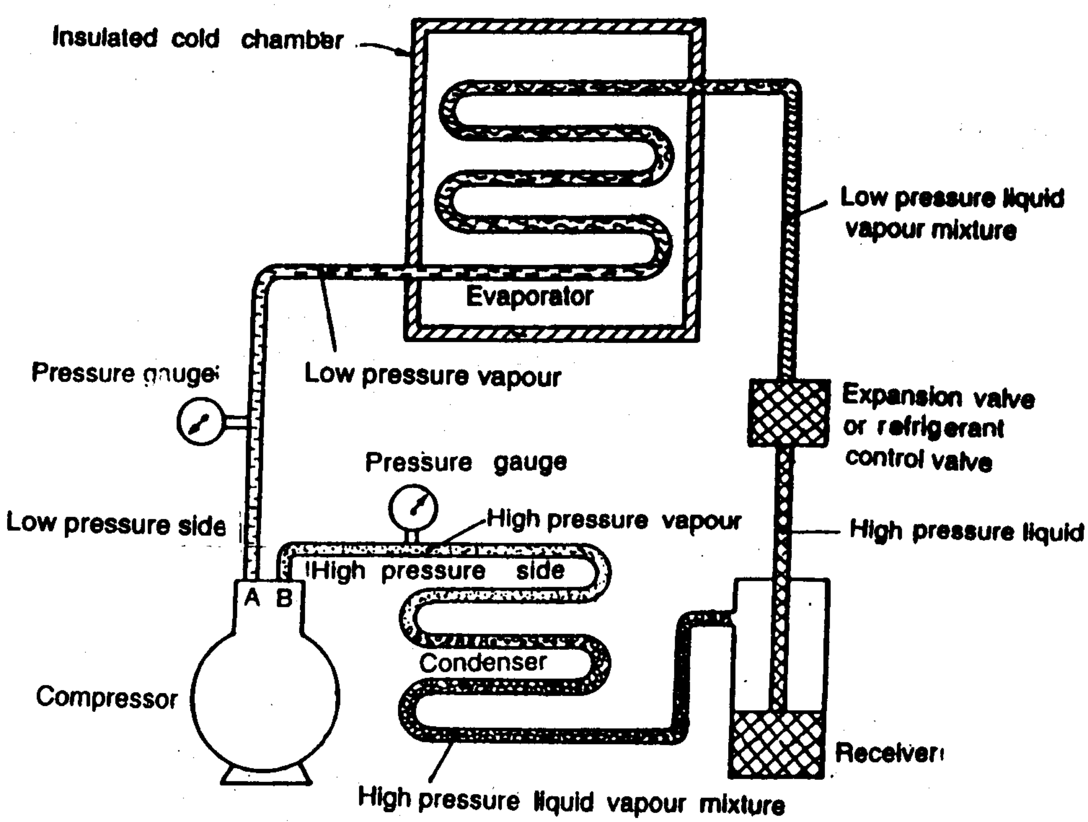
SIMPLE VAPOUR COMPRESSION REFRIGERATION SYSTEM

The simple vapor compression system can be explain as the heat engine which is works in reverse technically that can be known as Reverse Carnot engine. The simple vapor compression cycle transfer heat from lower temperature reservoir to higher temperature reservoir.

working fluid is a vapour. It readily evaporates and condenses or changes **It** is the most widely used refrigeration system. In this system, the alternatively between the vapor and liquid phase without leaving the refrigerating plant.

COMPONENTS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

1. Compressor
2. Condenser
3. Receiver
4. Expansion Valve
5. Evaporator



The detailed explanation of the above parts is as follows.

1. Compressor:

The vapour at low pressure and low temperature enters the compressor from the evaporator where it is compressed to high pressure and high temperature.

This high pressure and temperature vapour refrigerant are discharged into the condenser through the discharge valve.

2. Condenser:

The condenser or cooler consists of coils of pipe in which the high pressure and temperature vapour refrigerant are cooled and condensed.

The refrigerant while passing through the condenser gives up its latent heat to the surroundings condensing medium which is normally air or water.

3. Receiver:

The condensed liquid refrigerant from the condenser is stored in a vessel known as a receiver from where it is supplied to the evaporator through the expansion valve.

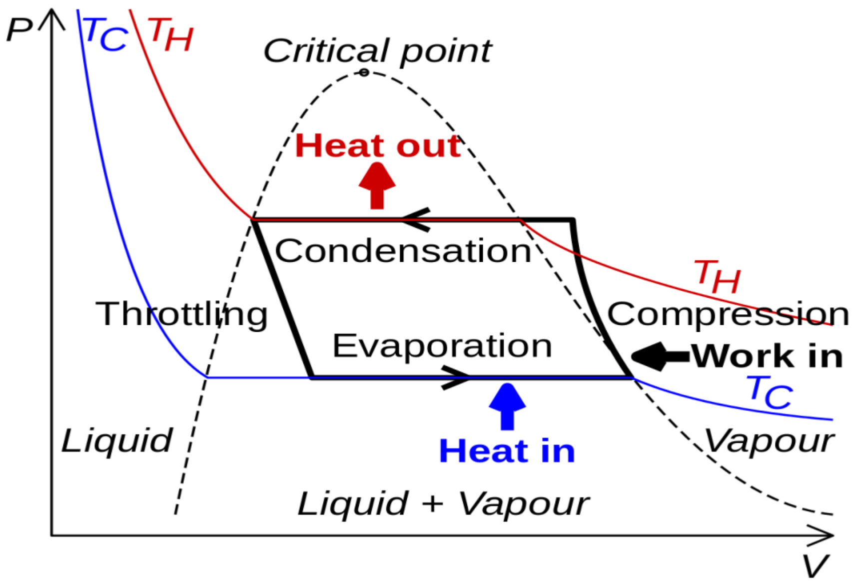
4. Expansion Valve:

It is also called a throttle valve. Its function is to allow the liquid refrigerant under high pressure and temperature to pass through it where it reduces its temperature and pressure.

5. Evaporator:

It also consists of coils of pipe in which liquid-vapour refrigerant at low pressure and temperature is evaporated and converted into vapour refrigerant at low pressure and temperature.

VAPOUR COMPRESSION REFRIGERATION CYCLE



The Vapor compression cycle process is proceeding in four steps. They are listed below

1. **Compression**
2. **Condensation**
3. **Throttling**
4. **Evaporation**

Compression (Reversible adiabatic compression):

The refrigerant of vapor compression cycle at low temperature and pressure stretched from evaporator to compressor where the refrigerant is compressed isentropically. The pressure is rises from p_1 to p_2 and temperature is rises from T_1 to T_2. The total work done per kg of refrigerant happened during isentropic compression can be express as,

$$w = h_2 - h_1$$

Where,

h_1 = Amount of enthalpy of vapor compression cycle in temperature T_1, at the step of suction of compressor

h_2 = Amount of enthalpy of vapor compression cycle in temperature T_2, at the step of discharge of compressor

Condensation (Constant pressure heat rejection):

The refrigerant of vapor compression cycle is passes through from **compressor to condenser** at high temperature and pressure. At constant pressure and temperature the refrigerant is completely condensed. The refrigerant changes its state from vapor to liquid

Throttling (Reversible adiabatic expansion):

At high temperature and high pressure the refrigerant of vapor compression cycle is expanded through the process of throttling. That time the expansion valve is stays in low temperature and pressure. A little amount of liquid refrigerant is evaporating by the help of expansion valve and a huge amount of liquid refrigerant is vaporised by the help of evaporator.

Evaporation (Constant pressure heat addition):

The refrigerant mixture of vapor and liquid is completely evaporated and changed itself into vapor refrigerant. During this evaporation process the refrigerant is absorb latent heat which state is cool. The amount of **latent heat absorption by the refrigerant in vapor cycle is known as Refrigerating effect**

Performance of vapour compression cycle in the refrigeration system:

The vapour compression cycle in the refrigeration system is working at evaporator in the law of Steady Flow Energy Equation,

$h_4 + Q_e = h_1 + 0$

$Q_e = h_1 - h_4$

The vapour compression cycle in the refrigeration system is working at condenser in the law of Steady Flow Energy Equation,

$h_2 + Q_c = h_3 + 0$

$Q_c = h_3 - h_2$

The vapour compression cycle in the refrigeration system is working at expansion valve in the law of Steady Flow Energy Equation,

$h_3 + Q = h_4 + W$

We know, value of Q and W is 0

So, we can write

$h_3 = h_4$

COP=RE/Work done

So **COP=$h_1 - h_4/h_2 - h_1$**

Advantages of Vapor Compression refrigeration cycle

1. Coefficient of performance is too high.
2. Size is not too big for this reason installation is easy.
3. Running cost is low.
4. Temperature can be easily handled by the help of regulating expansion valve.
5. Evaporator size is not big.

Disadvantages of Vapor Compression refrigeration cycle

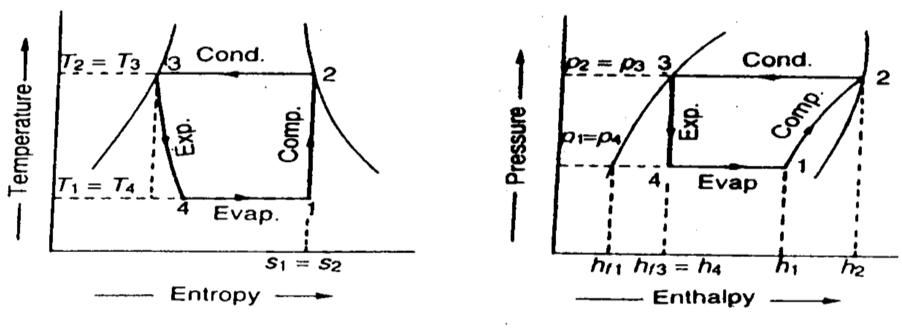
1. The refrigerants which are used they are toxic.
2. Initial cost is high.
3. Leakage is present.

TYPES OF VAPOR COMPRESSION CYCLES

The types of Vapor Compression Cycles which are important from the subject point of view are as follows.

1. Cycle with dry saturated vapor after compression
2. Cycle with wet vapor after compression
3. Cycle with superheated vapor after compression
4. Cycle with superheated vapor before compression
5. Cycle with under cooling or subcooling of the refrigerant

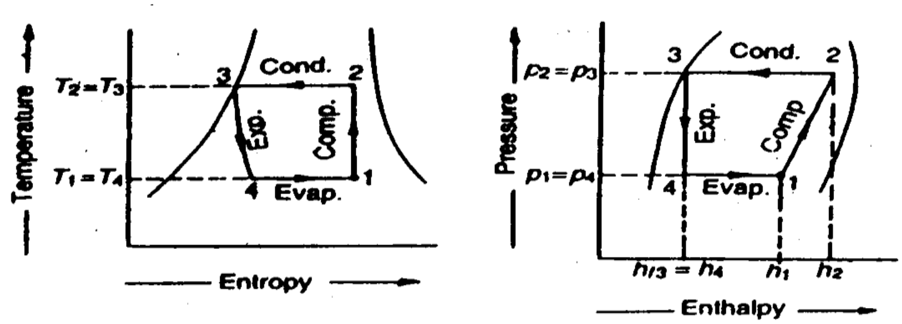
CYCLE WITH DRY SATURATED VAPOR AFTER COMPRESSION



(a) T-s diagram. (b) p-h diagram.

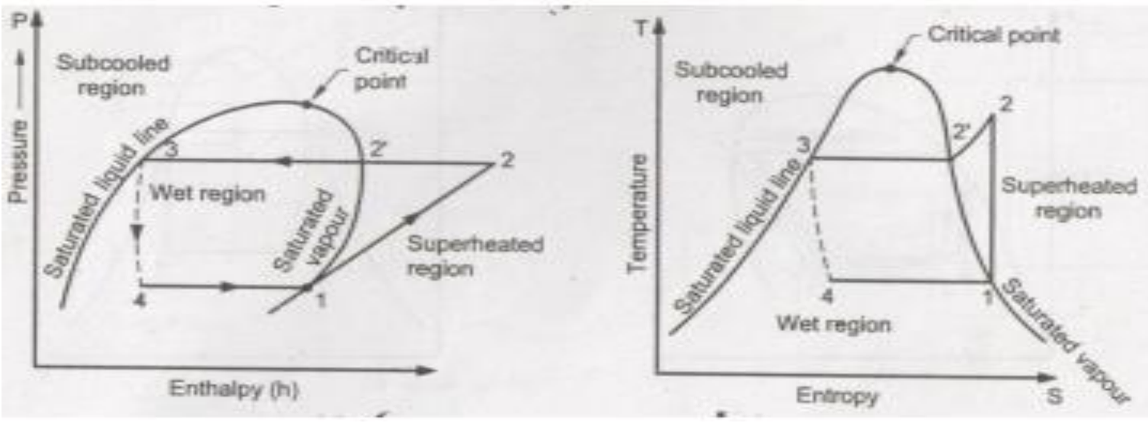
COP of the cycle= **$h_1 - h_4 / h_2 - h_1$**

CYCLE WITH WET VAPOR AFTER COMPRESSION

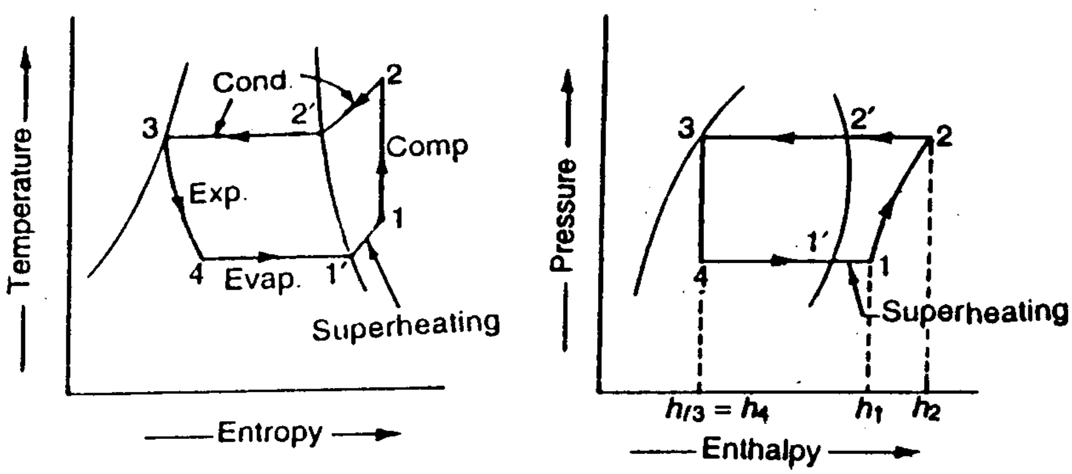


(a) T-s diagram. (b) p-h diagram.

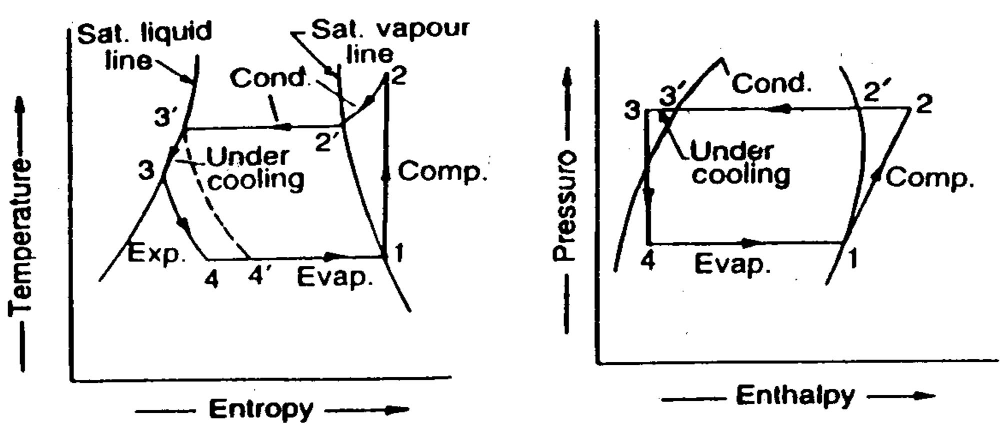
CYCLE WITH SUPERHEATED VAPOR AFTER COMPRESSION



CYCLE WITH SUPERHEATED VAPOR BEFORE COMPRESSION



CYCLE WITH UNDER COOLING OR SUBCOOLING OF THE REFRIGERANT



VAPOUR ABSORPTION REFRIGERATION SYSTEM

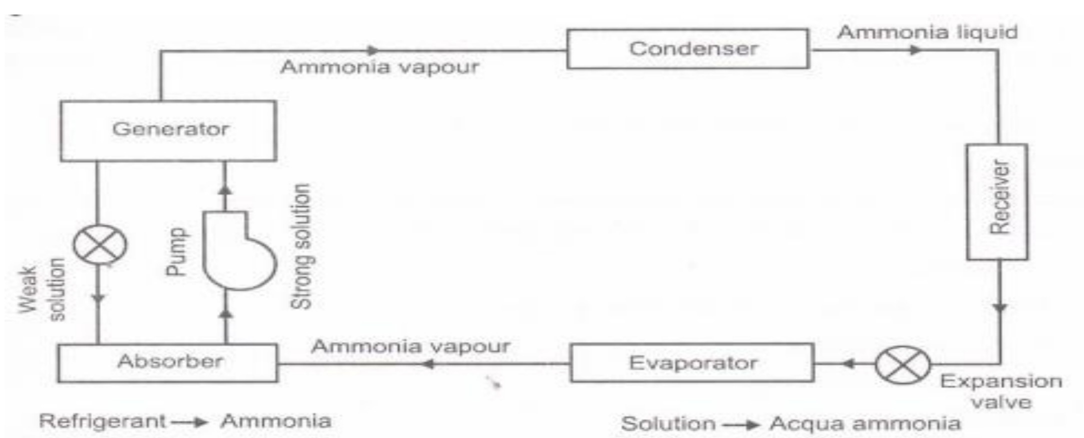
Vapour absorption refrigeration is quite similar to the Vapour compression refrigeration (VCR) system as it replaces the compressor in VCR with the absorber, pump and generator.
A vapour absorption refrigeration system (VARS) is a kind of refrigeration in which after evaporation the vapours of refrigerant are absorbed in an absorber solution. This kind of refrigeration is used in bigger plants to handle larger refrigeration loads. In such plants, the generator is run with the help of waste heat from the boilers, turbine exhaust steam, waste heat from D.G., etc. Sometimes it also uses solar energy for the generator.

SIMPLE VAPOUR ABSORPTION REFRIGERATION SYSTEM

The simple VARS system consists of the following components:

Absorber, Pump, Generator, Pressure relief valve, Condenser, Expansion device, and Evaporator.

.The VARS refrigeration system uses two working fluids for refrigeration i.e. refrigerant and absorbent. In the NH3–H2O refrigeration system, ammonia is used as a refrigerant while the water is used as an absorbent. In H2O–LiBr, VARS refrigeration water is used as a refrigerant while the LiBr is used as an absorbent



A) ABSORBER:-

The purpose of the absorber is to absorb the low-pressure refrigerant vapours in the solution of the refrigerant and absorbent.

The weaker solution from the generator and the low-pressure refrigerant vapours from the evaporator enters the absorber. Here the refrigerant vapours are absorbed to form a stronger solution.

During the absorption, the vapours of the refrigerant lose the latent heat to change their phase from vapour to liquid. Thus it raises the temperature inside the absorber which can lower the absorption capacity of the absorbent. To avoid this, the solution is cooled with the help of cooling water.

B) PUMP:- It is used to suck the strong solution from the absorber & deliver it to the generator at higher pressure.

C) GENERATOR:- It is used to heat the strong solution by use of heating coils, solar energy or waste heat. As the refrigerant has a lower boiling point than the absorbent, the refrigerant inside the solution gets vapourised leaving the solution weaker.

If this weak solution goes to the condenser, it may damage the system. Hence the weak solution from the generator returns to the absorber through pressure reducing valve (PRV).

D) CONDENSER:- The high-pressure refrigerant vapours from the generator enter the condenser. The condenser has a cooling medium to cool the hot vapours of the refrigerant. Here the refrigerant vapours get converted into the high-pressure saturated liquid refrigerant.

E) PRESSURE REDUCING VALVE (PRV):- The pressure-reducing valve is connected between the generator (works at high pressure) and absorber (works at low pressure). It lowers the pressure of weak solution coming from the generator and then it is passed to the absorber.

F) Expansion valve:- Expansion valve is located between the condenser & evaporator. After the condenser, the high-pressure liquid refrigerant enters the expansion valve. Here the high-pressure liquid refrigerant is converted into a mixture of low-pressure refrigerant (liquid + vapour).

G) Evaporator:- The evaporator is located in the enclosed space where cooling is carried out. In the evaporator, the low-pressure liquid refrigerant absorbs the heat in the enclosed space to provide a cooling effect. due to the absorption of heat, the liquid refrigerant gets converted into low-pressure refrigerant vapours.

PRACTICAL VAPOUR ABSORPTION REFRIGERATION SYSTEM

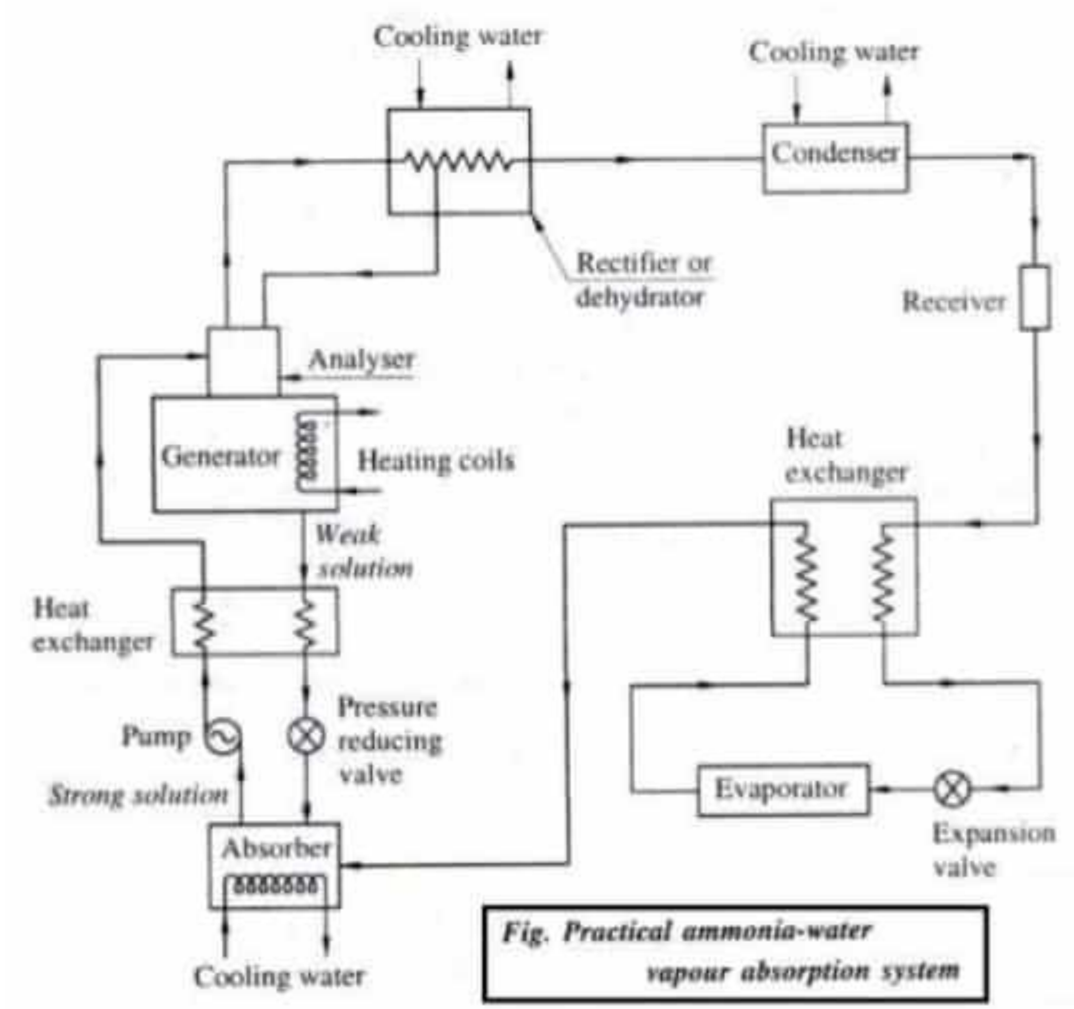


Fig. Practical ammonia-water vapour absorption system

Construction

- The vapour absorption system consists of a condenser, an expansion valve and an evaporator.
- They perform the same as they do in vapour compression method.
- In addition to these, this system has an absorber, a heat exchanger, an analyser and a rectifier.

Working

1. Dry ammonia vapour at low pressure passes in to the absorber from the evaporator.
2. In the absorber the dry ammonia vapour is dissolved in cold water and strong solution of ammonia is formed.
3. Heat evolved during the absorption of ammonia is removed by circulating cold water through the coils kept in the absorber.
4. The highly concentrated ammonia (known as Aqua Ammonia) is then pumped by a pump to generator through a heat exchanger.
5. In the heat exchanger the strong ammonia solution is heated by the hot weak solution returning from the generator to the absorber.
6. In the generator the warm solution is further heated by steam coils, gas or electricity and the ammonia vapour is driven out of solution.
7. The boiling point of ammonia is less than that of water.
8. Hence the vapours leaving the generator are mainly of ammonia.
9. The weak ammonia solution is left in the generator is called weak aqua.
10. This weak solution is returned to the absorber through the heat exchanger.
11. Ammonia vapours leaving the generator may contain some water vapour.
12. If this water vapour is allowed to the condenser and expansion valve, it may freeze resulting in chocked flow.
13. Analyser and rectifiers are incorporated in the system before condenser.
14. The ammonia vapour from the generator passes through a series of

trays in the analyser and ammonia is separated from water vapour.
15. The separated water vapour returned to generator.
16. Then the ammonia vapour passes through a rectifier.
17. The rectifier resembles a condenser and water vapour still present in ammonia vapour condenses and the condensate is returned to analyser.
18. The virtually pure ammonia vapour then passes through the condenser.
19. The latent heat of ammonia vapour is rejected to the cooling water circulated through the condenser and the ammonia vapour is condensed to liquid ammonia.
20. The high pressure liquid ammonia is throttled by an expansion valve or throttle valve.
21. This reduces the high temperature of the liquid ammonia to a low value and liquid ammonia partly evaporates.
22. Then this is led to the evaporator.
23. In the evaporator the liquid fully vaporizes.
24. The latent heat of evaporation is obtained from the brine or other body which is being cooled.
25. The low pressure ammonia vapour leaving the evaporator again enters the absorber and the cycle is completed.
26. This cycle is repeated again to provide the refrigerating effect.

Refrigerant Compressors

The compressor is referred to as the heart of mechanical refrigeration systems. The compressor is used to compress the vapour refrigerant coming from the evaporator and to raise its pressure and temperature more than that of the cooling medium. It also continuously circulates the refrigerant through the refrigerating system. Since the compression of refrigerant requires some work to be done on it, therefore a compressor must be driven by some prime-mover.

Necessity of compressor in a vapour compression system

It is that part in a vapour compression system which sucks the refrigerant vapours at low temperature and low pressure and compresses it into a lower volume at higher temperature and pressure and also it creates the flow of refrigerant from one part to other. The pressure difference between high and low side makes the refrigerant goes forcibly into cooling coil through refrigerant flow controls. Therefore the main job of compressor is to keep the difference in pressure at high side and low side of refrigeration system

Classification of compressor

The compressors may be classified in many ways, but the following are important from the subject point of view.

- According to the method of compressor
  - Reciprocating compressors
  - Rotary compressors
  - Centrifugal compressor
- According to the number of working strokes
  - Single acting compressor
  - Double acting compressors
- According to the number of stages
  - Single stage compressors
  - Multi stage compressor
- According to the method of drive employed
  - Direct drive compressor
  - Belt drive compressor
- According to the location of the prime movers

- Semi hermetic compressor (direct rive motor and compressor in separate housings)
- Hermetic compressors (Direct drive motor and compressor in same housing

Three main groups of compressor,

- Reciprocating compressor
- Rotary compressor
- Centrifugal compressor

Reciprocating compressors

Reciprocating compressors are those in which piston moves in a cylinder in reciprocating motion with the help of connecting rod, crank shaft etc. to compress the refrigerant.

The functions of reciprocating compressor in vapor compression refrigeration system are as follows.

* It sucks and discharge the refrigerant

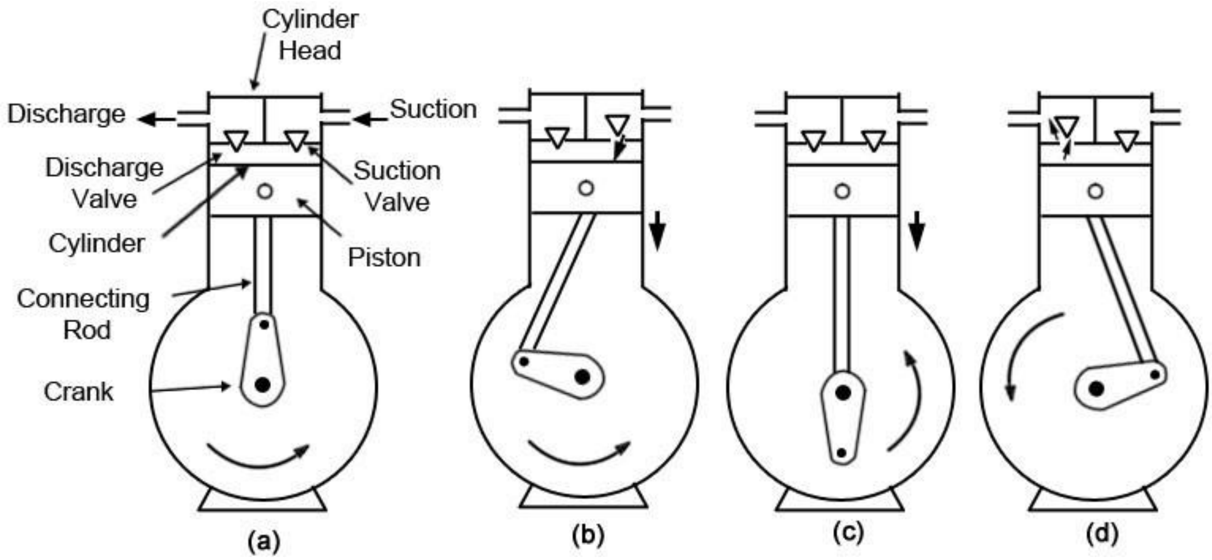
* It compresses the low temperature and low pressures vapor into high temperature and high pressure vapor.

* It creates the flow of refrigerant.

Reciprocating compressors are used for refrigerants which have comparatively low volume per kg and a large differential pressure, such as R717, R12,R22 and R-40. The reciprocating compressors are available in sizes from 1/12kw which are used in small domestic refrigerators and up to about 150kw for large capacity installations.

The two types of reciprocating compressor in general use are single acting vertical compressors and double acting compressors. The single acting compressors usually have their cylinders arranged vertically, radially or in a V or w form. The double acting compressors have their cylinders arranged horizontally.

Working principle of Reciprocating compressor



Let us consider that the piston is at the top of its stroke fig (a). This is called top dead centre position of the piston. In this position the suction valve is held closed because of the pressure in the clearance space between the top of the piston and the cylinder head. The discharge valve is also held closed because of the cylinder head pressure acting on the top of it.

When the piston moves down word (i.e during suction stroke) as shown in Fig (b) the refrigerant left in the clearance space expands. Thus the volume of the cylinder increases and the pressure inside the cylinder decreases. When the pressure becomes slightly less than the suction pressure or atmosphere pressure, the suction valve gets opened and the vapour refrigerant flows into the cylinder. This flow continues until the piston reaches the bottom of its stroke (i.e. Bottom Dead Centre). At the bottom of the stroke, as shown in Fig (c), the suction valve closes because of spring action. Now when the piston moves upward (i.e, during compression stroke) as shown in fig (d), the volume of the cylinder decrease and the pressure inside the cylinder increases. When the pressure inside the cylinder becomes greater than that on the top of the discharge valve, the discharged valve gets opened and the vapour refrigerant is discharged into the condenser and the cycle is repeated.

Different parts of the Reciprocating compressorPiston

The piston is made of cast-iron and is mechanically well polished. It has a drilled hole to fit the piston or wrist pin. This pin is fitted for joining the connecting rod to the piston. Piston it fitted with close tolerance in cylinder. The function of the piston is only to compress the refrigerant in an enclosed cylinder.

Piston rings

Piston rings are made of cast-iron which are fitted on pistons but some piston rings are made of bronze metal also. This metal works for long time and not rubbed. These rings are installed in grooves on the piston. Generally piston has two or more rings. The main function of the piston ring is to maintain the proper lubrication and to prevent the gas from escaping between the piston wall and cylinder wall.

Crank shaft

Crank shaft is a moving lever. It is used for inducing the torque. When it is used with the connecting rod it moves with the reciprocating motion. Crank shafts are made of carbon steel, cast steel or nickel chromium steel. Crank shafts are equipped with counter weights and are carefully balanced to ensure smooth and vibration less compressor operation. This counter weight is made of cast-iron.

Connecting rod

Connecting rod is used for connecting the piston and crank shaft. One end is connected to the piston by means of hardened, ground and highly polished steel wrist pin. It is made of cast steel or cast-iron. The wrist pin upper end of the connecting rod have an oscillating or reciprocating motion while the lower end of the connecting rod combines a reciprocating and rotary motion.

Rings

There are two types of rings i.e, compression rings and oil scrapper rings. The compression ring is provided on the top of the piston and is used to seal the difference between the piston and the cylinder wall. The oil scraper ring is provided below the piston.

Suction and discharge valve

The valve that controls the flow of refrigerant from the suction line into cylinder head is known as suction valve. The valve that discharges the compressed gas towards the discharged line is called discharged valve. These valves are named according to the function they perform.

Important terms used in reciprocating compressor

B.D.C

When the piston reaches at the bottom of the cylinder of compressor is called Bottom Dead Center.

T.D.C

When the piston reaches at he top of the cylinder of compressor is called Top Dead Centre.

Piston stroke

The distance covered by the piston from B.D.C to T.D.C or T.D.C to B.D.C is called piston stroke.

Suction stroke

when the piston moves from T.D.C to B.D.C and sucks gas through the suction valve then it is called suction stroke.

Compression stroke

when the piston moves from B.D.C to T.D.C and compresses and discharges the gas through the discharge valve then it is called compression stroke.

Piston displacement volume

Total cylinder volume swept by the piston in any certain time is called piston displacement volume. It is expressed in cubic meter per minute

Compression ratio

compressor ratio is the ratio of absolute discharge pressure or head pressure to the absolute suction Pressure.

Volumetric efficiency

It is the ratio of actual weight of refrigerant in a cylinder to the weight that the cylinder can theoretically hold.

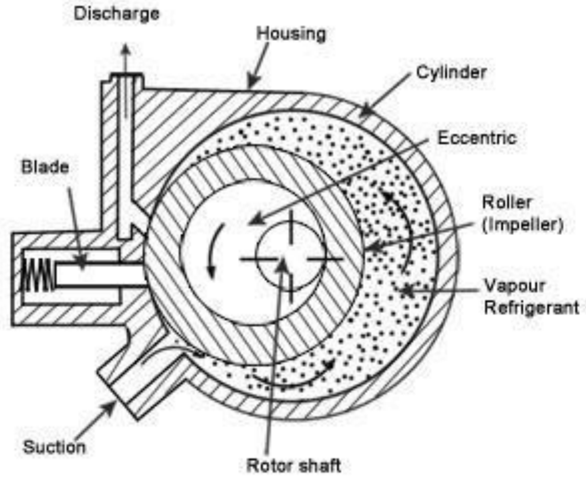
Rotary Compressors

In rotary compressors, the vapour refrigerant from the evaporator is compressed due to the movement of blades. The rotary compressors are positive displacement type compressors. Since the clearance in rotary compressors is negligible, therefore they have high volumetric efficiency. These compressors may be used with refrigerants R-12, R-22, R-114 and ammonia. These rotary compressors may be divided roughly into two types .In the first type one or more stationary blades are used for sealing the suction from the dicharge gases. The second type uses sealing blades which rotate with the shaft.

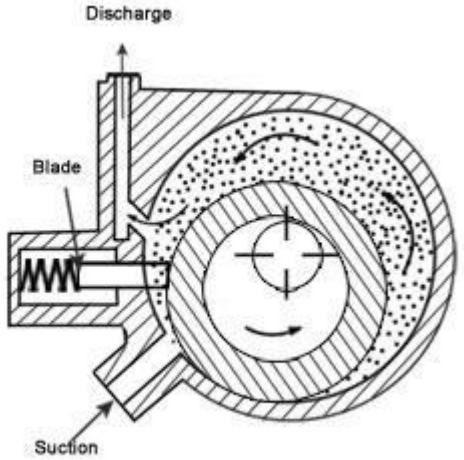
Single stationary blade type rotary compressor

A single stationary blade type rotary compressor is shown in figure. This consists of a stationary cylinder, a roller (or impeller) and a shaft has an eccentric on which the roller is mounted. A blade is set into the slot of a cylinder in such a manner that it always maintains contacts with the roller by means of a spring. The blade moves in and out of the slot to follow the rotor when it rotates. Since the blade separates the suction and discharge ports as shown in figure, therefore it is often called a sealing blade. When the shaft rotates, the roller also rotates so that it always touches the cylinder wall.

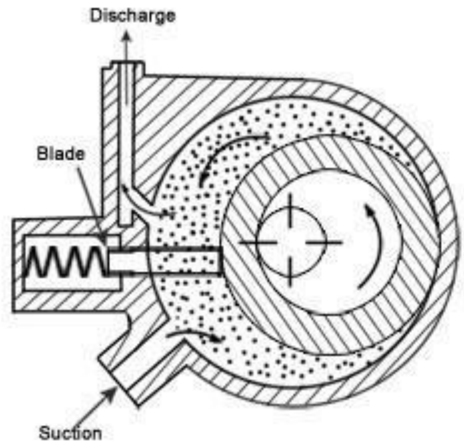
In figure (a) to (d) shows the various positions of roller as the vapour refrigerant is compressed. Figure (a) shows the completion of intake stroke (i.e. the cylinder is full of low pressure and temperature vapour refrigerant) and the beginning of compression stroke. When the roller rotates, the vapour refrigerant ahead of the roller is being compressed and the new intake from the evaporator is drawn into the cylinder, as shown in figure (b). As the roller turns mid position as shown in figure, more vapour refrigerant is drawn into the cylinder while the compressed refrigerant is discharged to the condenser. At the end of compression stroke as shown in figure (d), most of the compressed vapour refrigerant is passed through the discharge port to the condenser. A new charge of refrigerant is drawn into the cylinder. This, in turn is compressed and discharged to the condenser. In this way, the low pressure and temperature refrigerant is compressed gradually to a high pressure and temperature.



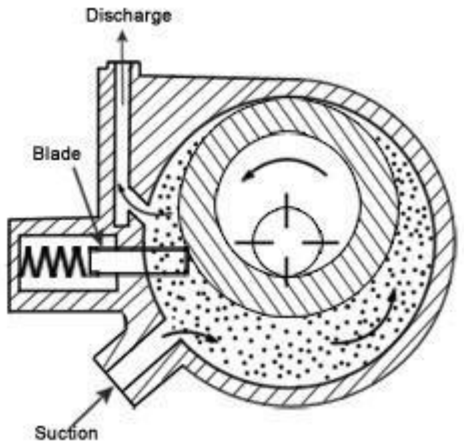
(a) Completion of intake stroke and beginning of compression



(b) Compression stroke continued and new intake stroke started



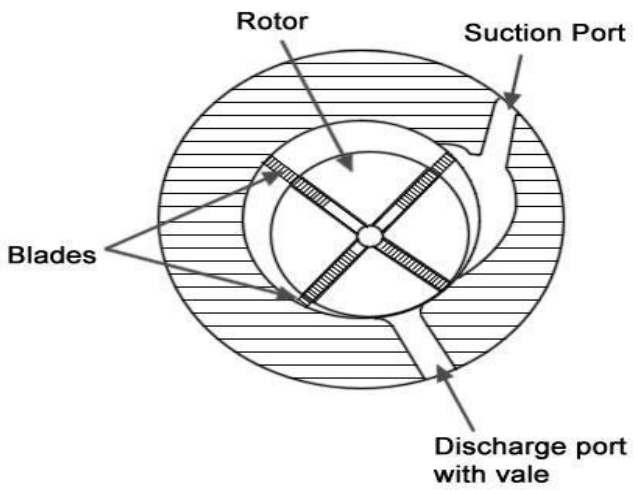
(c) Compression continued and new intake stroke continued



(d) Compressor vapour discharged to condensor and new intake stroke continued

Rotating blade type rotary compressor

The rotating blade type rotary compressor is shown in Fig.This compressor consists of a cylinder and a slotted rotor containing a number of blades. The centre of the rotor is eccentric with the centre of the cylinder. The blades are forced against the cylinder wall by the centrifugal action during the rotation of the motor.

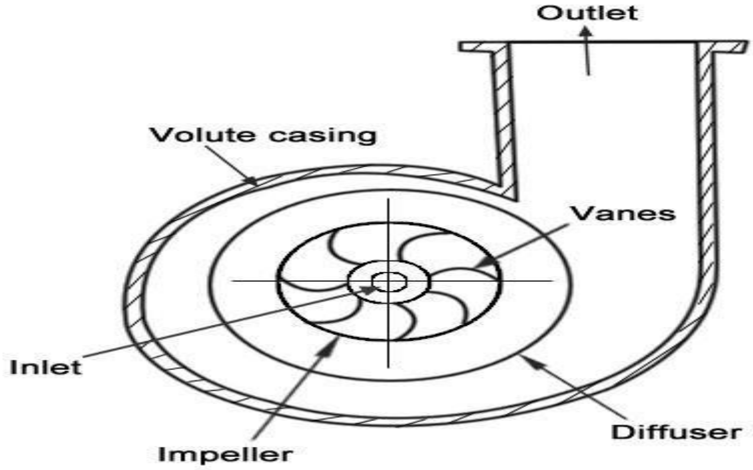


Rotating Blade type rotary Compressor

Centrifugal Compressors

Working principle

The centrifugal compressor for refrigeration systems was designed and developed by Dr. Willis H. Carrier in 1922. This compressor increases the pressure of low pressure vapour refrigerant to a high pressure vapour refrigerant by means of centrifugal force. The centrifugal compressor is generally used for refrigerant that require large displacement and low condensing pressure, such as R-Il and R-l13. However, the refrigerant R-12 is also employed for large capacity applications and low-temperature applications.



Centrifugal compressor

A single stage centrifugal compressor, in its simplest form, consists of an impeller to which a number of curved vanes are fitted symmetrically, as shown in Fig. The impeller rotates in an air tight volute casing with inlet and outlet points The impeller draws in low pressure vapour refrigerant from the evaporator. When the impeller rotates, it pushes the vapour refrigerant from the centre of the impeller to its periphery by centrifugal force. The high speed of the impeller leaves vapour refrigerant at a high velocity at the vane tips of the impeller. The kinetic energy thus attained at the impeller outlet is converted into pressure energy when the high velocity vapour refrigerant passes over the diffuser. The diffuser is normally a vaneless type as it permits more efficient part load operation which is quite usual in any air-conditioning plant. The volute casing collects the refrigerant from the diffuser and it further converts the kinetic energy into pressure energy before it leaves the refrigerant to the evaporator.

Note :

- In case of a single stage centrifugal compressor. The compression ratio that an impeller can develop is limited to about 4.5. But when high compression ratio is desired, multi-stage centrifugal compressors with inter coolers are employed.
- The centrifugal compressors have no valves, pistons and cylinders. The only wearing parts are the main bearings

Advantages and disadvantages of Centrifugal Compressors

Advantages

- Since the centrifugal compressors have no valves, pistons, cylinders, connecting rod, etc., therefore the working life of these compressors is more as compared to Reciprocating compressors.
- These compressors operate with little or no vibration as there are no unbalanced masses.
- The operation of centrifugal compressors is quiet and calm.
- The centrifugal compressors run at high speeds (3000 r.p.m. and above), therefore these can be directly connected to electric motors or steam turbines.
- Because of the high speed, these compressors can handle large volume of vapour refrigerant, as compared to reciprocating compressors.
- The centrifugal compressors are especially adapted for systems ranging from 50 to 5000 tonnes. They are also used for temperature ranges between - 90°C and + 10°C.
- The efficiency of these compressors is considerably high.
- The large sizes centrifugal compressors require less floor area as compared to reciprocating compressors.

Disadvantages

- The main disadvantage in centrifugal compressors is *surging. It occurs when the refrigeration load decreases to below 35 percent of the rated capacity and causes severe stress conditions in the compressor.
- The increase in pressure per stage is less as compared to reciprocating compressors.
- The centrifugal compressors are practical below 50 tonnes capacity load.
- The refrigerants used with these compressors should have high specific volume.

Condensors

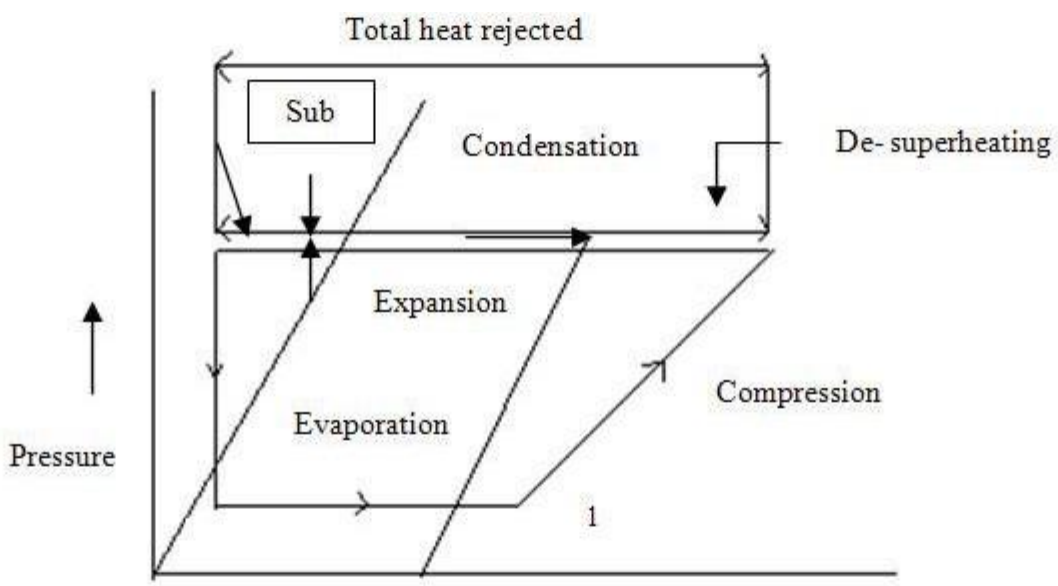
The condenser is an important device used in the high pressure side of a refrigeration system. Its main function is to transfer heat from the refrigeration system to condensing medium. The hot vapour refrigerant consists of the heat absorbed in the evaporator and the heat of compression added by the mechanical energy of the compressor. The heat from the hot vapour refrigerant in a condenser is removed first by transferring it to the walls of the condenser tubes and then from the tubes to the condensing or cooling medium. The cooling medium may be air or water or a combination of the two. The selection of a condenser depends upon the capacity of the refrigerating system, the type of refrigerant used and the types of cooling medium available.

Working of condenser

The compressor drawn in the superheated vapour refrigerant that contains the heat it absorbed in the evaporator and the compressor which adds more heat (i.e. the heat of compression) to the superheat vapour. This highly superheated vapour from the compressor is pumped to the condenser through the discharge line.

The condenser cools the refrigerant in the following three stages.

- First of all superheated vapour is cooled to saturation temperature to the pressure of the refrigerant



- Now the saturated vapour refrigerant gives up its latent heat and is condensed to a saturated liquid refrigerant. This process is called condensation.
- The temperature of the liquid refrigerant is reduced below its saturation temperature (i.e. sub cooled) in order to increase the refrigeration effect.

Factors Affecting the Condenser Capacity

The condenser capacity is the ability of the condenser to transfer heat from the hot vapour refrigerant to the condensing medium. The heat transfer capacity of a condenser depends upon the following factor.

Material

Different materials have different abilities of heat transfer, therefore the size of a condenser of a given capacity can be varied by selecting the right material. It may be noted that higher the ability of a material to transfer heat, the smaller will be the size of condenser.

Amount of contact

The condenser capacity may be varied by controlling the amount of contact between the condenser surface and the condensing medium This can be done by varying the surface area of the condenser and the rate of flow of the condensing medium over the condenser surface. The amount of liquid refrigerant level in the condenser also affects the amount of contact between the vapour refrigerant and the condensing medium.

Temperature Difference

The heat transfer capacity of a condenser greatly depends upon the temperature difference between the condensing medium and the vapour refrigerant. As the temperature difference increases, the heat transfers rate increases and therefore the condenser capacity increases.

Types of the condenser

- Air cooled condenser
- Water cooled condense
- Evaporative condenser

Air-cooled condensers

An air cooled condenser is one in which the removal of heat is done by air. It consists of steel or copper tubing through which the refrigerant flows. The size of tube usually ranges from 6 mm to 18 mm outside diameter depending upon the size of the condenser. Generally copper tubs are used because of its excellent heat transfer ability. The condenser with steel tubes is used in ammonia refrigerating systems.The main disadvantage of an air cooled condenser is that it operates at a higher condensing temperature than a water cooled condenser. The higher condensing temperature causes the compressor to work more

Types of air cooled condenser

- Natural convection air-cooled condenser

In natural convection air-cooled condenser the heat transfer from the condenser coils to the air is by natural convection. As the air comes in contact with the warm condenser tubes, it absorbs heat from the refrigerant and thus the temperature of air increases. The warm air being lighter, rises up and the cold air from below rises to take away the heat from the condenser since the rate of heat transfer in natural convection condenser is slower therefore they require a large surface area as compared to forced convection condensers. The natural convection air cooled condenser are used in small capacity applications such as domestic refrigerators, freezers, water cooler and air-conditioners.

- Forced convection air cooled condenser:

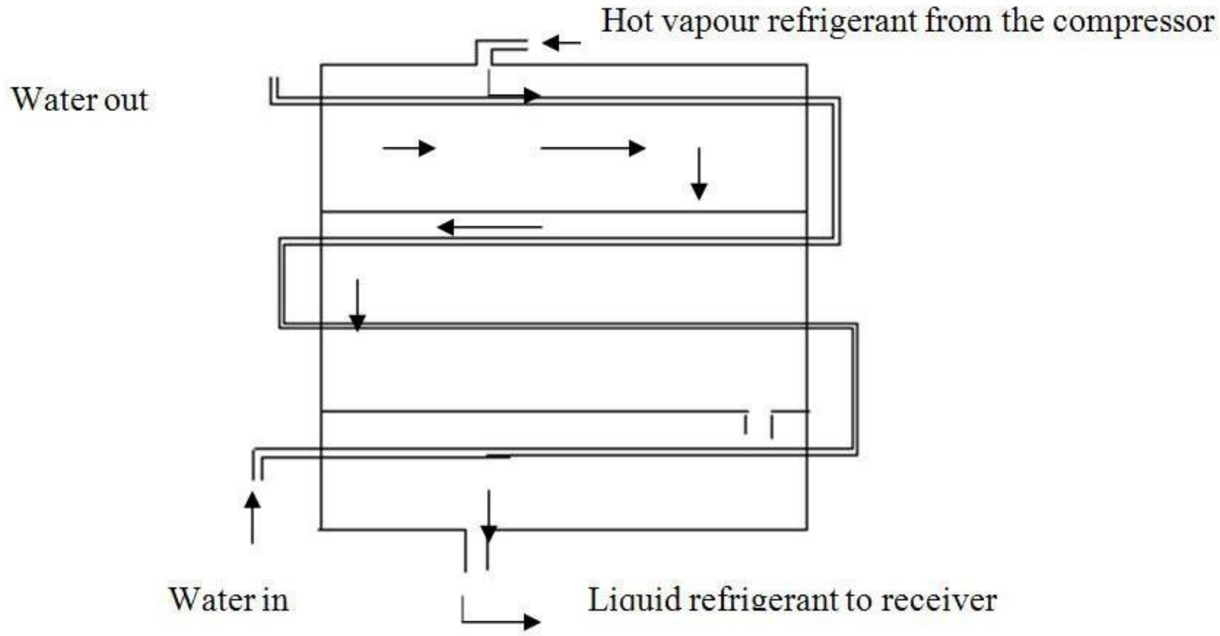
In forced convection air cooled condenser, the fan is used to force the air over the condenser coils to increase the heat transfer capacity.

Water cooled condenser

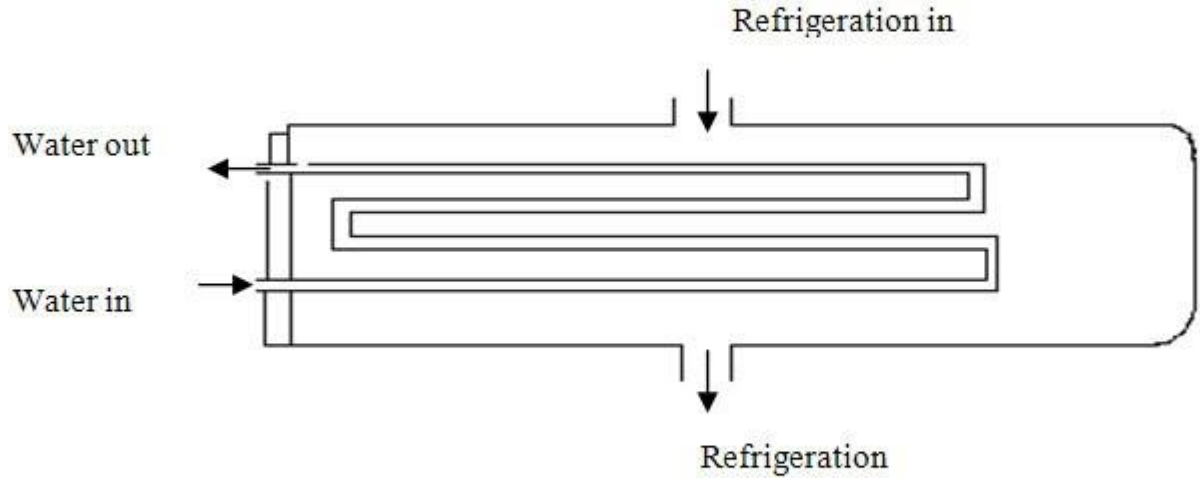
A water cooled condenser is one in which water is used as the condensing medium. They are always preferred where as adequate supply of clear expensive water and means of water disposal are available. These condenser are commonly used in commercial and industrial refrigerating units.

Tubes in tube or double tube condenser

This type of condenser consists of a water tube inside a large refrigerant tube. In this type of condenser the hot vapour refrigerant enters at the top of the condense



The water absorbs the heat from the refrigerant and the condensed liquid refrigerant flows at the bottom since the refrigerant tubes are exposed to ambient air, Therefore some of the heat is also absorbed by ambient air by natural convection. The cold water in the inner tubes may flow in either direction. Opposite to the refrigerant, it is said to be a counter flow system on the other hand, when the water enters at the top and flows in the same direction as the refrigerant, it is said to be parallel flow system.

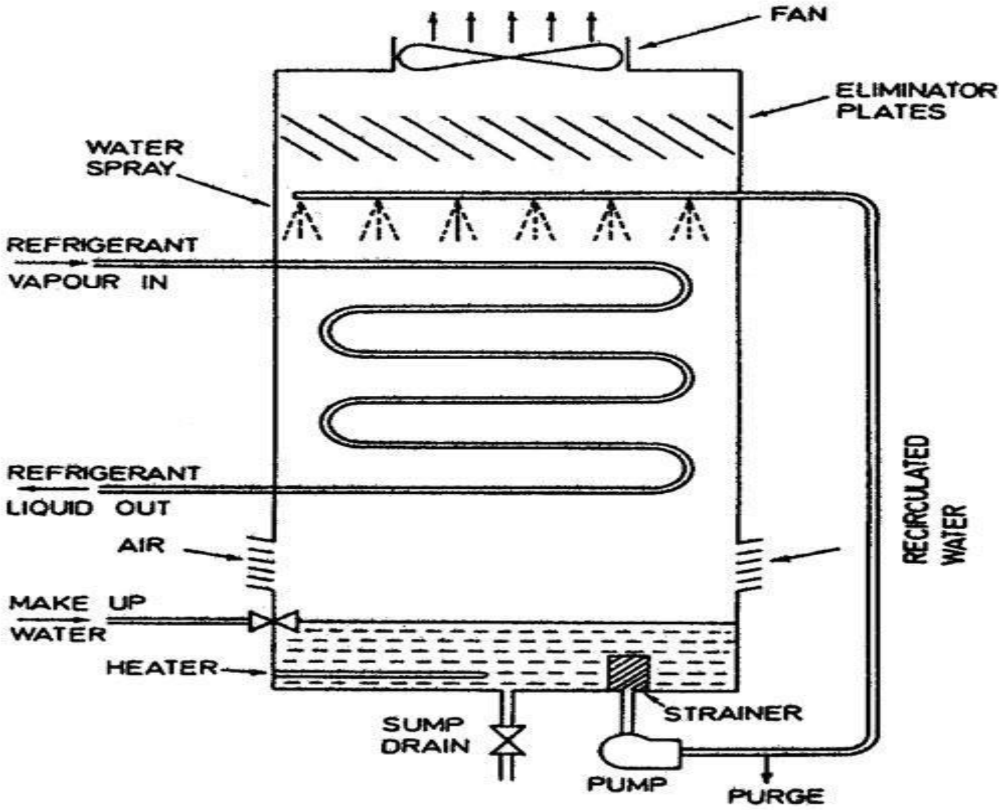


Shell and coil condenser

hell and coil water cooled condensers are widely used in the smaller size up to 10 tones capacity. They have the advantage of being compact in size and serve the dual function of condenser and receiver. As the name implies, a water coil is wound inside a shell. The refrigerant gas within the shell condenses on the outside of the water coils. The liquid refrigerant collects at the bottom of the shell where it is then removed through a bottom outlet.

Evaporative Condenser

The evaporative condenser use both air and water as condensing mediums to condense the hot vapour refrigerant to liquid refrigerant. These condenser combines the effectiveness of forced convection currents with the ability of a vaporizing liquid to absorb heat.



In its operation, the water is pumped from the sump to a spray header and sprayed through nozzles over the condenser coils through which the hot vapour refrigerant from the compressor is passing. The heat transfers from the refrigerant to the condensing tube walls and into the water that is wetting the outside surface of the tubes. At the same time, a fan draws air from the bottom side of the condenser and discharged out at the top of the condenser.The air causes the water from the surface the condenser coils to evaporate and absorb the latent heat of evaporation from the remaining water to cool it. Though most of the cooling takes place by evaporation, the air can also absorb some sensible heat from water. Since the heat for vaporizing the water is taken from the refrigerant therefore the vapour refrigerant condenses in to a liquid refrigerant.
The cold water that drops down into a sump is recirculated. In order to make up the deficiency caused by the evaporated water additional water is supplied to the sump. A float valve in the sump controls the make up supply. The eliminator is provided above the spray header to stop particles of water escaping along with the discharge air.

Comparison between Air cooled and water cooled condensers

s.l no	Air cooled condenser	Water cooled condenser
1	Construction of air cooled condenser is very simple. Therefore the initial cost is low. The maintenance cost is also low	Construction of water cooled condenser is complicated therefore the initial cost is high. The maintenance cost is also high.
2	There is no handling problem with air cooled condenser	The water cooled condenser are difficult to handle
3	The air cooled condenser do not require piping arrangement for carrying the air	The pipes are required to take water to and from the condenser
4	There is no problem in disposing of used air	There is a problem of disposing the used water unless recirculation system is provided.
5	There is no corrosion therefore fouling effect is low	There is a corrosion occurs inside water tubes therefore the fouling effects is high
6	The air cooled condenser have low heat transfer capacity due to low thermalconductivity of air	The water cooled condenser have high heat transfer capacity due to high thermalconductivity of water
7	These condenser are used for low capacity plans (less than STR)	These condenser are used for large capacity plants
8	The distribution of air on condenser surface is not uniform	There is even distribution of water on the condensing surface.

Evaporators

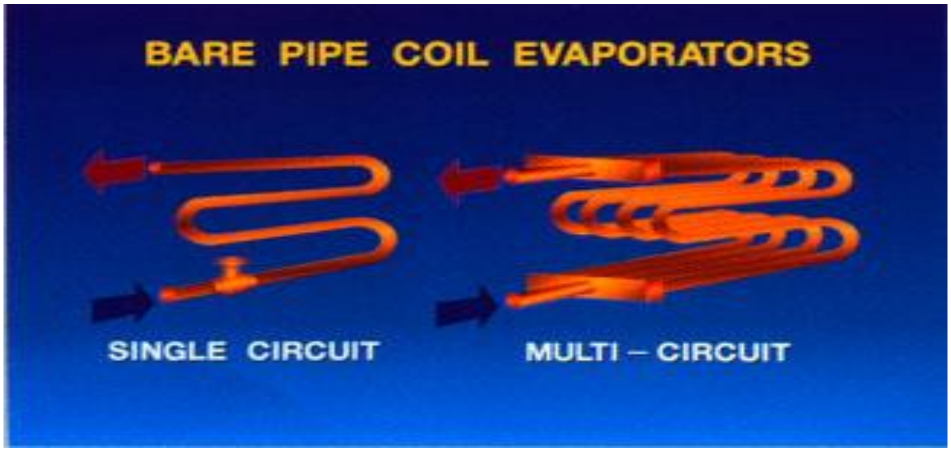
The evaporator's job is to absorb heat, which provides cooling. The type of evaporator depends on what type of appliance it is used in. This makes sense, since the requirements for a refrigeration system would be different than the requirements for an air conditioning system.

All evaporators are made of metals like copper and aluminum because they are **good conductors of heat**. A good conductor allows heat to transfer freely from air outside the coils to the refrigerant inside the coils.

There are four main types of evaporators.

- **Bare Tube** Evaporators,
- **Plate Surface** Evaporators,
- **Finned Tube** Evaporators, and
- **Shell and Tube** Evaporators.

Bare Tube Evaporator



Bare tube evaporators are the simplest type of evaporator. These evaporators are generally just refrigerant tubes that are made of either copper or aluminum.
There is refrigerant inside the refrigerant tube that absorbs heat from the air and vaporizes inside the tube. Heat transfers across the surface area of the metal refrigerant tubes.
We generally find these evaporators in household refrigerators and freezers. This is because bare tube evaporators are less effective than the other evaporators we will

talk about. These evaporators will not work for large cooling requirements in commercial uses.

Bare tube evaporators do have some advantages. They are:

- Easy to clean, and
- Easy to defrost.

Plate Surface Evaporator

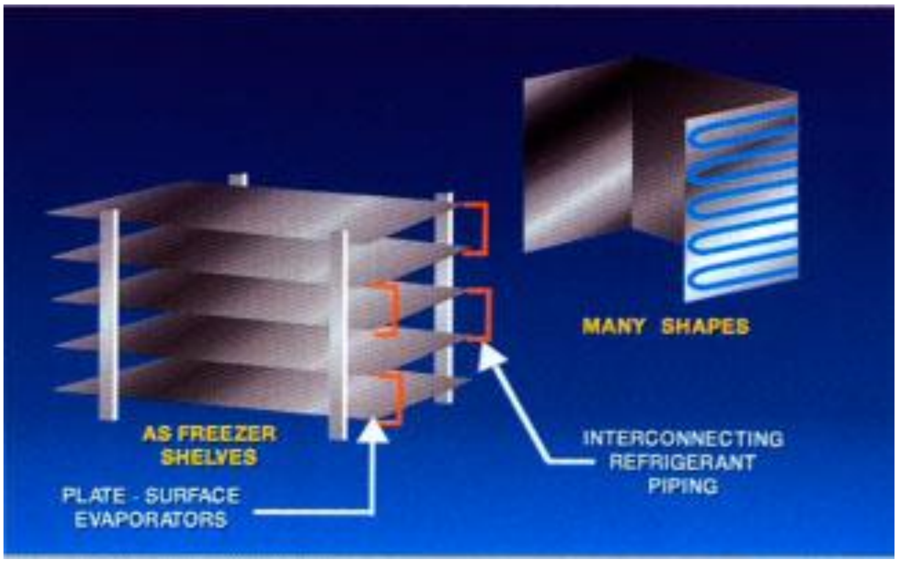


Plate surface evaporators are flat, as shown in this image. These evaporators are made up of two plates that are joined together. Usually the two plates are made of aluminum because it conducts heat well.
Liquid refrigerant flows through a tube made between the two plates. This tube carrying refrigerant is the raised part of the plate

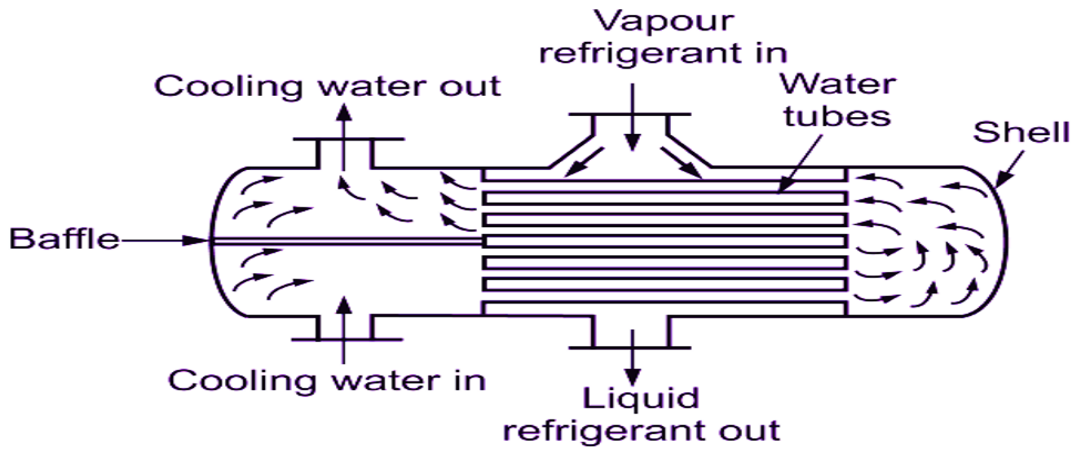
The benefits of plate surface evaporators are that they are:

- Easy to clean and defrost,
- Less likely to leak refrigerant, since the plates protect the tube carrying refrigerant, and
- Safe to handle

Finned Tube Evaporator

The finned tube evaporator is more complex and more effective. A fin is a very small plate that is attached to the body of the evaporator. As you can see in this image, finned tube evaporators have a lot of fins attached to its body.

Shell and Tube Evaporator



A shell and tube evaporator consists of a copper tube bundle inside a large outer shell. They are generally very efficient at cooling **large quantities of water.** This is why shell and tube evaporators are used for chillers in industrial or commercial settings where large quantities of cold water are needed.

The copper tubes contain the water that we are trying to chill. In this video, the red represents the hot water flowing through the inner copper tubes in the evaporator.

The outer shell of the evaporator is a large container of refrigerant fluid. This shell is sealed off and leakproof to prevent refrigerant from escaping. Heat will transfer from the water to the outer shell that contains refrigerant, which will cool the water.

REFRIGERANT FLOW CONTROL DEVICE

EXPANSION VALVE

Expansion valves are devices used to control the refrigerant flow in a refrigeration system. They remove pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapor in the evaporator. Expansion valves serve two purposes: controlling the amount of refrigerant entering the evaporator and maintaining the pressure difference between the condenser (high-pressure side) and the evaporator (low-pressure side).

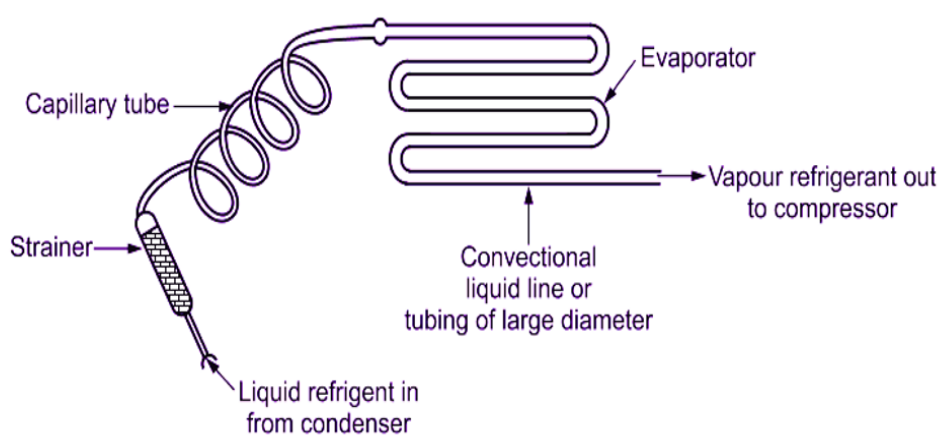
DIFFERENT TYPES OF EXPANSION VALVES

The Main Types of Expansion Valves are as Follows.

1. **Thermal Expansion Valves (TEVs)**
2. **Manual Valves**
3. **Capillary Tubes**
4. **Automatic Valves**
5. **Electronic Expansion Valves**
6. **Float Valves**

CAPILLARY TUBES

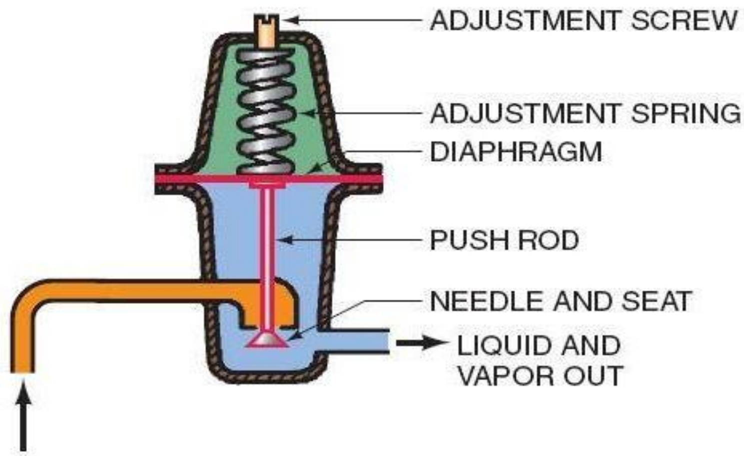
A capillary tube is a long, wound-up copper tube with a tiny opening that receives hot, high-pressure liquid refrigerant from the condenser. This small opening holds high pressure on one side of the tube and low pressure on the opposite side. The friction from the walls of the tube rapidly reduces the pressure of the refrigerant flowing through it.

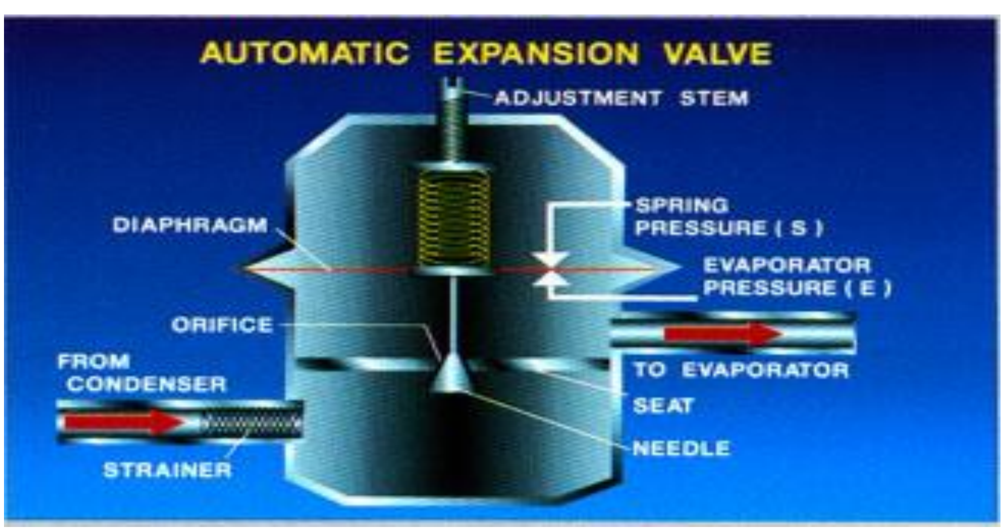


AUTOMATIC EXPANSION VALVES

Automatic Expansion Valve regulates the flow of refrigerant from the liquid line to the evaporator by using a pressure-actuated diaphragm. It maintains a constant pressure in the evaporator.

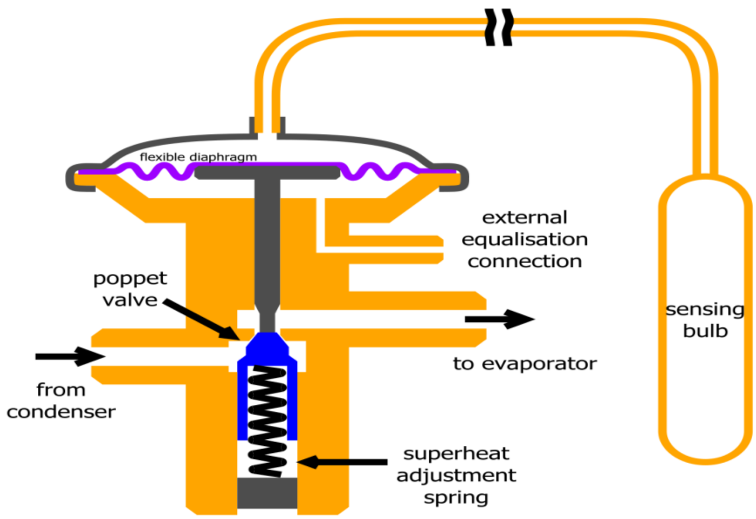
These types of expansion valves consist of a needle with a seat and a pressure bellows or diaphragm with a torsion spring capable of adjustment. Operated by evaporator pressure their chief disadvantage is their relatively poor efficiency compared with other types. Constant pressure in the evaporator also requires a constant rate of vaporization, which in turn calls for severe throttling of the liquid. There is also the danger of liquid being allowed to return to the compressor when the load falls below a certain level





THERMAL EXPANSION VALVES

Thermal expansion valves, or thermostatic expansion valves (often abbreviated as TEV, TXV, or TX valve), are the refrigeration and air conditioning throttling device that controls the amount of refrigerant liquid injected into a system's evaporator (based on the evaporator outlet temperature and pressure) called the superheat.



Components of thermostatic expansion valve

- **The valve body:** It holds the components and has an orifice inside to restrict the flow of refrigerant
- **The diaphragm:** It is a strong, thin flexible material, typically metal, which can flex to apply pressure to the pin.
- **The pin, or needle:** It moves up and down to vary the size of the opening within the orifice to control the refrigerant flow.
- **The spring:** It counteracts the force of the pin.
- **The sensing bulb and capillary line:** They measure the refrigerant temperature, at the evaporator exit, and react to causes the valve to open or close.

Thermal Expansion Valves Working Principle

- When the load on the evaporator increases, it causes the liquid refrigerant to boil faster in the evaporator coil. Since the feeler bulb is installed on the suction line, it is at the same temperature as the refrigerant at that point. So the temperature of the bulb increases due to the early vaporization of refrigerant.
- Thus the feeler bulb pressure increases and gets transmitted through the capillary tube to the diaphragm. The diaphragm moves downwards, opening the valve to admit more liquid refrigerant into the evaporator.
- This continues till pressure equilibrium on the diaphragm is reached, at which feeler bulb pressure acting at top of the diaphragm is balanced by spring and evaporator pressure acting at bottom of the diaphragm.
- When the evaporator load decreases, less liquid refrigerant evaporates in the coil, and the excess liquid flows towards the outlet. This cools the feeler bulb and its pressure and temperature decrease.
- This pressure makes the diaphragm move upward, reducing the valve opening and in turn decreasing refrigerant flow to the evaporator. This causes a decrease in evaporator pressure and again continues till diaphragm pressure equilibrium is reached

PSYCHROMETRY

The psychrometric is that branch of engineering science which deals with the study of. moist air i.e., dry air mixed with water vapour or humidity. It also includes the study of. behavior of dry air and water vapour mixture under various sets of conditions.

PSYCHROMETRIC TERMS

Dry air - Pure dry air is a mixture of various gases. Theoretical sample of air that has no water vapor. Pure dry air doesn't exist in nature

Moist Air - Mixture of dry air and water vapour

Saturated Air - Air that contains the maximum amount of water vapour that is possible at the given temperature and pressure

Dry-bulb temperature (DBT)(tdb) -The dry-bulb temperature is the temperature indicated by a thermometer exposed to the air in a place sheltered from direct solar radiation.

Wet-bulb temperature (WBT)(twb) - It is the temperature of air when it is affected by moisture. Wet Bulb temperature can be measured by using a thermometer with the bulb wrapped in wet muslin

Wet bulb depression - Difference between dry and wet bulb temperature

Dew point temperature(tdp) - The saturation temperature of the moisture present in the sample of air. It can also be defined as the temperature at which the vapour changes into liquid (condensation). It is the temperature at which a moist air sample at the same pressure would reach water vapor saturation.

Dew point Depression - Difference between tdb and tdp

Humidity - Humidity is the amount of water vapor present in the air.

Absolute humidity - The mass of water vapor per unit volume of air containing the water vapor at a given temperature and pressure. This quantity is also known as the water vapor density It is expressed in gram per cubic metre.

Relative humidity - is the ratio of actual mass of water vapour present in a given volume of moist air to the mass of water vapour in the same volume of moist air when it is saturated at the same temperature and pressure. RH is dimensionless, and is usually expressed as a percentage.

Specific humidity - is a ratio of the water vapor content of the mixture to the total air content on a mass basis in the moist air sample (dry air plus the water vapor). Sometimes referred to as the **Humidity ratio**.

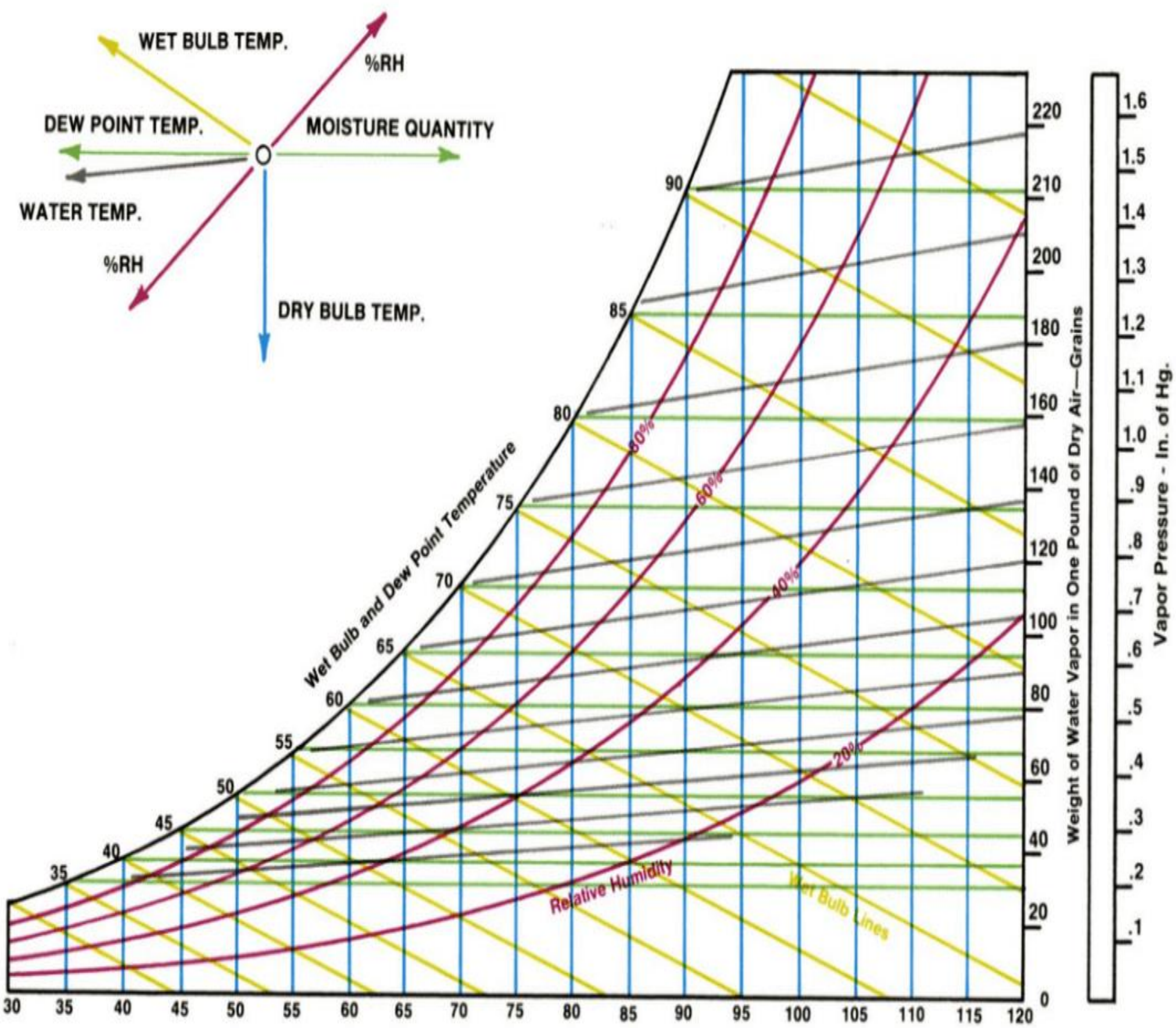
Degree of Saturation (Percentage Humidity). Degree of Saturation is the ratio of the humidity ratio of moist air - to the humidity ratio of saturated moist air at the same temperature and pressure.

Specific enthalpy . It is the sum of the internal (heat) energy of the moist air in question. In psychrometrics, the term quantifies the total energy of both the dry air and water vapour per kilogram of dry air.

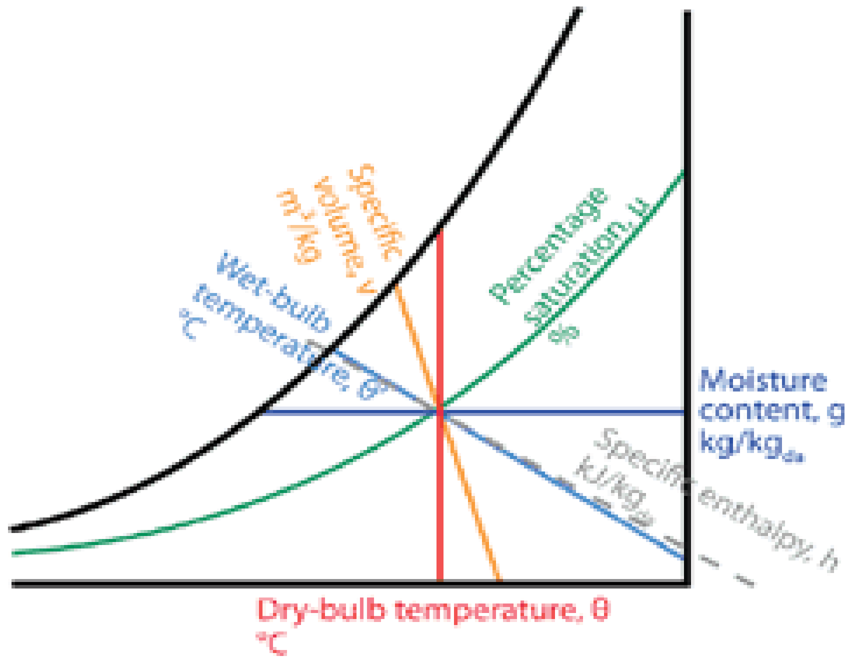
Specific volume - is the volume of the mixture (dry air plus the water vapor) containing one unit of mass of "dry air". The SI units are cubic meters per kilogram of dry air.

Adiabatic Saturation Temperature. Also called The thermodynamic wet-bulb temperature. It is the lowest temperature which may be achieved by evaporative cooling of a water-wetted (or even ice-covered), ventilated surface.

Psychrometric chart



A psychrometric chart is a graph of the thermodynamic parameters of moist air at a constant pressure, often equated to an elevation relative to sea level.



PSYCHROMETRIC PROCESS

Sensible heating

Sensible cooling

Humidification & dehumidification

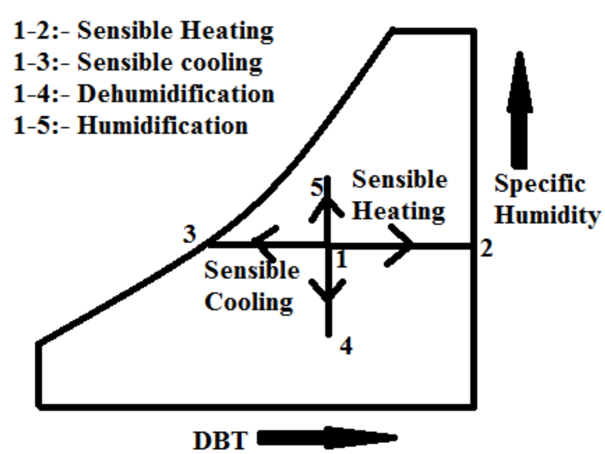
Cooling and adiabatic humidification

Cooling and humidification by water injection

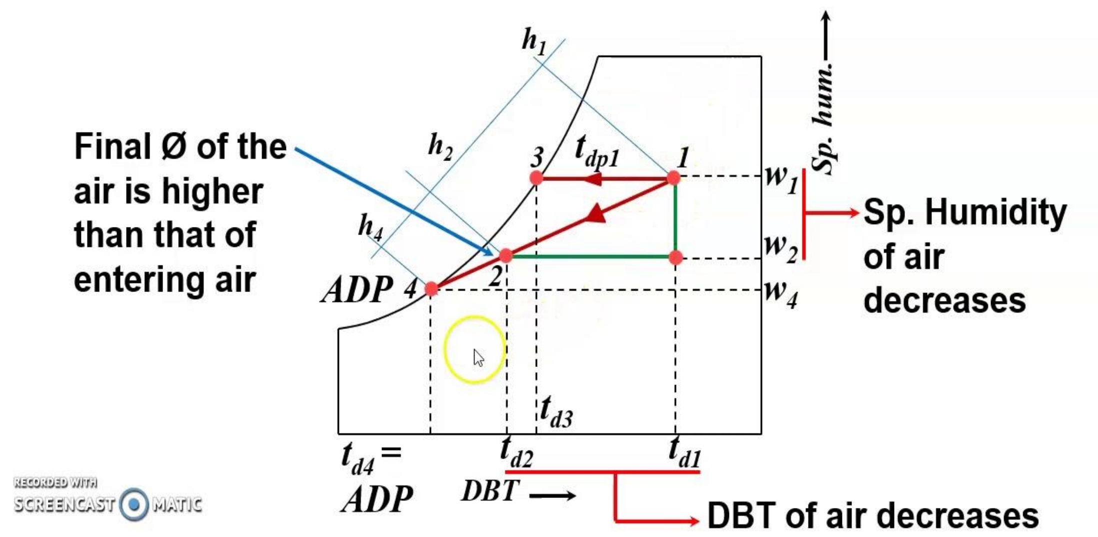
Heating and humidification

Humidification by steam injection

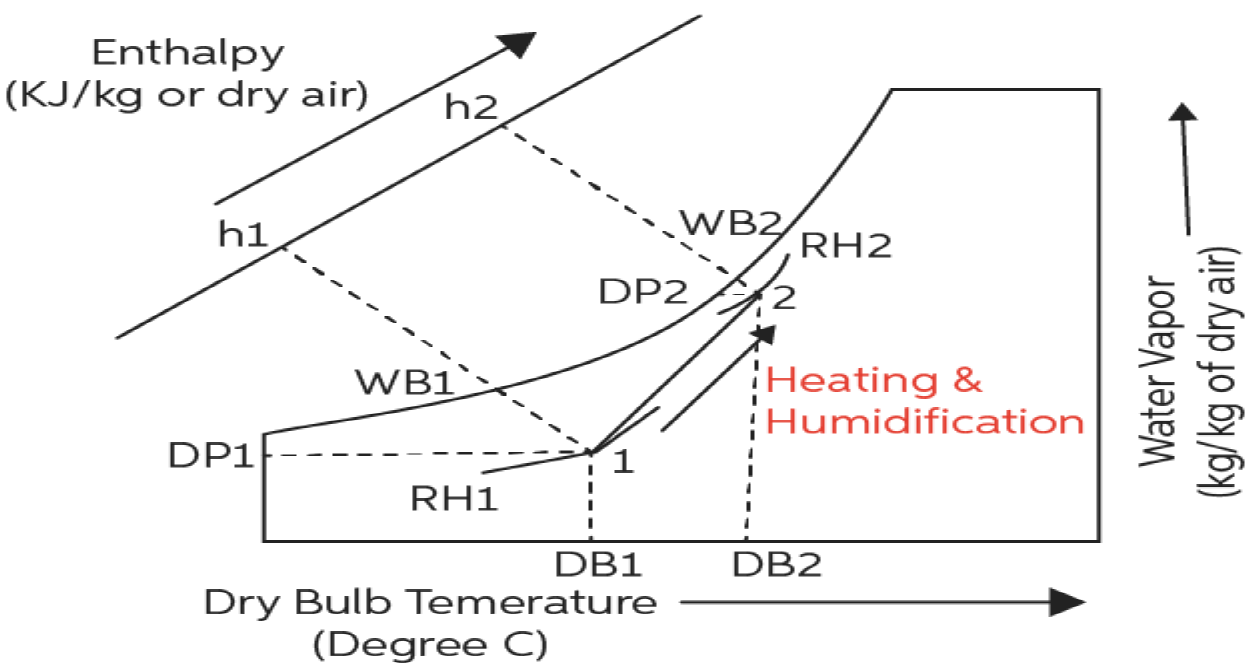
Adiabatic mixing of air streams



Cooling and Dehumidification



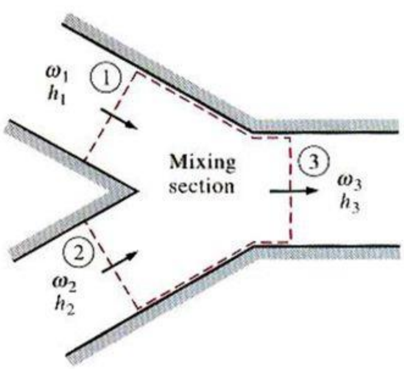
Heating & humidification

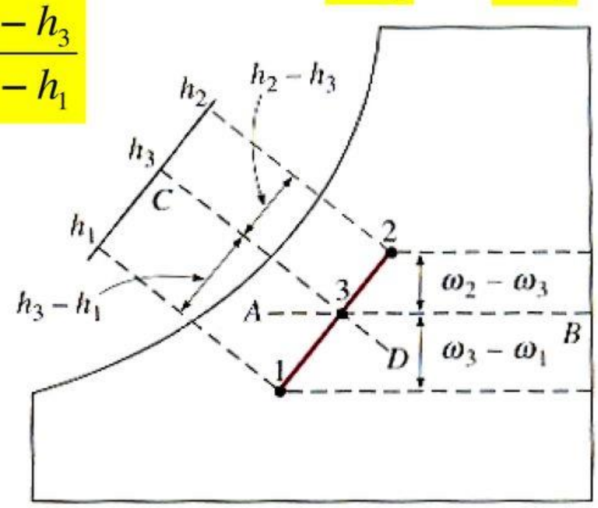


Adiabatic Mixing of Air streams

- **When two airstreams at two different states (states 1 and 2) are mixed adiabatically, the state of the mixture (state 3) will lie on the straight line connecting states 1 and 2 on the psychrometric chart, and the ratio of the distances 2-3 and 3-1 is equal to the ratio of flow rates** and $\dot{m}_{a_1}$ $\dot{m}_{a_2}$

$$\frac{\dot{m}_{a_1}}{\dot{m}_{a_2}} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1} = \frac{h_2 - h_3}{h_3 - h_1}$$





AIR CONDITIONING SYSTEM

HUMAN COMFORT

The human comfort depends upon physiological and psychological condition. The most acceptable definition, from the subject point of view, is given by the American Society of Heating, Refrigeration and air Conditioning Engineers (ASHRAE) which states : human comfort is that conditions of mind, which expressed satisfaction with the thermal environment. Factors Affecting Human Comfort

1. Effective temperature

2. Heat production and regulation in human body

3. Heat and moisture losses from the human body

4. Moisture content of air

5. Quality and quantity of air

6. Air motion

7. Hot and cold surfaces

8. Air stratification Effective Temperature

Effectice Temperature

The degree of warmth or cold felt by a human body depends mainly on the following three factors:

1. Dry bulb temperature,

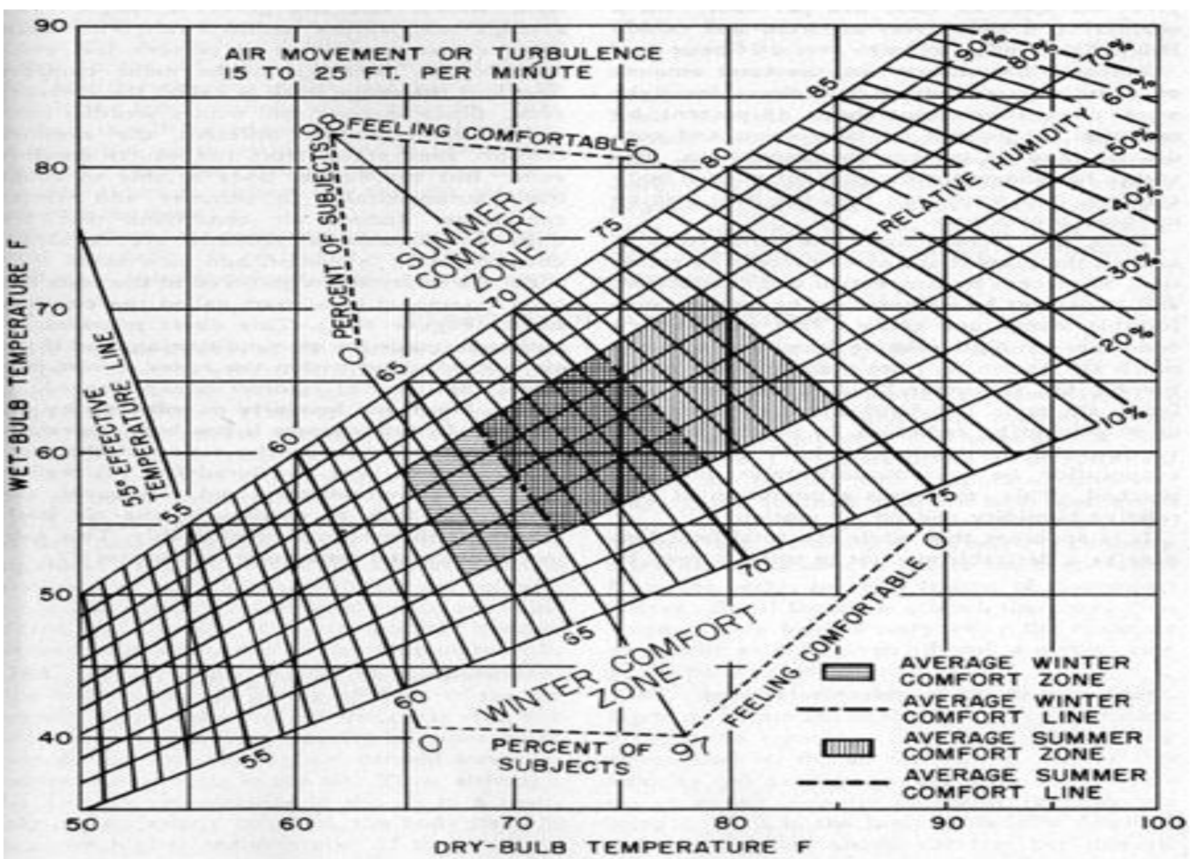
2. Relative humidity and

3. Air velocity.

In order to evaluate the combined effect of these factors, the effective temperature is employed. It is defined as that index which collates the com binned effects of air temperature, relative humidity and air velocity on the human body. The numerical value of effective temperate is made equal to the temperature of stills (i.e 5 to 8 m/min air velocity) saturated air,

which produces the same sensation of warmth or clones as produced under the given conditions. The practical application of the concept of effective temperature is presented by the comfort chart. This chart is the result of research made on different kinds of people subjected to wide range of environmental temperature, relative humidity and air movement by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). In the comfort chart, the dry bulb temperature is taken as abscissa and the wet bulb temperature of ordinates.

COMFORT CHART



Heat Production and Regulation in Human Body

The rate of heat production depends upon the individual's health, his physical activity and his environment. The rate at which the body produces heat is metabolic rate. The heat production from a normal healthy person when a sleep (called based metabolic rate) is about 60 wtts and it is about ten times more for a person carrying out sustained very hard work.

Heat and Moisture Losses from the Human Body

The heat is given off from the human body as either sensible or latent heat or both. In order to design any air-conditioning system for spaces which human bodies are to occupy, it is necessary to know the rates at which these two forms of heat are given off under different conditions of air temperature and bodily activity.

Moisture Content of Air

The moisture content of outside air during winter is generally low and it is above the average during simmer, because the capacity of the air to carry moisture is dependent upon its dry bulb temperature. This means that in winter, if the cold outside air having a low mist rue content leaks into the conditioned space, it will cause a low relative humidity unless minster is assed to the air by the processes of humidification. In summer, the reveres will take place unless moisture is removed from the inside air by the dehumidification process.

Quality and Quantity of Air

The air in an occupied space should, at all times, be free room toxic, unhealthful ordisagreeable fumes such as carbon dioxide. It should also be free from dust and odour.

Air Motion

The air motion which included the distribution of air is very important to maintain uniform temperate in the conditioned space. The air velocity in the occupied zone should not exceed 8 to 12m/min. Cold and Hot Surfaces: The cold or hot objects in a conditioned space may cause discomfort to the occupants.

Air Stratification

The movement of the air to produce the temperature gradient from floor to ceiling is termed as air stratification. In order to achieve comfortable conditions in the occupied space, the air conditioning system must be designed to reduce the air stratification to a minimum.

What is an air conditioning system ?

An air conditioning system is an electrical device that is purposely installed for the removal of heat and moisture from the interior of an occupied space. It is a process that is commonly used to achieve a more comfortable environment, basically for human and other animals.

Air conditioning system is also used to cool and dehumidify rooms that contain heat-producing electronic devices, such as computer server, power amplifiers. It also used in space that contains delicate products like artwo

Functions of the air conditioning system

Below are the major functions of an air conditioning system in modern houses:

- The primary purpose of air conditioning is to create a room climate comfortable for humans.
- Some special type of conditioning system is used to cool the temperature of electric devices.
- It controls the humidity of a room as 30 to 65% is permitted while the temperature should be between 20 and 26 degrees Celsius.
- Air conditioning system affects the room air to comfort people and their productivity is not impeded.
- The condition of the air is characterized by temperature, pressure and humidity. The air pressure is not changed.
- Air conditioning system can be for heating, dehumidifying, cooling, and humidifying.

Equipment Used in an Air Conditioning System

Following are the main equipment or parts used in an air conditioning system:

1. **Circulation fan:** The main function of this fan is to move air to and from the room.
2. **Air conditioning unit**: It is a unit, which consists of cooling and dehumidifying processes for summer air conditioning or heating and humidification processes for winter air conditioning.
3. **Supply duct**: It directs the conditioned air from the circulating fan to the space to be air-conditioned at the proper point.
4. **Supply outlets**: These are the grills, which distribute the conditioned air evenly in the room.
5. **Return outlets:** These are the openings in a room surface which allow the room air to enter the return duct.
6. **Filters:** The main function of the filters is to remove dust, “dirt and other harmful bacteria”s form the air.

Classification based on the season in the year

- A summer air conditioner which controls all four atmospheric condition for summer comfort.
- Winter air conditioner is designed for comfort in the winter.
- A year-round air conditioner which consists of heating and cooling tools with an automatic control that could serve in any weather condition in the year.

WINTER AIR CONDITIONING SYSTEM

The Winter Air Conditioning Diagram is shown below.

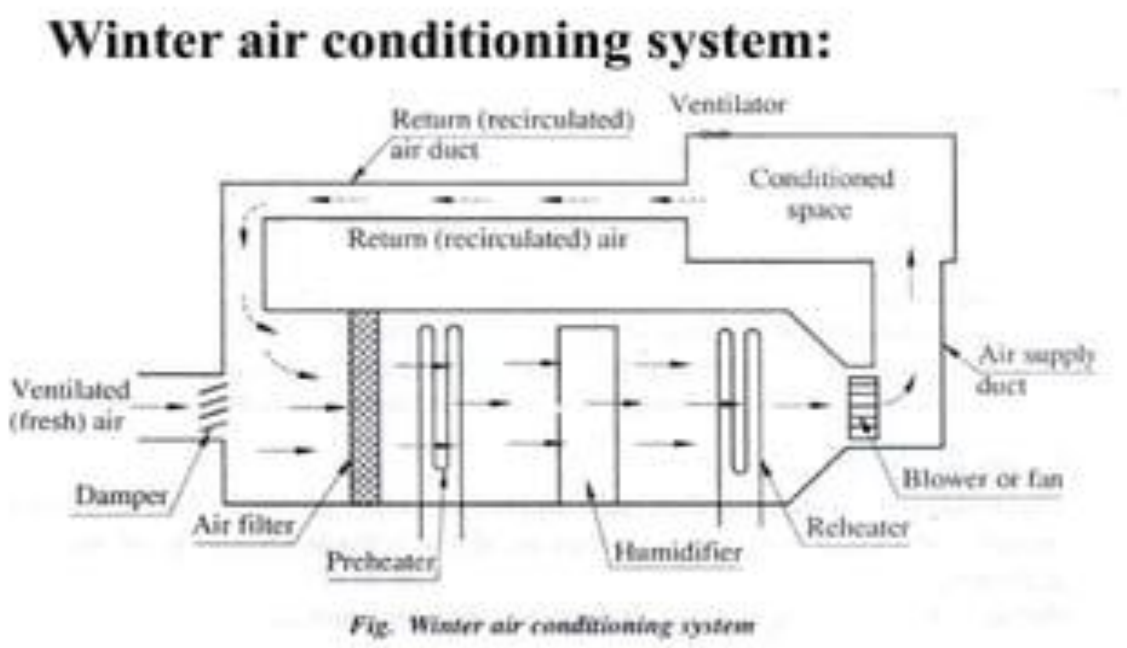


Fig. Winter air conditioning system

Working of Winter Air Conditioning System

In winter air conditioning, the air is heated and is accompanied by humidification.

The outside air flows through a damper and mixes up with the recirculated air which is obtained from the conditioned space.

The mixture here passes through a filter to remove dirt, dust, and other impurities.

The air now passes through a preheat coil to prevent possible freezing of water due to which dry bulb temperature increases to a very high value and the relative humidity drops to a low value.

This air is being pumped into the humidifier.

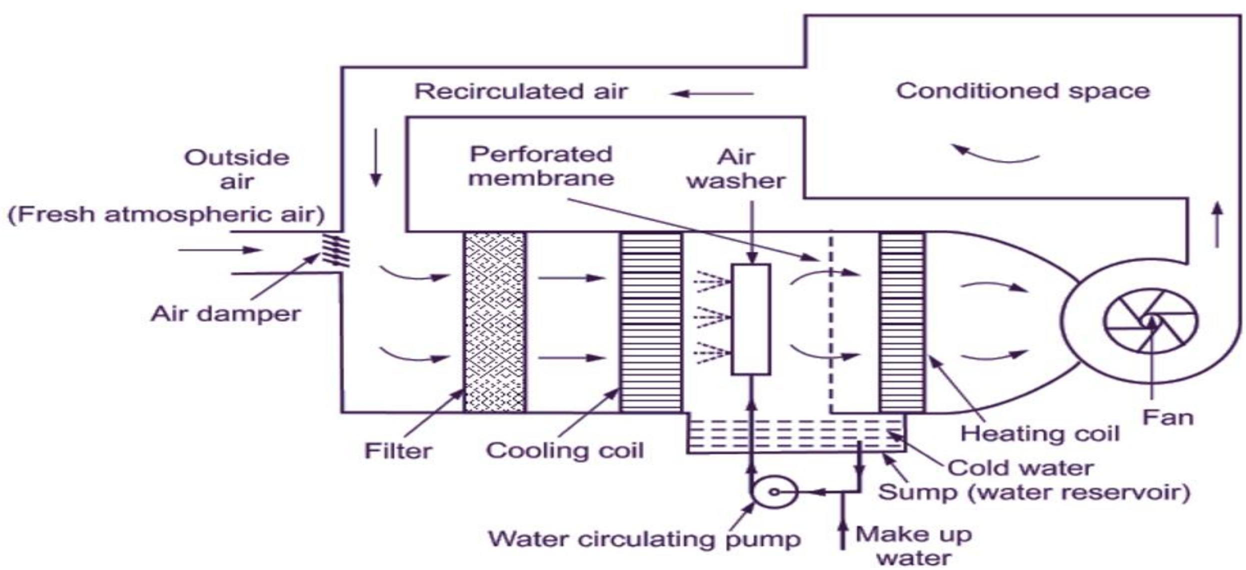
So, humidification of air (addition of moisture) is done and then the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature.Now the conditioned air is supplied to the conditioned space by means of a fan. From the conditioned space, a part of the used air is exhausted into the atmosphere by the exhaust fans or ventilators.The remaining part of the air known as recirculated air is again conditioned as shown in the figure.

Initially, the relative humidity is 60% in the winter season, so to reduce it, a process of reheating is done where it is reduced to 20%.So it is again humidified due to which it reaches a point of 80% or 100% RH where the DBT is very low.

So in order to get the desired dry bulb temperature, again the process of reheating is done where the desired percentage of 40% RH is also obtained.A damper is used in order to control the area and have an intake of the required amount of air.

SUMMER AIR CONDITIONING SYSTEM

The diagram of the summer air conditioning system is shown below.

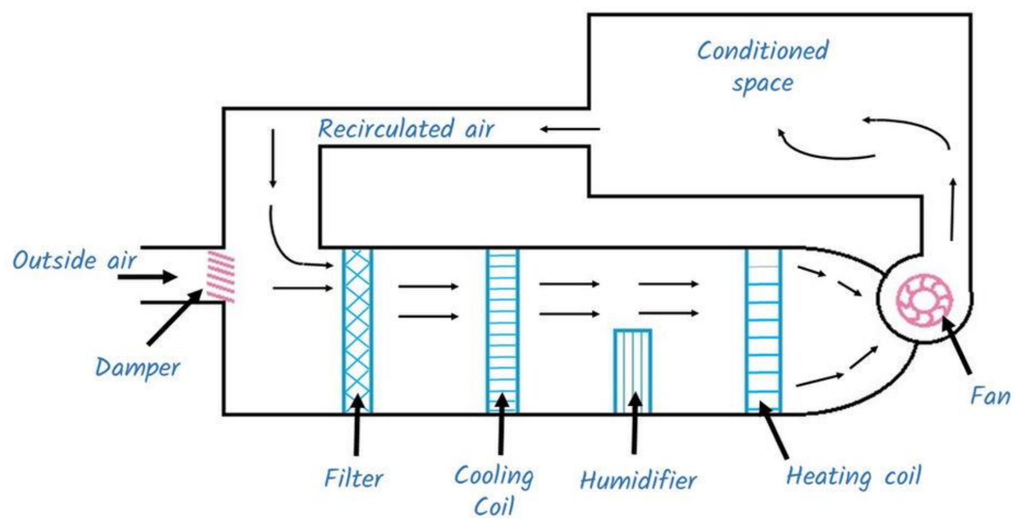


Working of Summer air conditioning system

The outside air(atmospheric air) flows through the air filter to remove impurities or dust particles present in the air. The air now passes through a cooling coil.The coil has a temperature much below the required dry bulb temperature of the air and very high relative humidity in the conditioned space.So the cooled air is pumped into a dehumidifier, where it loses its moisture in the conditioned space.After that, the air is made to pass through a heating coil which heats the air slightly.This is done to bring the air to the designed DBT and relative humidity(RH).Now the conditioned air is supplied to the conditioned space by a fan.From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators.The remaining part of the used air is again conditioned.The outside air is sucked and it is made to mix with the recirculated air to make up for the loss of conditioned air through exhaust fans or ventilation from the conditioned space.

YEAR ROUND AIR CONDITIONING SYSTEM

In a year-round air conditioning system, it should have equipment for both the summer and winter air conditioning. In the summer air conditioning system, the cooling operates to cool the air to the desired valve. The dehumidification is obtained by operating the cooling coil at a lower temperature than the dew point temperature.In the winter air conditioning system, the cooling coil is made inoperative and the heating coil operates to heat the air. The spray type humidifier is also used in the dry season to humidify the air.



GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

INDUSTRIAL-ENGG.-AND-MANAGEMENT

6TH SEMESTER

PREPARED BY

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INDUSTRIAL ENGINEERING AND MANAGEMENT

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PLANT ENGINEERING
Plant location and Plant layout

SECTION-A

1. **Define plant**.
   A Plant is a place where men, materials, money, equipments and machinery are brought together for manufacturing products.
2. **Define plant location.**
   Plant location means deciding a suitable location, area, place where the plant or factory will start functioning.
3. **Define plant layout.**
   a) Plant layout may also be defined as:"Plant layout means placing the right equipment coupled with right method in right place to permit the processing of products in most effective manner through shortest move in shortest time''.

   b) Plant layout means effective arrangement of various facilities of plant like arrangement of machines, material handling equipments, storage space, operating equipments and other supporting services.

4. **What are the functions of plant layout?**

a) The term plant layout does not necessarily mean planning a layout for a new plant only. It may involve

i) Expansion of existing plant.
ii) Minor improvements in existing plant.
iii) Re-layout of the existing plant.

b) Plant lay out begins with the design of factory building and goes up to the location and movement of work table.

5. **What are the types of plant layout generally used in an organisation?**

According to type of industry and volume of production following are the types of layouts used in an organisation:

a) Process layout or functional layout.
b) Product layout or line layout.
c) Combination layout or group layout.
d) Fixed position layout.
e) Cellular layout or group technology layout.

6. **Explain why plant location decisions are important to the organization?**
   a) Plant location means deciding a suitable location, area, place where the plant or factory will start functioning.

b) Plant location decisions are important to the organization setup because it depends on following factors:

- Nearness to raw materials
- Transport facilities
- Nearness to markets
- Availability of labour
- Availability of fuel and power
- Availability of water
- The following factors should also be considered for plant location.
  i) Climatic conditions.
  ii) Financial and other aids.
  iii) Land.
  iv) Community attitude.
  v) Presence of related industries.
  vi) Existence of hospitals, marketing centres, schools, banks, post offices, clubs, etc.
  vii) Housing facilities.
  viii) Security.

SECTION-B

1. **State the objectives of good plant layout.**
   - Material handling and transportation is minimized and efficiently controlled.
   - Work stations are designed suitably and properly.
   - Suitable spaces are allocated to production centres and service centres.
   - The movements made by the workers are minimized.
   - Waiting time of the semi-finished products is minimized.
   - Working conditions are safer, better and improved.
   - There is increased flexibility for changes in product design and future expansion.
   - There is utilization of cubic space (length, width and height).
   - There are improved work methods and reduced production cycle times.
   - There is increased productivity and better product quality with reduced capital cost.
2. **Describe the principles of plant layout.**

- **Integration.** It means the combination of production centres facilities like workers, machinery, raw material, etc in a logical and balanced manner.
- **Minimum movements and material handling.** The number of movements of workers and materials should be minimized. it is better to transport materials in optimum bulk rather than in small amounts.
- **Smooth and continuous flow.** Bottlenecks, congestion point and back tracking should be removed by proper line balancing techniques.
- **Cubic space utilization.** Besides using the floor space of a room, if the ceiling height is also utilized. More materials can be accommodated in the same room. Boxes or bags containing raw material or goods can stocked one above the other to store more items in the same room
- **Flexibility.** In automotive and other industries where models of products change after some time, it is better to permit all possible flexibility in the layout. The machinery is arranged in such a way that the changes of the production process can be achieved at the minimum cost.

- **Safe and improved environments.** Working places should be safe, well ventilated and free from dust, noise, fumes, odours and other hazardous conditions and increase the operating efficiency of the workers and improve their morale.

3. **Describe the factors governing or influencing the plant location.**

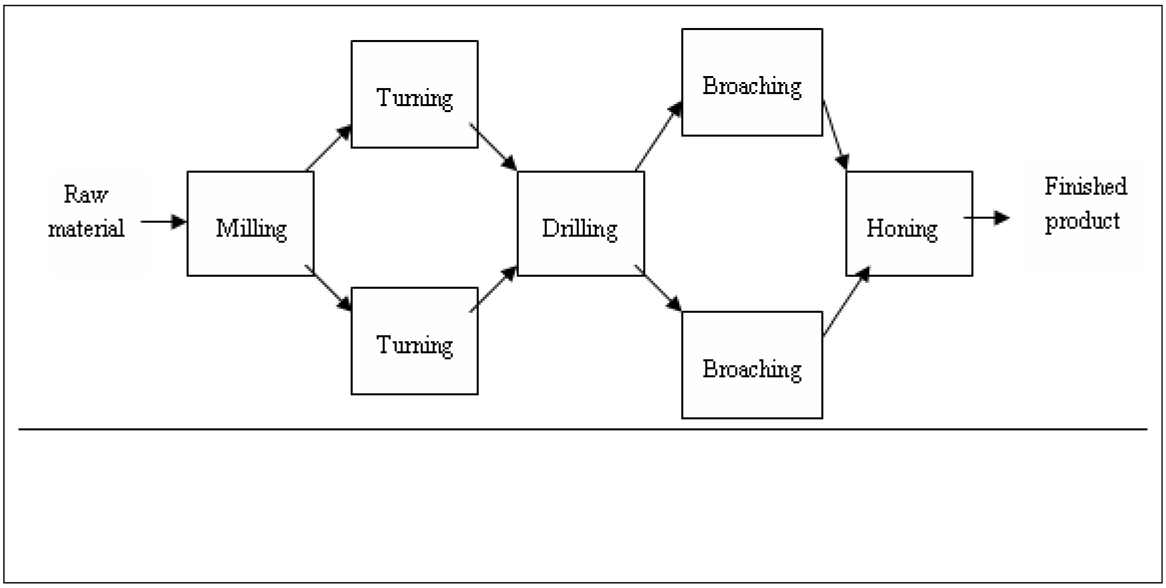
- **Nearness to raw materials**: -It will reduce the cost of transporting raw material from the vendor's end to the plant.
- **Transport facilities**: -depending upon the size of raw material and finished goods, a suitable method of transportation like roads, rail, water or air is selected and accordingly the plant location is decided.
- **Nearness to markets**: -It reduces the cost of transportation as well as the chances of finished products getting damaged and spoiled in the way, it can render quick service to the customers.
- **Availability of labour**:-Stable labour force, of right kind, of adequate size, and at reasonable rates with its proper attitude towards work are a few factors which govern plant location to a major extent.
- **Availability of fuel and power**: -Because of the wide spread use of electric power, in most cases fuel (coal, oil, etc) has not remained a deciding factor for plant location. Even then steel industries are located near source of fuel(coal) to cut down the fuel transportation costs.
- **Availability of water**: -Water is used for processing, as in paper and chemical industries and is also required for drinking and sanitation purposes. Depending upon the nature of plant, water should be available in adequate quantity and should be of proper quality.

The following factors should also be considered for plant location.

ix) Climatic conditions.
x) Financial and other aids.
xi) Land.
xii) Community attitude.
xiii) Presence of related industries.
xiv) Existence of hospitals, marketing centres, schools, banks, post offices, clubs, etc.
xv) Housing facilities.
xvi) Security.

4. **Describe Combination layout**.

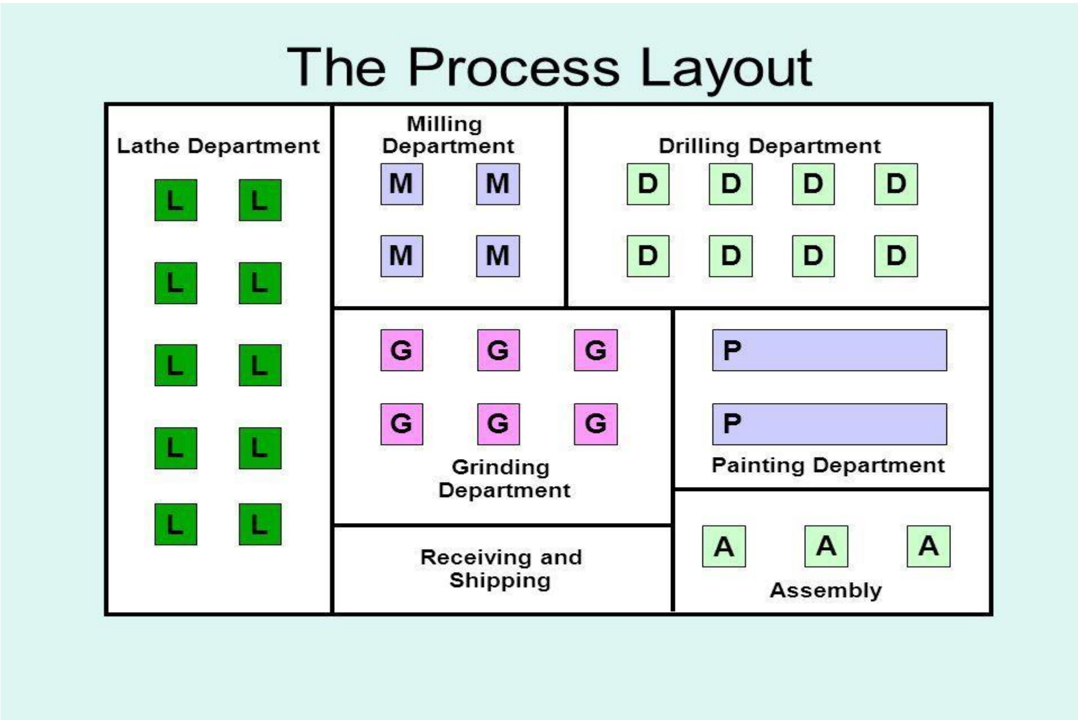
- A combination of process and product layouts combines the advantages of the both types of layouts. It is also known as group layout.
- Now a day's pure product or process layouts are rare, in combination layout where an item is being made in different types and sizes.
- In combination layout machinery is arranged in a process layout but the process grouping (a group of nos. of similar machines) is then arranged in a sequence to manufacture various types and sizes of products.
- A combination layout is also useful when a number of items are produced in same sequences.
- Files, hacksaws, circular metal saws, wood saws etc. can be manufactured on a combination type of layout.



SECTION-C

1. **Describe Process layout with advantages and disadvantages.**

- Process lay out is also known as functional lay out and is characterized by keeping similar machines or similar operations at one location.
- For example, all lathes will be at one place, all milling machines at another and so on, that ismachines have been arranged according to their functions.
- This type of layout is generally employed for industries engaged in job order production.
- This type of layout is particularly used when low volume of production is needed at regular intervals or low volume and high variety of products is required.



Advantages

- There is a greater flexibility in utilization of equipment, machines and man power.
- Lower initial investment is required as comparatively less number of machines is required.
- Better product quality, because the supervisors and workers attend to one type of machines and operations.

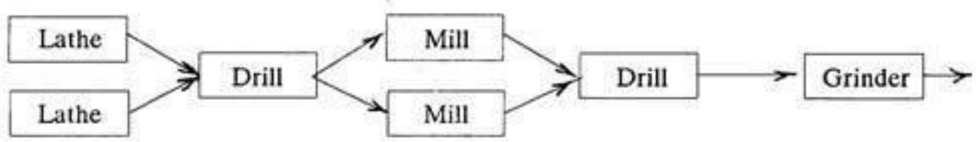
- Breakdown of machines can be easily handled by transferring the work to other machines.
- Varieties of job coming as different job orders make the work more interesting for the workers.
- Better utilization of the available equipment.

Disadvantages

- For the same amount of production, process lay out needs more space.
- Automatic material handling is extremely difficult.
- More material-in-process remains in queue for further operations.
- Completion of same product takes more time.
- Work-in-process inventory is large.
- Raw material has to travel larger distance for being processed to finished goods. This increases material handling and associated costs.

2. Describe Product layout with advantages and disadvantages.

- It is also known as line layout. Various operations on raw material are performed in a sequences and the machines are placed along the product flow line, i.e machines are arranged in the sequence in which the raw material will be operated upon.
- This type of lay out is used for continuous production or mass production i.e. a continuous flow of in – process material towards the finished product stage.
- Ex:- Raw material from the store is fed to three lines X, Y and Z. Material in X line gets processed on machines D , E , F and G and meets material of Y line after it has been processed on the main assembly line machines A and B. Products of X and Y lines are assembled at W andget processed on machines H and I still another part comes from Z line and assembles with the main product at V. After that the total assembly gets worked on machines M , N, O and P and goes to the stock room.



A Simple product layout.

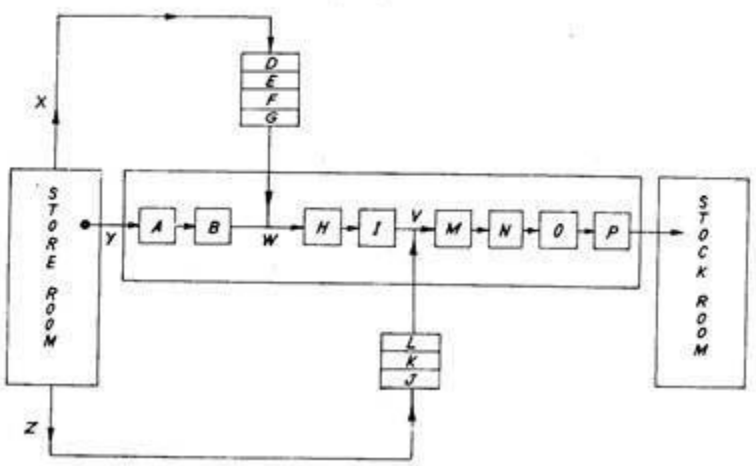


Fig. 4.2 Product layout.

Advantages

- Less space requirements for the same volume of productions.

- Automatic material handling, lesser material handling movements, times and costs.
- Less in-process inventory.
- Product completes in lesser time.
- Smooth and continuous work flow.
- Less skilled worker may serve the purpose.

Disadvantages

- The layout flexibility is considerably reduced.
- If any of the machines in the shop breaks down the other machines have to remain idle till that machine becomes again ready to commence operation.
- It is difficult to increase production beyond the capacities of the production lines.
- For expansion purpose, it is not possible to add more machines.
- Specialized and strict supervision is needed.

3. **Briefly explain the plant layout procedure.**
   <u>Plant layout procedure</u>

- Accumulate basic data.
- Analyses and coordinate basic data.
- Decide the equipment and machinery required.
- Select the material handling system.
- Sketch plan of the plot for making factory building.
- Determine a general flow pattern.
- Design the individual work station.
- Assemble the individual layout into the total layout.
- Calculate storage space required.
- Make flow diagrams for work stations and allocate them to areas on plot plan.
- Plan and locate service areas.
- Make master layout.
- Check final layout.
- Get official approval of the final layout.
- Install the approved layout.

4. **Briefly explain the storage space requirements in plant layout .**

- Adequate storage space allocation to different materials and supplies is of great importance otherwise a small increase in their quantities may give rise to congestion and the whole storage system may be out of system.
- The space to be provided for above factors depends upon:
  i) Size and weight of raw material, in-process good and finished goods.
  ii) Their quantities.
  iii) Frequency of use.
- The following items and the amount of stock holding determine the storage space requirements:
  i) Incoming new materials.

ii) Checking and sorting the raw materials

iii) Inspection of raw materials.

iv) Temporarily storing the new material before it is placed at the proper location.

v) In-process inventory.

vi) Tools and other supplies.

vii) Finished products.

- Bins, drums, barrels, racks, shelves, tanks, pallets etc may be usefully employed for storage purposes.

  Ex.-

  i) Liquid materials are stored in drums, cans, barrels and bottles.

  ii) Gases are kept in cylinders whereas solid materials can be placed in boxes, barrels, bags, pallets, container etc.

  iii) Casting or forging can be stored in pallets and stocked in rows.

  iv) Toxic materials are generally stored in well ventilated areas.

- The storage space should be such that the materials can be quickly and easily taken out for delivery or stocked as soon as they are received in the factory.

Plant maintenance

Section - A

1. **What is plant maintenance?**

- **Maintenance** on **plant** and equipment is carried out to prevent problems arising, to put faults right, and to ensure equipment is working effectively. **Maintenance** may be part of a planned programme or may have to be carried out at short notice after a breakdown. Maintenance of a machines means efforts directed towards the up keep and the repair of that machine.
- Every machine is thoroughly tested and inspected by the manufactures before selling it and by purchaser before it is put to use when it is used.
- It will be subjected to wears and tear hence proper attention should be given to protect the machine and it's components from undue wear and thus protects them from failures.

2. **Classify different types of plant maintenance.**

- According to size of industry, following are the types of plant maintenance used in industry:
  - Breakdown or Corrective maintenance
  - Scheduled maintenance
  - Preventive maintenance
  - Predictive maintenance

3. **State the objectives of plant maintenance.**

- The objective of plant maintenance is to achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.
- Machine and other facilities should kept in such a condition which permits them to be used at their optimum capacity without any interruption or hindrance.
- Every machine is thoroughly tested and inspected by the manufactures before selling it and by purchaser before it is put to use when it is used. It will be subjected to wears and tear hence proper attention should be given to protect the machine and it's components from undue wear and thus protects them from failures.

4. **What do you mean by breakdown?**

- Corrective or breakdown maintenance implies that requires are made after the equipment is out of order and it cannot perform its normal function any longer, e.g., an electronic motor willnot start, a belt is broken, etc .
- **Typical Causes Of Equipment Break Down:**
  - Failure to replace worn out parts.
  - Luck of lubrications.
  - Neglected cooling system.
  - Indifference towards minor faults.
  - External factors

Section –B

1. **Describe the objectives of plant maintenance.**

- The objective of plant maintenance is to achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.

- Machine and other facilities should kept in such a condition which permits them to be used at their optimum capacity without any interruption or hindrance.
- Maintenance division of a factory ensure the availability of the machines, buildings and services required by other section of the factory for the performance of their functions at optimum return on investment whether this investment be in material, machinery or personnel.
- Maintenance of a machines means efforts directed towards the up keep and the repair of that machine.

2. **Explain scheduled maintenance with advantages.**

- Scheduled maintenance is a stitch-in-time procedure aimed at avoiding breakdowns.
- Breakdowns can be dangerous to life and as far as possible should be minimize.
- Scheduled maintenance particle incorporates inspection, lubrication; repair and overhaul of certain equipments which if neglected can results in break down.
- Inspection, lubrication, servicing, etc., of these equipments are included in the predetermined schedule.
- Scheduled maintenance practice is generally followed for overhauling of machines, cleaning of water and other tanks, white-washing of buildings, etc.

3. **Describe predictive maintenance.**

- It comparatively a newer maintenance technique.
- It makes use of human senses or other sensitive instruments such as: Audio gauges, Vibration analyzers, Amplitude meters, Pressure, temperature and resistance strain gauges, etc., to predict troubles before the equipments fail.
- Ex: - Unusual sounds coming out of rotating equipment predicate a trouble; an electric cable excessively hot at one point predicates a trouble. Simple hand touch can point out many unusual conditions and thus predict a trouble.
- In predictive maintenance, equipment conditions are measured periodically or on a continuous basis and this enable maintenance men to take a timely action such as equipment adjustments, repair or overhaul.
- Predictive maintenance extends the service life of equipment without fear of failure.

4. **What are the recent developments in plant maintenance?**

- In recent years there has been a tendency to use a variety of management techniques for plant maintenance. These techniques have led to
  - An increase in maintenance efficiency.
  - Reduced maintenance cost.
  - Improved Services.

Use Of Work study: -

- Work study can improve maintenance scheduling and eliminate a great deal of frustration and anxiety on the part of production supervision.

Use Of Network Planning Techniques: -

- CPM has enabled some firms to cut their down time by 20 to 30%.
- Maintenance costs have been cut down.
- Plant utilization has been raised.
- CPM is very useful for planning and controls of large maintenance projects.
- Dramatic reductions in time (about70%) were experienced with the overhaul of generating plant by central electricity generating board in Great Britain, by using network planning techniques.

- When applied to the maintenance and overhaul of a refinery, PERT reduced its shutdown time from 18 to 16 days and thus added 90,000 barrels to its production volume.

  Use Of Computers: -
- Computers when used for managing maintenance problems provide more efficient operation and control. Computers can prepare maintenance work orders giving accurate work order descriptions and job timing.

Section - C

1. Describe the duties and functions of plant maintenance department.

The different duties, functions and responsibility of the maintenance department are as follows:

- **Inspection: -**
  - Inspection is concerned with the routine schedule checks of the plant facilities to examine their conditions and to check for needed repairs.
  - Inspection ensures the safe and efficient operation of equipment and machinery.
- **Engineering: -**
  - Engineering involves alteration and improvements in existing equipments and building to minimize breakdowns.
  - Maintenance department also undertake engineering and supervision of constructional projects that will eventually become part of the plant.
- **Maintenance: -**
  - Maintenance of existing plant equipment.
  - Maintenance of existing plant building and other service facilities such as yard, central stores, roadways, etc.
  - Engineering and execution of planned maintenance, minor installation of equipment, building and replacements.
- **Repair: -**
  - Maintenance department carries out corrective repairs to alleviate unsatisfactory conditions found during maintenance inspection.
  - Such a repair is an unscheduled work often of an emergency nature, and is necessary to correct breakdowns and it includes trouble calls.
- **Overhaul: -**
  - Overhaul is a planned, scheduled reconditioning of plant facilities such as machinery, etc.
  - Overhaul involves replacement, reconditioning, reassembly, etc.
- **Construction: -**
  - In some organizations maintenance department is provided with equipment and personnel and it takes up construction job also.
  - Maintenance department handles construction of wood, brick and steel structures, cement and asphalt paving, electrical installation, etc.
- **Salvage: -**
  - Maintenance department may also handle disposition of scrap or surplus materials. This function involves,
  - Segregation, reclamation and disposition of production scrap, and
  - The collection and disposition of surplus equipments, materials and supplies.
- **Clerical Jobs: -**

- Maintenance department keeps records
- Of costs,
- Of time progresses on jobs,
- Pertaining to important features of buildings and production equipments; electrical installations; water, steam, air and oil lines ; transportation facilities, etc.
- Generation and distribution of power and other utilities.
- Administration and supervision of labour force.
- Providing plant production, including fire protection.
- Insurance Administration.
- Establishing and maintaining a suitable store of maintenance materials.
- Janitorial service.
- Housekeeping.
- Good housekeeping involves upkeep and cleaning of equipments, building, toilets, wash-room, etc.
- Pollution and noise abatement.

2. Explain breakdown maintenance with disadvantages.

- Corrective or breakdown maintenance implies that requires are made after the equipment is out of order and it cannot perform its normal function any longer ,e.g., an electronic motor will not start, a belt is broken, etc. Under such conditions, production department cells on the maintenance department to rectify the defect. The maintenance department cheeks into the difficulty and makes the necessary. After removing the fault, maintenance engineers do not attend the equipment again until another failure or breakdown occurs.
- After removing the Fault, maintenance engineer do not attend the equipment again until another failure or breakdown occurs.
- This type of maintenance may be quite justified in small factories which:
  i) Are indifferent to the benefits of scheduling;
  ii) Do not feel a financial justification for scheduling techniques; and
  iii) Gets seldom demands in excess of normal operating capacity.
- In many factories make-and-mend is the rule rather than the expectation.
- Breakdown maintenance particle is economical for those equipments whose down-time and repair costs are less this way than with any another type of maintenance.
- Breakdown maintenance involves little administrative work, few records and a comparative small staff.
- **Typical Causes Of Equipment Break Down:**
  i) Failure to replace worn out parts.
  ii) Luck of lubrications.
  iii) Neglected cooling system.
  iv) Indifference towards minor faults.
  v) External factors.
- **Disadvantages Of Breakdown Maintenance:**
  i) Breakdown generally occurs at in opportunity times. This leads to poor, hurried maintenance and excessive delays in productions.
  ii) Reduction of output.
  iii) Faster plant deterioration.
  iv) More spoilt material.

v) Direct loss of profit.

3. Explain preventive maintenance with objectives.

Preventive Maintenance: -

- Preventive maintenance is a system of scheduled, planned maintenance tries to minimize the problem of breakdown maintenance.
- It is a stitch-in-time procedure.
- It locates weak spots in all equipments, provides them regular inspection and minor repairs there by reducing the danger of unanticipated breakdown. The underlying principle of preventive maintenance is that prevention is better than cure.
- Periodic inspection of equipment and machinery to un cover conditions that lead to production breakdown and harmful depreciation.
- Upkeep of plant equipment to correct such conditions while they are still in a minor stage.

Objectives Of PM: -

- To minimize the possibility of unanticipated production interruption or major breakdown by locating or uncovering any condition.
- To make plant equipment and machinery always available and ready for use .
- To maintain the value of equipment and machinery by periodic inspections, repairs, overhauls, etc.
- To maintain the optimum productive efficiency of the plant equipment and machinery.
- To maintain the operational accuracy of the plant equipment.
- To reduce the work content of maintenance jobs.
- To achieve maximum production at minimum repair cost.
- To ensure safety of life and limbs of the workmen.

Advantages Of PM: -

- Reduced breakdowns and connected down-time.
- Lesser odd-time repairs and reduced overtime to the maintenance work-force.
- Greater safety for workers.
- Fewer large-scale and repetitive repairs.
- Low maintenance and repair costs.
- Less standard-by or reserve equipment, and spare parts.
- Identification of equipments requiring high maintenance cost.
- Lower unit cost of manufacture.
- Better product quality and fewer product rejects.
- Increased equipment life.

Inventory control

Section - A

1. **Define inventory control.**

- Inventory control may be defined as the scientific method of finding out how much stock should be maintained in order to meet the production demands and be able to provide right type of material at right time in right quantities and at competitive price.

2. **Classify different types of inventories a manufacturing organization keeps.**

- Inventory may be classified as follows:

  (i) Raw inventories: - They include, raw material and semi-finished products supplied byanother firm and which are raw items for the present industry.

  (ii) In-process inventories: - They are semi-finished goods at various stages of manufacturing cycle.

  (iii) Finished inventories: - They are the finished goods lying in stock rooms and waiting dispatch.

  (iv) Indirect inventories: - They include lubricants and other items (like spare parts) needed for proper operation, repair and maintenance during manufacturing cycle.

3. **What are the types of costs associated with inventory control?**

- There are two types of costs associated with inventory, they are
- Inventory procurement costs: - which consist of expenditure connected with

  i) Receiving quotations;
  ii) Processing purchase requisition;
  iii) Following up and expediting purchase order;
  iv) Receiving material and then inspecting it; and
  v) Processing seller's (vendor's) invoice.

Procurement costs decrease as the order quantity increases.

- Inventory Carrying costs, which vary with quantity ordered, based on average inventory andconsist of:

  i) Interest on capital investment;
  ii) Cost of storage facility, up-keep of material, record keeping etc ;
  iii) Cost involving deterioration and obsolescence; and
  iv) Cost of insurance, property tax, etc.

4. What is EOQ?

- Economic order quantity (EOQ) is the order quantity of inventory that minimizes the total cost of inventory management.
- Economic Order Quantity (EOQ) is a production formula used to determines the most efficient amount of goods that should be purchased based on ordering and carrying costs. In other words, it represents the optimal quantity of inventory a company should order each time in order to minimize the costs associated with ordering and holding inventory.
- If C is the cost for one item, I is the cost of carrying inventory in percentage per period, including insurance, obsolescence, taxes etc, P is the Procurement cost associated with one order, and U is total quantity used per period say annually. Then Q the economic lot size or E.O.Q is, $Q = \frac{\sqrt{\mathbf{2UP}}}{\mathbf{CI}}$

5. What are the objectives of inventory control?

- The objectives are:

i) To minimize investment in inventory,

ii) To maximize the service levels to the firm's customers and its own operating departments.

6. State the advantages of maintaining inventory control.

- One does not face shortage of materials.
- Materials of good quality and procured in time minimises defects in finished goods.
- Delay in production schedules is avoided.
- Production targets are achieved.
- Accurate delivery dates can be ascertained and the industry builds up reputation and better relations with customers.

Section – B

1. **What are the objectives of inventory control and how to achieve it?**

- The objectives are:

i) To minimize investment in inventory,

   i) To maximize the service levels to the firm's customers and its own operating departments.
   ii) To avoid shortage of materials.
   iii) Materials of good quality and procured in time minimises defects in finished goods.
   iv) To avoid Delay in production schedules is.
   v) To achieve Production targets.

- Inventory control aims at keeping track of inventories. In other words, inventories of required and in desired quantities should be made available to different departments as and when they need.
- This is achieved by,
  - Purchasing material at an economical price, at proper time and in sufficient quantities to run short of them at any instant.
  - Providing a suitable and secure storage location.
  - Providing enough storage space.
  - A definite inventory identification system.
  - Adequate and responsible store room staff.
  - Suitable requisition procedure.
  - Up-to-date and accurate record keeping.
  - Periodic inventory checkup.
  - Division of inventory under A, B and C items, exercising the control accordingly and removing obsolete inventory.

2. **Describe the functions of inventory control.**

- Maintain smooth and efficient production flow.
- Purchase in desired quantities and thus nullify the effects of changes in prices or supply.
- Keeps a process continuous operating.
- Create motivational effect. A person may be tempted to purchase more displayed if inventories are in bulk.

Section – c

1. **Explain ABC analysis.**

Necessity: - As the size of the industry increases, the number of items to be purchased and then to be taken of also increases. Purchase and control of all items at a time and in bulk much before their use, irrespective of their usage value, price or procurement problems, blocks and involves a lot of money and man hours, and is therefore uneconomical. ABC analysis helps segregating the items from one another and tells how much valued the items is and controlling it to what extent is in the interest of the organization.

PROCEDURAL STEPS: -

1. Identify all the items used in an industry.
2. List all the items as per their value.
3. Count the number of high valued medium valued and low valued items.
4. Find the percentage of high, medium and low valued items. High valued items

Contribute for 70% or so of the total inventory cost and medium and low valued items, 20 and 10% respectively.

5. A graph can be plotted between percent of items (on X-axis) and per cent of total inventory cost (on Y-axis).

It can be seen that 70% of the total inventory cost is against 10% of the total items (called, A-items), 20% against 20%of the items (B-items) and 10% against a big bulk, i.e. 70% of the items(called C-items).

Thus, ABC analysis furnishes the following information: -

A-ITEMS

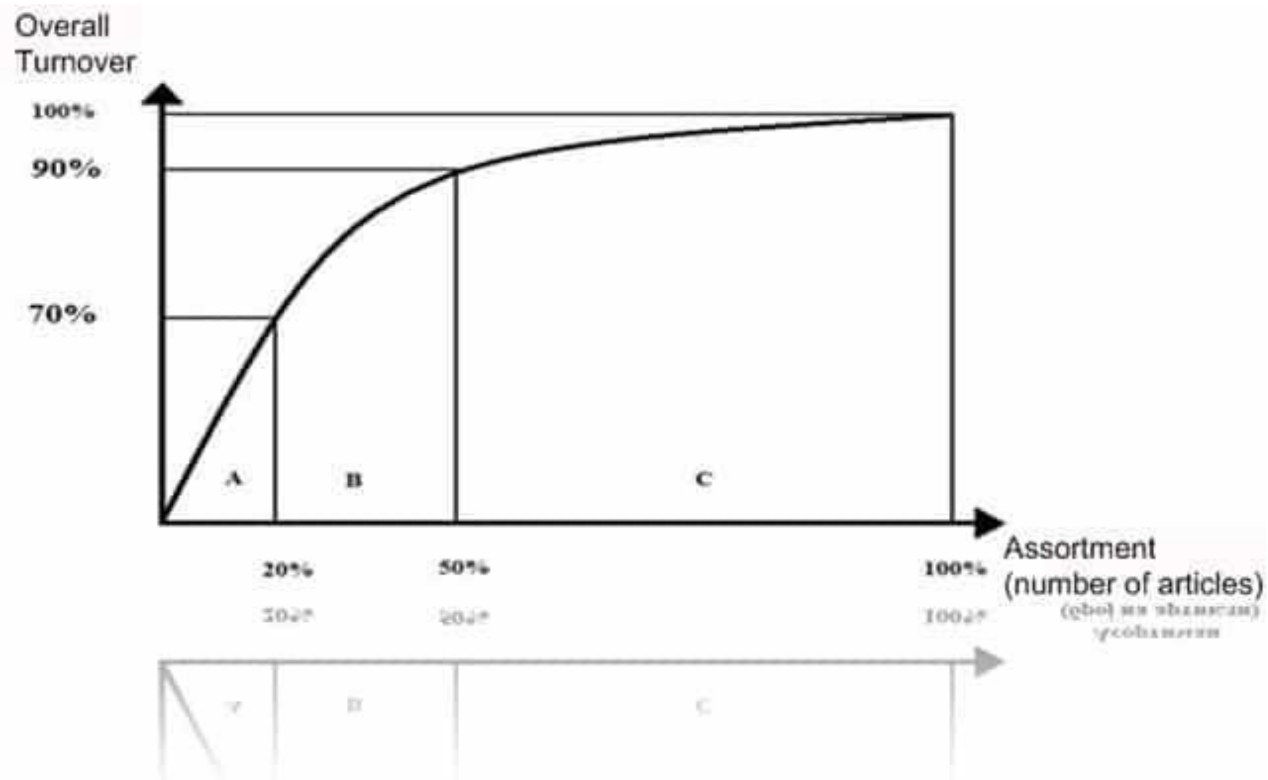
- A-items are high valued but are limited or few in number. They need careful and close inventory control. Minimum and maximum limits, and reorder point is set for A items. Such items should be thought of in advance and purchased well in time.
- A detailed record of their receipt and issues should be kept, and proper handling and storage facilities should be provided for them.
- Such items being costly are purchased in small quantities often and just before their use .This of course increases the procurement costs and involves a little risk of non-availability. However, the locked-up inventory cost decreases and the problems of storage and care taking are minimized.
- A-items generally account for 70-80% of the total inventory cost and they constitute about 10% of the total items.

B-ITEMS

- B-items are medium valued and their number lies in between A and C-items. Such items need moderate control. They-are more important than C-items.
- They are purchased on the basis of past requirements; a record of receipts is issues are kept and a procurement order is placed as soon as the quantity touches reorder point.
- These items being comparatively less costly, a safety stock of up to 3 months may be kept, whereas it needs a stock of fortnight or so in the case of A-items. B-items also require careful storage and handling.
- In brief, B-items need every care but not so intensive as is required for A-items.
- B-items generally account for 20 to 15% of the total inventory cost and constitute about 15% to 20% of the total items.

C-ITEMS

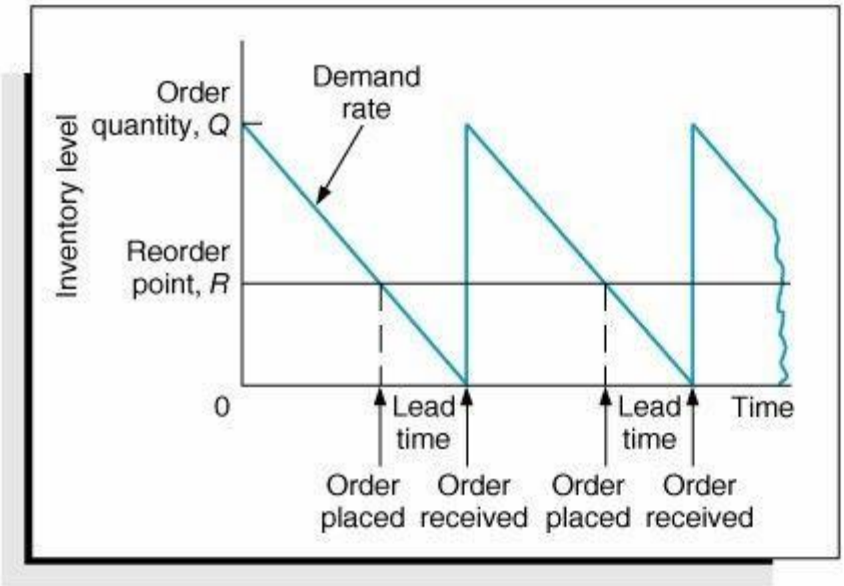
- C-items are row valued, but maximum numbered items.
- These items do not need any control, rather-controlling them to uneconomical.
- These are the least important items like clips, all pins, washer, rubber bands, etc. They aregenerally produced just before they finish.
- C-items generally account for 10 to 5% of the total inventory cost and they constitute about 75%of the total items.



2. Briefly explain the EOQ model.

ECONOMIC ORDER QUANTITIY MODEL: -

- Economic order quantity (EOQ) is the order quantity of inventory that minimizes the total cost of inventory management.
- Economic Order Quantity (EOQ) is a production formula used to determine the most efficient amount of goods that should be purchased based on ordering and carrying costs. In other words, it represents the optimal quantity of inventory a company should order each time in order to minimize the costs associated with ordering and holding inventory.
- A problem which always remains is that how much material may be ordered at a time. An industry making bolts will definitely like to know the length of steel bars to be purchased at any one time. This length of steel bars is called "Economic order Quantity" and an economic order quantity is one which permits lowest cost per unit and is most advantageous.
- Before calculating economic order quantity it is necessary to become familiar with terms like maximum inventory, minimum inventory, standard order and order point, which are known as quantity Standards.
- Starting from an instant when inventory OA is in stores, it (inventory) consumes gradually in quantity from A along AD at a uniform rate. It is preknown that it takes L number of days between initiating order and receiving the required inventory. Therefore, as the quantity reachespoint B, purchase
- Requisition is initialled which takes from B to C that is time R. From C to D is the inventory procurement time P. At the point D when only reserve stock is left, the ordered material is supposed to reach and again the total quantity shoots to its maximum value, i.e. the point A, (A =A,).
- Maximum Quantity OA is the upper or maximum limit to which the inventory can be kept in the stores at any time.
- Minimum Quantity OE is the lower or minimum limit of the inventory which must be kept in the stores at any time.
- The purpose should be to hold enough and not excessive stock of material. Stock holding:-
  i) Avoids running out of stock.
  ii) Helps creating a buffer stock which may be utilized if the material falls below the minimum level.
  iii) Makes sure the predefined delivery dates.
  iv) Provides quick availability of materials.
  v) Takes care of price fluctuations and shortage of inventory in the market.
  vi) Advises regarding, obsolete and slow-moving items.
  vii) Helps in standardization and thus reducing the variety of items to be handled.



- Standard Oder: - (A'D) is the difference between maximum and minimum quantity and it isknown as economical purchase inventory size.
- Reorder Point (B) indicates that it is high time to initiate a purchase order and if not done so the inventory may exhaust, and even reserve stock utilized before the new material arrives.
- From B^1 to $D^{1,}$ it is as lead time (L) and it may be calculated on the basis of past experience. It includes: -

  i) Time to prepare purchase requisition and placing the order;

  ii) Time taken to deliver purchase order to the seller;

  iii) Time for seller (vendor) to get or prepare inventory; and

  iv) Time for the inventory to be dispatched from the vendor’s end and to reach the customer.
- Time' (a) above is known as requisition time (R) and (b) +(c) +(d)is the procurement time (p).
- The economic lot size for an order or the economic order quantity depends upon two types of costs:
- Inventory procurement costs, which consist of expenditure connected with

  i) Receiving quotations;

  ii) Processing purchase requisition;

  iii) Following up and expediting purchase order;

  iv) Receiving material and then inspecting it; and

  v) Processing seller's (vendor's) invoice.

  vi) Procurement costs decrease as the order quantity increases.
- Carrying costs, which vary with quantity ordered, base on average inventory and consist of:

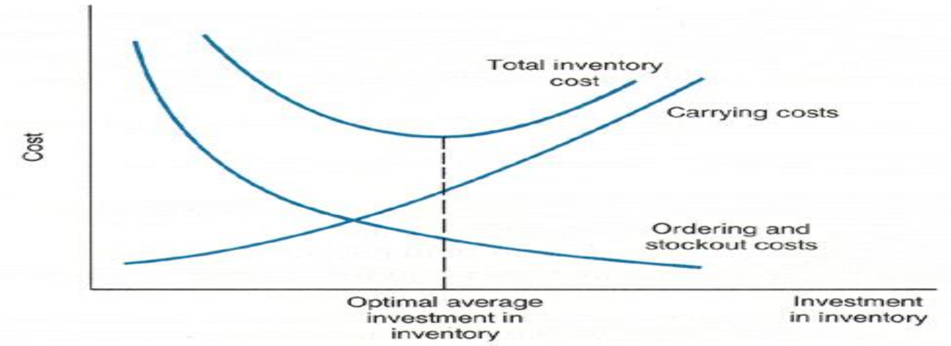
  i) Interest on capital investment;

ii) Cost of storage facility, up-keep of material, record keeping etc ;

iii) Cost involving deterioration and obsolescence;

iv) Cost of insurance, property tax, etc.

- Carrying costs are almost directly proportional to the order size or lot size or order quantity, the procurement costs and inventory carrying costs have been plotted with respect to quantity in lot. Total cost is calculated by adding procurement cost and carrying cost. Total cost is minimum at the point A and thus A' represents the economic order quantity or economic lot size.



- Another method of finding E.O.Q. that is by mathematical means is given below:-
- If C is the cost for one item, I is the cost of carrying inventory in percentage per period, including insurance, obsolescence, taxes etc, P is the Procurement cost associated with one order, and U is total quantity used per period say annually. Then Q the economic lot size or E.O.Q is, $Q = \frac{\sqrt{2UP}}{CI}$.

1. **A company requires 16000 units of raw material costing Rs.2 per unit. The cost of placing an order is Rs. 45 and the carrying costs are 10% per year per unit of the average Inventories. Determine: (i) the economic order quantity, (ii) cycle time.**
2. **The rate of use of a particular raw material from stores is 20 units per year. The cost of placing and receiving an order is Rs.40. The cost of each unit is Rs 100. The cost of carrying inventory in percent per year is 0.16 and it depends upon the average stock. Determine the economic order quantity. If the lead time is 3 months, calculate the reorder point.**
3. **Find the economic order quantity from the following data:**
   i) Average annual demand = 30,000 units
   ii) Inventory carrying cost = 12% of the unit value per year
   iii) Cost of placing an order = Rs. 70
   iv) Cost of unit = Rs. 2
4. **Given data:**
   i) Annual usage, U= 60 unit
   ii) ii) Procurement cost, P=Rs. 15 per order
   iii) iii) Cost per piece, C=Rs. 100
   iv) iv) Cost of carrying inventory I, a percentage including expenditure on obsolescence, taxes, insurance, deterioration etc. = 10%.
   Calculate E.O.Q.

Operation Research (LPP) & Network Analysis

Section - A

1. **Define operation research.**
    - Operations research is the organised application of modern science, mathematics and computer techniques to complex military, government, business or industrial problems arising in the direction and management of large systems of men, materials, money and machines. The purpose is to provide the management with explicit quantitative understanding and assessment of complex situations; to have sounder basis for arriving at best decisions.
    - Operations Research signifies research on operations. However, it takes into consideration a particular view of operations and a particular kind of research.
2. **Define Linear Programming.**
    - Linear programming is powerful mathematical technique for finding the best use of the limited resources of a concern. It may be defined as a technique which allocates scarce available resources under conditions of certainty in an optimum manner, (i.e., maximum-minimum) to achieve the company objectives which may be, maximum overall profit, or minimum overall cost.
    - It had its early use for military applications but presently it is employed widely for business problems. It finds applications as resource allocation like crude oil distribution to refineries, production distribution; in agricultural works like blending fertilizers, selecting the right crop to be planted; in army such as bombers placements, troops deployment; and in finance, personnel and advertising.
3. **Define event.**
    - An event is a specific instant of time which marks the start and the end of an activity.
    - Event consumes neither time nor resources.
    - It is represented by a circle and the event number is written within the circle. Event and node are synonyms. Examples of event are – Start the motor, loan, approved, etc.
4. **Define activity.**
    - Every project consists of a number of job operations or tasks which are called activities.
    - An activity is an even element of a project and it may be process, a material handling or material procurement cycle, etc. for example, 'Install machinery ','arrange foreign exchange 'are activities.
    - An activity is shown by an arrow and it begins and ends with an event unlike event, an activity consumes time resources an activity may be performed by an individual or a group of individuals.
    - An activity is normally given a name like A, B, C, etc., which is marked bellow the arrow and the estimated time to accomplish the activity is marked above the arrow.
    - Activities are classified as: critical activity, non-critical activity and dummy activity
5. **Define float or slack.**
    - Float or slack, means spare time, a margin of extra time over and above its duration which a non-critical activity can consume without delaying the project.

- Float is the difference between the time available for completing an activity and the time necessary to complete the same.
- Slack is with reference to an event and float is with respect to an activity. In other words, slack is used with PERT and float with CPM—but in general practice, they maybe used interchangeably.
- It is the additional time which a non-critical activity can consume without increasing the project duration. However, total float may affect the floats in previous and subsequent activities.

Total float=(LST-EST) or (LFT-EFT) and it can be negative also.

6. Define critical path.

- It is that sequence of activities which decide the total project duration. Critical path is formed by critical activities.
- A critical path consumes maximum resources. It is the longest path and consumes maximum time. A critical path has zero float.
- The expected completion dates cannot be met, if even one critical activity is delayed.
- A dummy activity joining to critical activities is also a critical activity.
- A critical path reveals those activities which must be manipulated by some means or the other if the scheduled completion dates are to be met.

7. Differentiate between EST and LST.

- **Earliest start time (EST):** - It is the earliest possible time at which an activity can start and is calculated by moving from first to last event in a network diagram.
- **Latest Start Time (LST):** - It is the latest possible time by which an activity can start. LST=LFT – duration of that activity.

8. Differentiate between EFT and LFT.

- **Earliest finish time (EFT):** - It is the earliest possible time at which an activity can finish.EFT=EST + duration of that activity.
- **Latest Finish Time (LFT):** - It is calculated by moving backward., from last event timeof the head event.

9. Define duration and total duration of activity.

- **Duration:** - Duration is the estimated or actual time required to complete a task or an activity.
- **Total project Time:** - It is the time which will be taken to complete a project and is found from the sequence of critical activities. In other words, it is the duration of critical path.

10. Define Network Diagram.

Network diagram is the basic feature of network planning. It is a diagram which represents all the events and activities in sequence, along with their interrelationships and inters dependencies.

11. Where LPP is applied?

Linear programming can be applied effectively only if,

a) The objectives can be stated mathematically.
b) Resources can be measured as quantities (number, weight etc.).
c) There are too many alternate solutions to be evaluated conveniently.
d) The variables of the problem bear a linear (straight line) relationship, ie., a change in one variable produces proportionate changes in other variables. In other words, doubling the

units of resources will double the profit. Problem solving is based upon the system of linear equations.

12. What do you mean by CPM?

- CPM - (CRITICAL PATH METHOD):- CPM is a technique used for planning, controlling the most logical and economic sequence of operation for accomplishing a project.
- The network utilized in CPM is for optimising the use of limited resources, progress and control. CPM is applicable to both large and small projects.

13. How estimated time is calculated in PERT?

The t_o, t_m, t_p are combined statistically to develop the expected time for an activity. Therefore expected time **(t_e)** = $\frac{\mathbf{to+(4\times tm,)+tp}}{\mathbf{6}}$

t_o = optimistic time, t_m= most likely time, t_p = Pessimistic time

Section –B

1. What do you mean by PERT?

- PERT – (PROJECT EVALUATION AND REVIEW TECHNIQUE):- PERT describes basic network technique which includes planning, monitoring and control of projects.
- PERT finds application in planning and control of complex set of tasks, functions and relationships.
- PERT is a very useful device for planning the time and resources.
- PERT actually developed as a research and development planning tool where activity timing could not be estimated with enough certainty.
- Because of the uncertainty of activity timing PERT acquired the shape of probability concepts which helps in estimating activity timings.
- For dealing with uncertainties associated with different activities PERT approach the expected time for each activity from the following three estimation-
    - Optimistic time (t_o) - It is the shortest possible time in which an activity can be completed if everything goes exceptionally well.
    - Most likely time (t_m) – It is the time in which the activities are normally expected to complete under normal conditions.
    - Pessimistic time (t_p) – it is the time which an activity will take to complete in case of difficulties i.e. if mostly the things go wrong conditions. It is the longest of all the three estimations.
- The t_o, t_m, t_p are combined statistically to develop the expected time for an activity. Therefore, expected time **(t_e)** =$\frac{\mathbf{to+(4\times tm,)+tp}}{\mathbf{6}}$
- **Standard deviation (S_t) = ($t_p - t_o$)/6**
- **Variance = $(S_t)^2$ = [($t_p - t_o$)/6]^2**

2. Define activity, critical activity, non-critical activity, dummy activity and critical path.

Activity: - Every project consists of a number of job operations or tasks which are called activities.An activity is an even element of a project and it may be process, a material handling or materialprocurement cycle, etc. for example, 'Install machinery ','arrange foreign exchange 'are activities. An activity is shown by an arrow and it begins and ends with an event unlike event, an activityconsumes time resources an activity may be performed by an individual or a group of individuals.An activity is normally given a name like A, B, C, etc., which is marked bellow the arrow and theestimated time to accomplish the activity is marked above the arrow

Activities are classified as:

i. **Critical Activities: -** In a network diagram critical diagram, critical activities are those which if consume more than their estimated time, the project will be delayed. An activity is called critical if it's earliest start time plus the time taken by it is equal to the latest finishing time. A critical activity is marked either by a thick arrow or to distinguish it from a mom-critical activities.

ii. **Non-Critical Activities: -** Such activities have provision so that, even if they consume a specified time over and above the estimated time, the project will not be delayed . ActivitiesB and D are non-critical activities.

iii. **Dummy Activities:** - When two activities start at the same instant of time the head events are joined by a dotted arrow and this is known as a dummy activity. Dummy activity does not consume time. A dummy activity may be non-critical or critical. It becomes a critical activity when its earliest start time is same as its latest finishing time.

Critical Path: - It is that sequence of activities which decide the total project duration. Critical path is formed by critical activities. A critical path consumes maximum resources. It is the longest path and consumes maximum time. A critical path has zero float. The expected completion dates cannot be met, if even one critical activity is delayed. A dummy activity joining to critical activities is also a critical activity. A critical path reveals those activities which must be manipulated by some means or the other if the scheduled completion dates are to be met

3. **Briefly explain about operation research.**

Operations research is the organised application of modern science, mathematics and computer techniques to complex military, government, business or industrial problems arising in the direction and management of large systems of men, materials, money and machines. The purpose is to provide the management with explicit quantitative understanding and assessment of complex situations; to have sounder basis for arriving at best decisions.

Methodology of operations Research: -

Various steps involved are as follows:

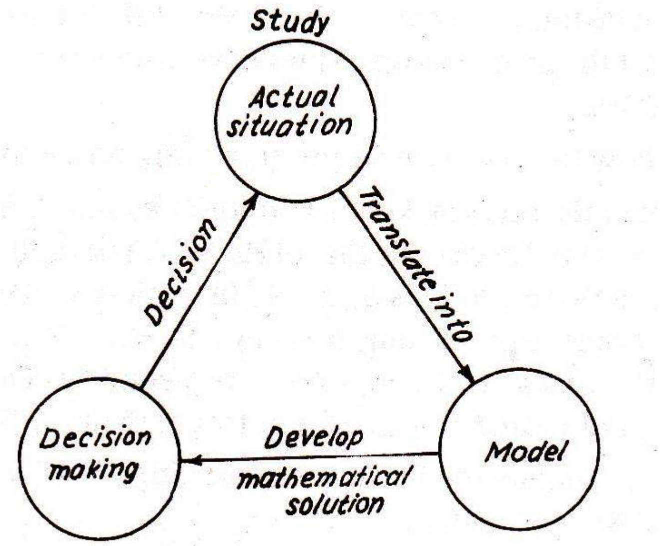
- Understand the actual real situation, capture the same and define the problem.
- Formulate a mathematical model
- Develop a mathematical solution - Data is supplied to the model. Information is computed, and results are analyzed to find the mathematical solution for alternative policies.
- Interpret the solution and prepare the information in such a form that it is meaningful, intelligible and quantitative. Translate it into a decision.
- Implement the decision to the real (actual) situation.
- Verify the results

After applying the solution to real situation, the actual results produced by the model must be tested statistically and verified to explore any significant deviation from the expected results. If found so, the model can be modified and again the cycle is repeated.

METHODS OF OPERATIONS RESEARCH: -

Various techniques used in Operations Research to solve optimization problems are as follows:

1. Linear programming:
   a) Graphical linear programming,
   b) Transportation Method:
      i. Vogel's Approximate Method.
      ii. North-West Corner Method.
   c) Simplex method,
2. Waiting line or Queuing theory.
3. Game theory.
4. Dynamic programming.



Operations Research Procedure.

4. **What are the three possible times used in PERT?**
   - For dealing with uncertainties associated with different activities PERT approach the expected time for each activity from the following three estimation-
     - Optimistic time (t_o) - It is the shortest possible time in which an activity can be completed if everything goes exceptionally well.
     - Most likely time (t_m) – It is the time in which the activities are normally expected to complete under normal conditions.
     - Pessimistic time (t_p) – it is the time which an activity will take to complete in case of difficulties i.e. if mostly the things go wrong conditions. It is the longest of all the three estimations.
   - The t_o, t_m, t_p are combined statistically to develop the expected time for an activity. Therefore, expected time **(t_e)** = $\frac{\mathbf{to+(4\times tm,)+tp}}{\mathbf{6}}$
   - **Standard deviation (S_t) = (t_p – t_o)/6**
   - **Variance = $(S_t)^2$ = [(t_p – t_o)/6]^2**
5. **With the help of suitable example explain how a LPP formulate graphically?**

<u>EXAMPLE: -</u> A furniture manufacturer makes two products x_1 and X_2, namely Chairs and Tables.

Each chair contributes a profit of Rs. 20 and €ach table that of Rs. 40. Chairs and Tables, from raw material to finished product, are processed in three sections s_1, s_2, s_3. In section s_1 each chair (X_1) requires one hour and each table (X_2) requires 4 hours of processing. In section S_2, each chair requires 3 hours and each table one hour and in section S_3, the times are 1 and 1 hour respectively. The manufacturer wants to optimize his profits if sections S_1, S2 and s_3 can be availed for not more than24,21 and8 hours respectively.

Solution: - (Always use graph paper for solving LPP graphically)

The First Step is to formulate the linear programming model, i.e., a mathematical model from the data given above. The model is as under:

Maximize $\quad Z = \text{Rs. } 20X_1 + \text{Rs. } 40X_2 \ldots\ldots\ldots\ldots (Z)$

Subject to

$$X_1 + 4X_2 \leq 24 \ldots\ldots\ldots\ldots (C_1)$$
$$3X_1 + X_2 \leq 21 \ldots\ldots\ldots\ldots (C_2)$$
$$X_1 + X_2 \leq 8 \ldots\ldots\ldots\ldots (C_3)$$
$$X_1, X_2 \geq 0 \ldots\ldots\ldots\ldots (C_4)$$

C_1 is constraint No. 1 and so on.

The *Second Step* is to convert the constraint inequalities temporarily, into equations, *i.e.*,

$$X_1 + 4X_2 = 24 \ldots\ldots\ldots\ldots (C_1)$$
$$3X_1 + X_2 = 21 \ldots\ldots\ldots\ldots (C_2)$$
$$X_1 + X_2 = 8 \ldots\ldots\ldots\ldots (C_3)$$

In *Third Step* axis are marked on the graph paper and are labelled with variables X_1 and X_2.

Fourth Step is to draw straight lines on the graph paper using the constraint equations, and to mark the feasible solution on the graph paper. For example, taking first constraint equation.

$$X_1 + 4X_2 = 24$$

Substitute $\quad X_1 = 0$, then $X_2 = 24/4 = 6$

Next, Substitute $\quad X_2 = 0$, then $X_1 = 24$

Mark the point of 24 at X_1 axis and point of 6 on X_2 axis. Join them. This straight line represents C_1 equation. Similarly constraint equations C_2 and C_3 can be plotted (Fig. 11.2).

According to constraint C_4, X_1 and X_2 are greater than (or equal to) zero, hence the marked area (region) between $X_1=X_2=0$ and C_1, C_2, C_3 represents the feasible solution.

As the *Fifth Step*, a (dotted) straight line representing the equation (Z) is drawn, assuming any suitable value of Z say 120.

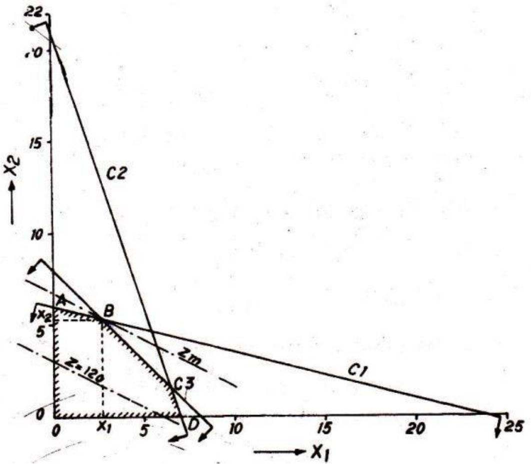
In the *Sixth step*, a straight line Z_m is drawn parallel to the line Z, at the farthest point of the region of feasible solution, *i.e.*, point B, at the intersection of C_1 and C_3. The co-ordinates of point B can be found by solving equations C_1 and C_3.

$$X_1+4X_2 = 24 \qquad ...(C_1)$$
$$X_1+X_2=8 \qquad ...(C_3)$$

Subtracting, $3X_2 = 16$, therefore, $X_2 = \frac{16}{3}$ and $X_1 = \frac{8}{3}$

These values of X_1 and X_2 can also be read from the graph itself. Thus the maximum value of Z is

$$Z_m = 20X_1+40X_2 = 20 \times \frac{8}{3} + 40 \times \frac{16}{3} = \frac{800}{3} = 266.6 \text{ (Ans)}$$



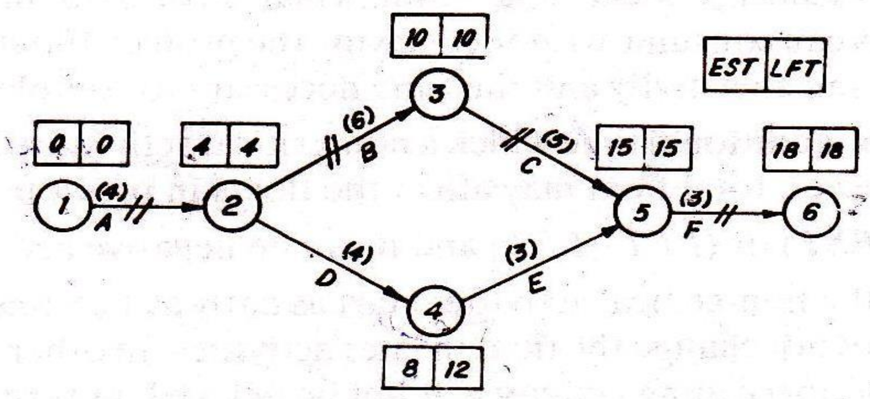
Section – C

1. Differentiate between PERT and CPM.

PERT	CPM
i. A probabilistic model with uncertainty in activity duration. Expected time is calculated from t_o, t_m and t_p.	A deterministic model with well-known activity times based upon past experience. It assumes that, the expected time is actually the time taken.
ii. An event-oriented approach.	An activity-oriented system.
iii. PERT terminology uses words like network diagram, events, and slack.	CPM terminology employs words like arrow diagram, nodes, and float.
iv. The use of dummy activities is required for representing the propersequencing.	The use of dummy activities is not necessary. The arrow diagram thus becomes slightly simpler.
v. PERT basically does not demarcate between critical and non-critical activities.	CPM marks critical activities.
vi. PERT finds applications in projects where resources are always made available as and when required.	CPM is employed to those projects where minimum overall costs are of primary importance. There is better utilization of resources.
vii. Especially suitable in defense projects	Suitable for problems in industrial setting,

and R&D where activity times cannot be reliably predicted.	plant maintenance, civil construction projects, etc.

2. **A small engineering project consists 6 activities namely A, B, C,D, E, and F with duration of 4, 6, 5, 4, 3 and 3 days respectively. Draw the network diagram and calculate EST, LST, EFT, LFT and floats. Mark the critical path and find total project duration.**
3. Solution:-



(1) *EST* is calculated by starting from event-1, *i.e.*, activity *A* and giving it a time 0 (*EST*).

Now *EST* of activity *B*=0+duration of activity *A*=4

EST of activity *C*=*EST* of activity B+duration of activity *B*=4+6=10 and so on.

EST of activity *F* can be found by following two paths, *i.e.*, 1-2-3-5 and 1-2-4-3. The path 1-2-3-5 gives 15th day whereas the path 1-2-4-5 estimates 11th day as *EST* of activity *F*.

TABLE 10.1

Activity	*Duration (days)*	*EST*	*LST*	*EFT*	*LFT*	*Total Float*	*Free Float*	*Independent Float*
A	4	0	0	4	4	0	0	0
B	6	4	4	10	10	0	0	0
C	5	10	10	15	15	0	0	0
D	4	4	8	8	12	4	0	0
E	3	8	12	11	15	4	4	0
F	3	15	15	18	18	0	0	0
Col. 1	Col. 2	Col. 3 from N.W. diagram	Col. 4 *LFT* −*D*	Col. 5 *EST* +*D*	Col. 6 from N.W. diagram	Col. 7 *LST*−*EST* or *LFT*−*EFT*		

Naturally the bigger value (15) is selected because until activity *C* is completed which ought to finish on 15th day, activity *F* cannot be started.

EST for other activities is calculated by proceeding similarly, in the forward direction from the first event to the last event.

(2) *LFT* is calculated in a similar manner as *EST* but by proceeding backward from the last event to

the first one. For example

LFT for activity $F=18$

LFT for activity C and $E=18-$duration of activity $F=15$

LFT for activity D $= LFT$ for activity E$-$duration of activity E

$= 15-3=12$ and so on.

(3) LST for each activity is calculated from the relation,

$LST=LFT$ of an activity$-$duration of that activity.

For example, LST of activity $D=12-4=8$.

(4) EFT for each activity is calculated from the relation

$EFT=EST$ of an activity$+$duration of that activity.

For example, EFT of activity $D=4+4=8$.

(5) Total float$=(LST-EST)$ or $(LFT-EFT)$

For example, total float for activity

$D=(8-4)$ or $(12-8)=4$.

(6) Free float$=EST$ of tail event$-EST$ of head event$-$activity duration.

For example, free float for activity D,

$= 8-4-4=0$

(7) Independent float$=EST$ of tail event$-LFT$ of head event$-$activity duration.

For example, Independent float for activity D

$= 8-4-4=0$

(8) Critical path is one which consumes maximum time and it is 1-2-3-5-6. The total project duration, therefore, is

4+6+5+3=18days. (Ans).

4. **Maximize: $Z=5X+6Y$**
   Subject to: $X+4Y \leq 32$; $2X+Y \leq 36$
5. **Maximize: $Z=8X+6Y$**
   Subject to: $4X+2Y \leq 60$; $2X+4Y \leq 48$
6. **Maximize: $Z=10X+5Y$**
   Subject to: $4X+5Y \leq 100$; $2X+4Y \leq 80$
7. **Minimize: $Z=20X+10Y$**
   Subject to: $X+2Y \geq 40$; $4X+3Y \geq 60$; $3X+Y \geq 30$; $X, Y \geq 0$
8. **Maximize: $Z=X+5Y$ when**
   Subject to: $5X+6Y \leq 30$; $3X+2Y \leq 12$; $X,Y \geq 0$
9. **Minimize: $Z=2x+3Y$when**
   Subject to: $x+Y\geq6$; $2x+Y\geq7$; $x+4Y\geq8$; $x,Y\geq0$

PRODUCTION, PLANNING AND CONTROL

INTRODUCTION: -

Products are manufacture by the transformation of raw material (in to finished goods).This is how production is achieved. Planning looks ahead, anticipates possible difficulties and decides an advance as to how the production, best, be carried out. The control phase makes sure that the programmed production is constantly maintained.

A production planning and control system has many functions to perform, some, before the arrival of raw material and tools, and others while the raw materials undergoes processing. The various functions are as follows:

a) Forecasting: Estimation of type, quantity and quality of future work.
b) Order writing: Giving authority to one or more persons to undertake a particular job.
c) Product design: Collection of information regarding specifications, bill of materials, drawing ,etc.
d) Process planning and routing: Finding the most economical process of doing a work and (then) deciding how and where the work will be done.
e) Material control: It involves determining the requirements and control of materials.
f) Tool control: It involves determining the requirements and control of tools used.
g) Loading: Assignment of work to manpower, machinery etc.
h) Scheduling: It is the time phase of loading and determines when and in what sequence the work will be carried out. It fixes the starring as well as the finishing time for the job.
i) Dispatching: It is the transition from planning to action phase. In this phase the worker is ordered to start the actual work.
j) Progress reporting:
   i. Data regarding the job progress is collected.
   ii. It is interpreted by comparison with the preset level of performance.
k) Corrective action:
   i. Expediting means taking action if the progress reporting indicates a deviation of the plan from the originally set targets.
   ii. Replanning - Replanning of the whole affair becomes essential; in case expediting fails to bring the deviated plan to its actual (right) path

Process Planning: -

Definition and Concept:-

- Process planning means the preparation of work detail plan.

- Since the process is required to manufacture a product, it is necessary to plan the process.
- Process planning is determined the most planning is determining the economical method of performing an operation or activity.
- Process planning comes after it has been decided as what is to be made.
- Process planning develops the broad plan of manufacture for the component or product.
- Process planning takes as its input the drawing or other specifications which show what is to be made and forecasts or orders which indicate the product quantity to be manufactured.

Information Required to Do Process Planning: -

- Quantity of work to be done along with product specifications.
- Quality of work to be completed.
- Availability of equipments, tools and personnel (giving dates, etc.).
- Sequence in which operations will be performed on the raw material.
- Names of equipments on which the operations will be performed.
- Standard time for each operation.
- When the operations will be performed.

Process Planning Procedure: -

The different steps involved are:

1. **Selection Process: -**

- A process is necessary in order to shape, form, condition and join materials and components with the help of machines and labour in order to convert raw material into a finished product.
- One should select the most economical process and sequence that satisfy the product specifications.

The selection of process depends upon:

a) Cur-rent production commitments. If enough work has already been allocated to more efficient Equipments, the current work may have to be passed on to less efficient machines to complete the same In time.

b) Delivery date: An early delivery date may:

i. Force the use of less efficient machines,

ii. Rule out the use of special tools and jigs as they will take time for design and fabrication.

c) Quantity to be produced:

- Small quantity will not probably justify the high cost of preparation and efficient set-ups. Thus, quite possible they may have to be made on less efficient machines and vice-versa.

d) Quality standards :

- Quality standards may limit the choice of making the product on a particular machine, etc.

2. **Selection Of Material:-**
    - Material should be of right quality and chemical composition as per the product specifications.
    - Shape and size of material should restrict the scrap (i.e., material removed forgetting the product shape).
3. **Selection Of Jigs, Fixtures and Other Special Attachments: -**

These supporting devices are necessary:

- To give higher production rate;
- To reduce cost of production per piece.

4. **Selection Of Cutting Tools and Inspection Gauges: -**

They, respectively, are necessary to:

- Reduce production time.
- Inspect accurately and at a faster rate.

5. Make the process layout indicating every operation and the sequence in which each operation is to be carried out.
6. Find set-up time and standard time for each operation.
7. Manifest process planning by documents such as operation and Route sheets, which summarize the operations required, the preferred sequence of operations, auxiliary tools required, estimated operation times etc.

Scheduling: -

Concept: Scheduling means- when and in what sequence the work will be done. It involves deciding as to when the work will start and in certain duration of time how much work will be finished . Scheduling deals with orders machines, i.e., it determines which order will be taken up on which machine and in which department by which operator. While doing so, the aim is to schedule as large amount of work as the plant facilities can conveniently handle by maintaining a free flow of material along the production line.

Scheduling may be called the time phase of loading. Loading means the assignment of tasks or work to a facility whereas scheduling includes in addition, the specification of time and sequence in which the order/work will be taken up.

Factors Affecting scheduling: - The following factors affect production scheduling and are considered before establishing the scheduling plan.

a) External factors:
    1. Customer's demand,
    2. Customer’s delivery dates, and
    3. Stock of goods already lying with the dealers and retailer.

b) Internal factors:

1. Stock of finished goods with the firm,
2. Time interval reprocesses finished goods from raw material. In other words-how much time will be required to manufacture each component subassembly and then assembly (i.e., the final product),
3. Availability of equipment and machinery; their total capacity and specifications,
4. Availability of materials; their quantity and specification,
5. Availability of manpower (number, type and kind of skill,
6. Additional manufacturing facilities if require, and
7. Feasibility of economic production runs.

<u>Scheduling Procedure and Techniques: -</u> Scheduling normally starts with the master schedule.

A-master schedule resembles central office which processes information about all the order in hand. Master schedule, is a weekly breakdown of the production requirements. The total capacity in any week is of 100 hours of work in foundry shop.

MASTER SCHEDULE FOR THE FOUNDRY SHOP Maximum Production 100 hrs Minimum Production 8 hrs			
WEEK-1	WEEK-2	WEEK-3	WEEK-4
15	18	20	15
25	25	12	10
20	28	32	
35			

Master schedule for a foundry shop.

As the orders are received, depending upon their delivery dates they are marked on the master schedule, when the shop capacity is full for the present week the newly acquired orders are carried over to the next and so on. A master schedule is thus update continuously, It depicts a carried over to the next week and so on. A master schedule is thus updated continuously; it depicts a running total of the production requirements and shows the work ahead- yet to be completed. Master schedule is actually the basis for all subsequent scheduling techniques.

A Master Schedule possesses the following advantages, disadvantages and applications.

<u>Advantages: -</u>

1. It is simple and easy to understand,
2. It can be kept running (i.e., current),

3. It involves less cost to make it and maintain,
4. It can be maintained by non-technical staff, and
5. A certain percentage of total weekly capacity can be allocated for rush orders.

Disadvantages: -

1. It provides only overall picture, and
2. It does not give detailed information.

Applications: -

It finds applications:

1. In big firms, for the purpose of loading the entire plant,
2. In Research and Development organizations, and
3. For the overall planning in foundries, computer centres, repair shops, etc.

Perpetual Scheduling: -

Like master scheduling, it is also simple and easy to understand, is kept Current, involves less costs and can be maintained by clerical staff. But, the information which it provides is very gross and at the same time it is not clear from the chart-when the work will take place.

Making of perpetual schedule involves two steps:

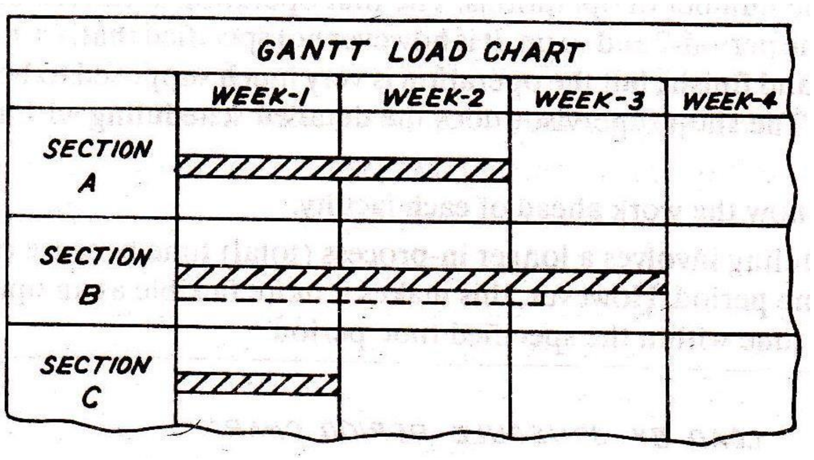
i. Preparation of load Analysis sheet from the orders in hand.

Figure :-

LOAD ANALYSIS SHEET			
	LOAD IN HOURS/DAYS		
ORDER NO.	SECTION A	SECTION B	SECTION C
X-320	25	10	16
Y-210	10	15	10
Y-314	18	20	8
Z-150	8	25	—
⋮	⋮	⋮	⋮

Load analysis sheet

ii. The total load against each section is added up and knowing the weekly capacity (department), of a section the number of weeks load against each department is calculated and plotted on a Gantt load chart as shown in Fig:-



Gantt load chart.

The shaded bars show the actual work load against each section.

Additional information, if any (regarding the work load), can be indicated by dotted line.

Dispatching: -

It is concerned with getting the work started. Dispatching ensures that the plans are properly implemented. It is the physical handing over of a manufacturing order to the operating facility (a worker) through the release of orders and instructions in accordance with a previously developed plan of activity (time and sequence) established by the scheduling section of the production planning and control department. Dispatcher transmits orders to the various shops. Dispatch function determines-by whom the job shall be done and it co-ordinates production. It is the key point of a production communication system. It creates a direct link between production and sales.

A dispatcher is familiar with the productive capacity of each equipment. He always keeps an eye over the progress of orders which move at different speeds on different routes.

Dispatch Procedure: -

The product is broken into different components and components into

Operations. A route sheet for the part (component) C having three operations on it is shown in Fig:-

ROUTE SHEET PART C
Material
Operation-1
Operation-2
Operation-3

Route Sheet.

The various steps of dispatch procedure for each operation are listed below,

in sequence.

(a) Store Issue Order: Authorize stores (department) to deliver require raw material.

(b) Tool Order: Authorise tool store to release the necessary tools. The tools can be collected by the tool room attendant.

(c) Job Oder: Instruct the worker to proceed with the operation.

(d) Time Ticket: It records the beginning and ending time of the operations and forms the basis for worker's pay.

(e) Inspection Order: Notify the inspectors to carry out necessary inspections and report the quality of the component.

(f) Move Order: Authorise the movement of materials and components from one facility (machine) to another for further operations.

In addition, there are certain other dispatch aspects which have to be taken care of,

1. All production information should be available beforehand.
2. Various order cards, and specification drawings should be ready.
3. Equipments should be ready for use.
4. Progress of various orders should be properly recorded on the Gantt charts or display boards.
5. All production records should be properly maintained.

Routing: -

Routing lays down the flow of work in the plant. It determines what work is to be done and where and how it will be done. Taking from raw material to the finished product, routing decides the path and sequence of operations to be performed on the job from one machine to another. The purpose is to establish the optimum sequence of operations. Routing is related to considerations of layout, temporary storage of in-process inventory and material handling.

Routing in continuous industries does not present any problem because of the product type of layout, where the equipment is laid as per the sequence of operations required to be performed onthe components (from raw material to the finished products).

In open job shops, since, every time the job is new, though operation sheets (sometimes) may serve the purpose, but the route sheets will have to be revised and this involves a greater amount of work and expertise.

Routing Procedure: -

Various procedural steps are as follows:

a) The finished product is analysed from the manufacturing standpoint in order to decide how many components can be made in the plant and how many others will be purchased (Make/Buy decision) from outside through vendors, by subcontracting, etc. Make/buy decision depends upon the work load in the plant, availability of equipment and personnel to manufacture all components, and the economy associated with making all components within the plant itself.

b) A parts list and a bill of materials is prepared showing name of the part, quantity, material specifications, amount of materials required, etc. The necessary materials, thus, can be procured.

c) From production standards-machine capacities, machine characteristics and the operations which must be performed at each stage of manufacture are established and listed in proper sequence on an operation and route sheet, (See figure). The place where these operations will be performed is also decided.

Actually, operation sheet and route sheet are separate. An operation sheet shows everything about the operations, i.e., operation description, their sequence, type of machinery, tools, set up and operation times, whereas a route sheet besides listing the sequence of operations and relation between operation and machine, also details the section (department) and the machines to whom the work will flow. First two columns of Fig. are mainly those of route sheet which show the manufacturing route for given component.

OPERATION & ROUTE SHEET

Component No.	Drawing ....
Name of Component	
....	Quantity ....
Material	To be completed on ....

ROUTING		OPERATION NO.	OPERATION DESCRIPTION	TOOLS REQD.	FIXTURES & OTHER ACCESS-ORIES	TIME		
SECT-ION	MACH-INE					SET UP	OPERA-TION	TOTAL

Operation and route sheet

The difference between an operation sheet and a route sheet is that an operation sheet remains same for the components if the order is repeated but the route sheet may have to be revised if certain machines are already committed to other orders (jobs) on hand. Except this small difference, both the sheets contain practically the same information and thus are generally combined into one sheet known as 'operation and route sheet'.

d) The next step is to determine the lot size or the number of components one lot or batch. to be manufactured in in the case of an order from a particular customer, it is generally equal to a number within 10% of the order quantity. In other cases the principle of economic batch quantity can be applied to determine the batch size.

e) Standard scrap factors (single or cumulative) and the places (i.e., after a particular operation or assembly) where scrap is very likely to occur are identified. The actual scrap in each can be recorded on the control chart. Causes for points out of control limits are explored and corrected. The variable like workers, machinery and schedules may also be adjusted to minimize scrap.

f) The cost of the component is analysed and estimated through the information obtaine6 in steps (a) to (e) above. The cost consists of material and labour charges, and other specific and general indirect expenses.

Progress Control:-

Once the actual production has started, it becomes essential to keep an eye at the progress of the work so that, if required, timely corrective action can be taken. progress control means - trying to achieve the standards set, i.e., a certain level of efficiency or a certain volume of production in a specified duration. The system of progress control should be such that it furnishes timely, adequate and accurate information about the progress made, delays and under- or over- loading.

Steps Followed In Progress Control:-

a) Setting up a system to watch and record the progress of the operating facility (production section).
b) Making a report of the work progress or work accomplishment.

c) Transmission of report to :
   1. Control group for necessary control action, and
   2. Accounting group for recording material and labour expenditures.
d) Interpretation of the information contained in the progress report by the control group.
e) Taking corrective action, if necessary.

INSPECTION AND QUALITY CONTROL

INSPECTION:

- Inspection is the continuous process adopted during various stages of manufacturing to control the product quality.
- Inspection is the art of comparing materials, products or performances with established standards.
- Inspection means checking the acceptability of manufactured products.
- The act of checking weather a product actually performs the function it is supposed to do or not, is called inspection.
- Inspection means checking of materials, manufactured products or components, standard parts at various stages of manufacturing by comparing them with suitable standards.

NEED OF INSPECTION:

- It helps to purchase good quality raw material, tools and equipments.

- It ensures that the parts, materials or components conform to established standards.
- It compares the product with the established standards, which helps in quality control.
- It finds the defect in raw material before use.
- It finds the defective parts and stops their further processing before assembly.
- It checks the finished product to measure its defects or weaknesses.
- It controls the cost of reproduction of products or other expenses of defective parts.
- It helps to maintain customer relationships by supplying no faulty products to them.
- It controls workmanship of workers.
- It prevents further work on spoiled in-process products.
- It separates defective components from non-defective ones ensuring the quality of products.

PLANNING OF INSPECTION:

- ***What to inspect*? –** In the inspection the *parameters* (such as: diameter, length) are checked or inspected by the working persons. These parameters may be different for different kind of jobs. The inspector determines what parameters are to be inspected in inspection.
- ***When to inspect*? –** There are three basic steps for the *time of inspection* such as - incoming material inspection, material inspection at each and every stage of halt during the processes and final inspection of outgoing products. The inspector decides the time of inspection in these cases.
- ***Who should inspect*? –** Before the production process some *skilled persons* should appoint for the inspection of products for their accuracy.
- ***Where to inspect*?** – Generally, three types of *places* are selected for inspection such as: floor,centralized or separate inspection room. The selection of places depends upon the manufacturing conditions.
- ***How to inspect?* –** The factors which influence the method of inspection includes type of product, operations involved etc.
- ***How much to inspect?* –** The degree of inspection depends upon many factors such as nature of the product, accuracy of the product, production process, reliability of standards, customers requirements and particular requirements of any manufacturing systems.

TYPES OF INSPECTION:

Depending upon the variety of products and requirements, inspections are classified as follows.

- **Remedial and Preventive Inspection –** In ***preventing inspection*** special attention is given to the accuracy of manufacturing process so that the possibility of defects and waste is completely removed. It is also known as constructive inspection. In ***remedial or corrective inspection,*** the defective parts are detected and the good products are chosen among the defective parts.
- **Operative or Stage Inspection –** This inspection takes place at each stage or at the end of some functional operations. It eliminates the defective parts, checks the causes of defects, minimizes the wastage and and controls the cost.
- **Incoming or Receiving Inspection –** The inspection of raw materials, purchased parts, assemblies, equipments before its delivery for process is known as Incoming inspection. It controls the quality of the above and eliminates the material of below specifications.
- **In-process Inspection** – During the manufacturing process this inspection is done to control the quality at each and every stage by preventing the unnecessary hand work during assembly, large waste, extra work on defective products.

- **Final Inspection –** In this inspection the finished product is checked at its every surface manually and by using the testing equipments for the acceptance of the products.

FACTORS INFLUENCING THE QUALITY OF MANUFACTURE:

The following factors are generally affecting the quality of manufacture.

- **Market demand –** It depends upon the demand of customers according to the product type, quality and quantity.
- **Man power –** Skilled persons are required for the quality design & quality manufacturing.
- **Materials –** Materials of right specification always gives good quality products, but it should be selected on the basis of production cost and requirements.
- **Money –** There is an important role of money to achieve quality. Investment is necessary at each stage of manufacturing for the maintenance, losses and improved products.
- **Management –** Managing committee should be conscious about the quality.
- **Machines and Methods –** To meet good quality improved machineries, good technologies and advanced methods are necessary.
- **Motivation of employees –** Employees should be motivated for the production of better quality products by doing some financial and non-financial benefits.
- **Modern information approaches –** The quality of products can be improved by adopting modern information approaches to various productions and marketing processes.

QUALITY CONTROL:

- Q*uality* suggests that the products are made according to the specifications determined by the customer's demand. It comes if the production and service is in economic conditions with the full certification of the customer.
- The quality of a product is known from the feedback received from end user or customer. In other words the quality means to enable production and service at most economical levels for full customer satisfaction.
- Quality is the degree of fitness which serves the purpose at the lowest cost. The quality of a product can be defined broadly in three aspects:
  - i) Quality design: - The quality of design concerned with durability, strength,interchangeability and chemical compositions of materials.
  - ii) Quality of performance: - The characteristics such as mechanical functioning, relativeassembly measure the performance of the product.
  - iii) Quality appearance: - the characteristics such as size confirming to the drawings, finishand workmanship result in the quality of appearance.
- Q*uality control* prevents the product form rejection. It helps to maintain and achieve the quality as per the specification and demand of customer. Quality is to be planned, achieved, controlled and improved continuously.
- Quality control is a mechanism by which the products are made to the specifications determined by the customer's demand.
- A quality control system performs inspection, testing and analysis to know whether the quality of a product is as per laid standards or not.
- Quality control is industrial management technique by which products of uniform acceptable quality are manufactured.

NEED OF QUALITY CONTROL:

- To assure that only good quality products are sent to the customers.

- To bring down the effective overall cost so as to survive in the market competition by controlling the processes and reducing the waste and scraps.
- Find out a way-out of manufacturing difficulties.
- To bring the concept of interchangeability in the products.
- To reuse the rejected products, if possible.

STATISTICAL QUALITY CONTROL:

S*tatistical quality control* (SQC) is a method of applying the statistical techniques to the collection and analyzing the inspection and other data to achieve and maintain the economy in manufacturing process. It base on the theory of probability to control the quality deviations.

Advantage of SQC:

1. Cost effectiveness 2. Time reduction 3. Efficiency 4. Guaranteed Quality

5. Easy to adopt 6. Suitable for destructive tests

BASIC STATISTICAL CONCEPTS:

Concept of variation: We know that no two identical parts can be produce in manufacturing, but special care may be taken for preparing similar parts, considering some negligible variation.

Cause of variation: Various causes of variation are machine vibrations, tool wear, poor maintenance, friction or loss of lubrication, unskilled worker, and improper temperature etc.

Variables: These are the characteristics which can be actually measured such as length, mass.

Attributes: Attributes are the data which are discrete in nature, i.e. Characteristics showing an object confirming or not confirming the specification.

Frequency distribution: Frequency represents the number of repeated data or value in a lot or how many times a data/value are repeated in a lot. To count the frequency of a value, the measured data is tabulated in ascending or descending order. This is known as frequency distribution. It is used for analyzing the quality of the product.

There are two methods to represent data. Such as: Graphical representation of frequency distribution and Empirical description of distribution. Graphical representation includes two methods such as: Frequency Polygon and Histogram.

Frequency Polygon: It shows a plot between the frequency and observation. It gives a picture of frequency distribution.

Sorted dimensions of lot of 7 items

Sl. No.	*Dimension in mm*
1	25
2	26
3	26
4	27
5	27

Data grouped & frequency added

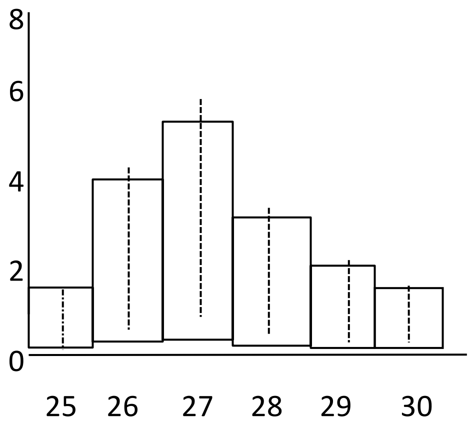
Sl. No.	*Dimension*	*Frequency*
1	25	1
2	26	2
3	27	3
4	30	1

Grouping of data for a fixed range interval

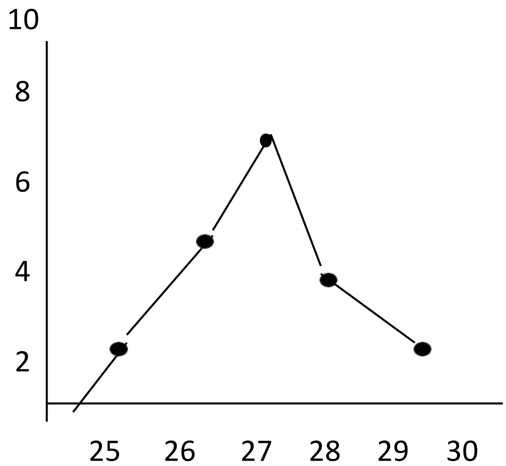
Class interval	*Frequency*	*Mid point*
24-26	3	25
27-29	3	28
30-32	1	31

Histogram: A histogram represents a bar chart where the base of rectangular bars represents the mid points of cell values and height is proportional to the frequency of occurrences of mid-points. It is used as a tool for the in-coming inspection.

If the histogram is symmetrical, it indicates that the overall process is normal and the variations are due to the chance causes. If the histogram is unsymmetrical, it shows the unreal process variation which needs improvements.



(Frequency Histogram)



(Frequency polygon)

EMPIRICAL / QUALITATIVE DISTRIBUTION:

There are three methods of representing central tendency such as mean, median and mode.

Mean/Arithmetic value/ Average value:

The arithmetic mean of a group of values is determined by adding the items and dividing the total by the number of items.

If X_1, X_2, X_3, …… X_n are the ***n*** values of the items in a sample, then their average mean is given by:

$$\bar{X} = \frac{X_1+X_2+X_3+\cdots+X_n}{n} = \frac{\sum X}{n};$$

If X_1 occurs f_1 times, X_2 occurs f_2 times, X_3 occurs f_3 times, …… X_n occurs f_n times, then we can write:

$\boldsymbol{n} = f_1 + f_2 + f_3 + \ldots\ldots\ldots\ldots\ldots + f_n$

And $$\bar{X} = \frac{f_1X_1+f_1X_2+f_1X_3+\cdots+f_1X_n}{f_1+f_2+f_3+\ldots.+f_n} = \frac{\sum fX}{\sum f} = \frac{\sum fX}{n}$$

Median:

When different items in a group are arranged in a serial order either ascending or descending, the middle item of this series is termed as median. It shows the average position.

If there are '*n*' observations where *n* is odd, then their median is given by: ($\frac{n+1}{2}$)th value.

If there are '*n*' observations where *n* is even, then their median is given by the average of (n/2)th and ($\frac{n}{2}$ +1) th value.

If the data is grouped in frequency format, then the median is given by: M = L + $\frac{(\frac{n}{2}-f_c)}{f_m} \times i$

Where, M = median

L = lower value of class having median

N = total number of values

fc = cumulative frequency of cells below 'L'

fm = frequency of median

i = class interval

Mode:

Mode is the most common value in the group occurring or repeating largest number of items. It is the value of the measurement which occurs with the greatest frequency or it is the observed value corresponding to the high point of graph. It is used to indicate a group.

Consider the recorded observation: 2, 3, 2, 4, 5, 2, 7, 6, 2, 4, 2. Here, 2 occurs repeatedly; thus, mode = 2. If there will be two values which occurs equal number of times, then the two values will be considered as mode.

The empirical formula used to calculate mode is given by: Mode = L + $\frac{f_2}{f_1+f_2} \times I$ Where, L = lower limit of class of mode

f_1 = frequency of class before the class of mode

f_2 = frequency of class after the class of mode

i = class interval

Dispersion:

The extent to which the data or value is distributed about the central tendency is known as the dispersion. It gives a better idea about the group. There are several measures of dispersion as follows.

1. **Range:**
   It is the difference between lowest and highest observed value in the group. It is used in control charts.
2. **Mean deviation:**

   It is defined as the deviation or variation of each figure in the group from its arithmetic mean and all such deviations summed up and divided by the number of items in the group will give the mean deviation. i.e. mean deviation ($\bar{X}$) = $\frac{\sum(x-\bar{x})}{n}$

where $\bar{X}$ is the arithmetic mean

3. **Variance:**

   It is obtained by dividing the sums of the squares of the deviations from the arithmetic mean divided by the number of observations n. it is also the square of standard deviation.

   i.e. variance = $\frac{\sum(X-\bar{x})^2}{n}$

4. **Standard deviation:**

   The square root of variance is called as standard deviation. It is denoted by the symbol 'σ. It is defined as the root mean square of the differences between the observations and the mean.

   i.e. standard deviation (σ) = $\sqrt{\frac{\sum(X-\bar{x})^2}{n}}$

5. **Average of sample average:**

   To find out values of the standard deviation for whole production lot when a number of samples have been collected at random from a production lot with average, $\bar{x}$ calculated. For each sample, average of the sample average, $\bar{\bar{x}}$ is calculated. i.e. $\bar{\bar{x}} = \frac{\sum \bar{x}}{n}$, where n = number of samples & $\bar{x}$ = average of a single sample

6. **Average of sample range:**

   To know the range representative of the whole lot, average of sample range $\bar{R}$ is calculated. At first the range of number of samples is calculated and then the average of sample range is calculated.

   i.e. $\bar{R} = \frac{\sum R}{n}$, where n = number of samples

NORMAL DISTRIBUTION CURVES:

Normal curve is a graphical representation of a frequency distribution which indicates the distribution of the characteristic among the whole production lot. It may be of different shapes.

Characteristics of normal distribution curves:

1. The normal distribution curve is bell shaped and symmetrical about its mean value.
2. A population by infinite size is represented by it.
3. The mean ($\bar{X}$) and standard deviation (σ) of the normal distribution fully describe its curve.
4. Theoretically the normal distribution curve range is from - ∞ to + ∞. Practically the range is considered from 3 σ values to the left and 3 σ values to the right of the mean.
5. Mean is shown as zero.

In figure s symmetrical bell-shaped normal curve is shown. It extends from - ∞ to + ∞. The area contained in each column of the histogram is proportional to the frequency within its cell. There are two statistical controls average ($\bar{X}$) and standard deviation (σ) used to control the construction of curve. The number of cells is increased by decreasing the width of the cell, when number of observations is large. It is divided into six equal cells. The top line of the histogram approaches a smooth curve. The height of the curve at any point is proportional to the frequency at that point & area between any two limits is proportional to the frequency of occurrence within these limits.

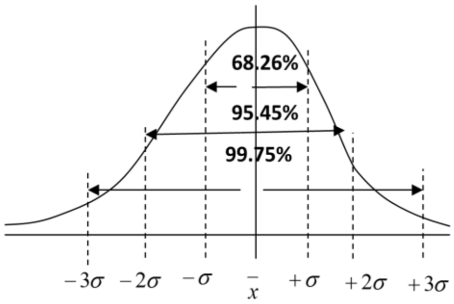
The mathematical equation of the normal curve is given by the formula:

$y = \frac{1}{\sigma\sqrt{2x}} \times e^{i}$ where, $i = \frac{(x-\bar{X})^2}{2\sigma^2}$

y = height of the curve at point *x* of the variable

$\bar{X}$= population average or average of lot

σ = standard deviation of the population



(Normal Curve)

Binomial distribution:

The binomial theorem is used in binomial distribution. i.e. the expansion of $(p+q)^n$ gives the probability of any combination of 'p' and 'q' where 'p' represents the defectives and 'q' represents good or non-defective parts. The binomial theorem is stated as follows:

$$(p+q)^n = \sum_{k=0}^{n} \binom{n}{k} p^k q^{n-k} = p^n + np^{n-1}.q + \frac{n(n+1)}{2!} . p^{n-2}q^2 + \ldots\ldots + q^n$$

Probability of 'r' defectives = ${}^nC_r\, q^{n-1}p^r$; where, ${}^nC_r = \frac{2!}{r!(n-r)!}$

The *average* of binomial distribution is given by: $\bar{X}$= np

$\bar{X}$= average number of defectives per sample

n = size of random samples taken

p = the fraction defective of sample

The *standard deviation* of binomial is given by: $\sigma = \sqrt{n\,p\,q} = \sqrt{n\,p\,(1-p)}$

Poisson's distribution:

This distribution is applicable where the probability of failure 'p' is very small. When there is large number of trials then failure occur at large intervals only. At this time Poisson's distribution is applicable for close approximation. The larger the value of n and smaller the value of p, the Poisson's approximation holds well.

In the Poisson's distribution the probability of finding 'k' defectives is given by:

$P(k) = \frac{\lambda^k . e^{-\lambda}}{k!}$ where, e = 2.71828 + (the base of natural algorithm)

λ = np (the average value of the expected number of defectives)

For the probability of 0 defectives $P(k) = e^{-\lambda}$

Average of the Poisson: average ($\bar{X}$) = np or λ

Standard deviation of Poisson: standard deviation = $\sqrt{n\,p}$ or $\sqrt{\lambda}$

CONTROL CHART:

A control chart is a graphical representation of the collected information. It is used for the study and control of the repetitive processes. It detects the variations in processing and shows the deviation in specified tolerance limit if exist. It is used to identify the quality variations and gives the good quality assurance at lower inspection cost.

Most commonly used control charts are:

1. Control charts for measurable quality characteristics or control charts for variables ($\bar{X}$ and R charts; $\bar{X}$ and σ charts)
2. Control charts for fraction defective (P-chart)
3. Control chart for number of defects per unit (C-chart)

The control charts for variables are useful for controlling the processes. The control charts for fraction defective and defects per unit are the attribute control charts.

Advantage of Control chart:

1. Control charts are used to indicate whether the process is in control or out of control.
2. It helps in decisions on acceptance or rejection of manufactured or purchased products.
3. It determines process variability.
4. It detects unusual variations occurring in a process.
5. It gives warning in time to rectify the process so that scrap or percentage rejection can be reduced.
6. It gives information about the selection of process and setting of tolerance limits.
7. The inspection work reduces.
8. It built up the organization reputation through customer's certification due to good quality of products.

TOTAL QUALITY MANAGEMENT:

Total quality management is an effective system adopted for quality development, quality maintenance and quality improvement of various groups in an organization to enable the production and services at the most economical levels to fulfill customer satisfaction.

Objectives:

1. Development of product specification based on needs of users and economical consideration. Meeting the customer requirements.
2. Interaction with product design.
3. Reliability and development testing.
4. Process capability studies.
5. Continuous improvement of quality at every level, at every place and at every stage.
6. Quality planning for control of production process / assembly operations.
7. Quality control of incoming materials.
8. Vendor quality control and vendor development.
9. Interaction and testing during manufacture.
10. Interaction with service engineering.
11. Training of staff and customers.
12. Cost reduction.
13. Quality audit etc.

Benefits of TQM:

1. It makes the company a leader not a follower.
2. It creates a direct connection between customers, management and workers. It leads to effective team worm.
3. It makes the company more sensitive to customer needs.

4. Better product quality.
5. Staffs are motivated and quality conscious.
6. Productivity improvement.
7. Reduced quality cost.
8. Enhances problem solving capacity.
9. Increased market.
10. Increase position in competitive market and profits.
11. Improvement of human relations and work area.
12. Better customer care and better satisfaction.
13. Employee empowerment.
14. Enhancement of job interest and security for employees.
15. More training and improvement in skills of employees.
16. More recognition for staffs.

Reference: - i) A Textbook of Industrial Engineering and Management by O.P. Khanna

ii) A text book of Inspection and Quality Control by J.S. Narang and A. Gupta

iii) A Textbook of Industrial Engineering and Production Management by Martand Telsang

Reference Link: -

i) https://youtu.be/OshyCwH3TJM
ii) https://youtu.be/0BVzjOzllrE
iii) https://youtu.be/BWbnKgFNcKg
iv) https://youtu.be/a2QgdDk4Xjw
v) https://youtu.be/4fMhJbnRT5I
vi) https://youtu.be/0x6A3YXOAtY
vii)https://youtu.be/iIIPJaK9mnU
viii)https://youtu.be/oIG_NDb2g3U
ix) https://youtu.be/gUPUuhVZfFE
x) https://youtu.be/z03knktfqY8
xi) https://youtu.be/pzzku4PqdHQ

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

ENVIRONMENTAL-STUDIES

3RD SEMESTER

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Unit 1: The Multidisciplinary nature of environmental studies

Definition –

Environmental studies are an interdisciplinary subject examining the interplay between the social, legal, management, and scientific aspects of environmental issues. Interdisciplinary means that issues are examined from multiple perspectives.

Scope of environmental studies-

The environmental studies discipline has multiple and multilevel scopes. This study is important and necessary not only for children but also for everyone. The scopes are summarized as follows:

1. The study creates awareness among the people to know about various renewable and non-renewable resources of the region. The endowment or potential, patterns of utilization and the balance of various resources available for future use in the state of a country reanalysed in the study.

2. It provides knowledge about ecological systems and cause and effect relationships.

3. It provides necessary information about biodiversity richness and the potential dangers to the species of plants, animals, and microorganisms in the environment.

4. The study enables one to understand the causes and consequences due to natural and main induced disasters (flood, earthquake, landslide, cyclones etc.,) and pollution and measures to minimize the effects.

5. It enables one to evaluate alternative responses to environmental issues before deciding on an alternative course of action.

6. The study exposes the problems of overpopulation, health, hygiene, etc. and the role of arts, science and technology in eliminating/ minimizing the evils from society.

inherited from our ancestors to the younger generating without deteriorating their quality.

Importance of environmental study -

- Environmental study is based upon a comprehensive view of various environmental systems. Its aims to make the citizens competent to do scientific work and to find out practical solutions to current.
- environmental problems. The citizens acquire the ability to analyse the environmental parameters like the aquatic, terrestrial and atmospheric systems and their interactions with the biosphere and anthroposphere.

Importance

• World population is increasing at an alarming rate especially in developing countries. The natural resources endowment in the earth is limited.

• The methods and techniques of exploiting natural resources are advanced.

• The resources are over-exploited and there is no foresight of leaving the resources to the future generations.

• The unplanned exploitation of natural resources leads to pollution of all types and at all levels.

• The pollution and degraded environment seriously affect the health of all living things on earth including man.

• The people should take a combined responsibility for the deteriorating environment and begin to take appropriate actions to space the earth.

• Education and training are needed to save the biodiversity and species extinction.

• The urban area, coupled with industries, is major sources of pollution.

• The number and area extinct under protected area should be increased so that the wild life is protected at least in these sites.

• The study enables the people to understand the complexities of the environment and need for the people to adapt appropriate activities and pursue sustainable development, which are harmonious with the environment.

• The study motivates students to get involved in community action, and to participate in various environmental and management projects.

• It is a high time to reorient educational systems and curricula towards these needs.

Need for public awareness –

- Increasing population, Urbanization and poverty have generated pressure on the natural resources and lead to a degradation of the environment. To Prevent the Environment from Further Degradation, the supreme court has ordered and initiated environmental protection awareness through government and non-government agencies to take part in protecting our environment.
- Environmental pollution cannot be prevented by laws alone. Public participation is equally important with regard to environmental protection.
- Climate change, loss of biodiversity, declining fisheries, ozone layer depletion, illegal trade of endangered species, destruction of habitats, land degradation, depleting ground water supplies, introduction of alien species, environmental

pollution, solid waste disposal, storm water and sewage disposal pose a serious threat to ecosystems in forest, rural, urban and marine ecosystems.

- Both formal and informal education on the environment will give the interested individual the knowledge, values, skills and tools needed to face the environmental challenges on a local and global level.

Unit 2: Natural Resources

Renewable and non renewable resources:

Renewable Resources

The resources which cannot be exhausted even after continuous utilization are termed as renewable resources. Examples of renewable resources are the sun, wind, and tidal energy.

Non-Renewable Resources

The resources which cannot be immediately replaced once they are depleted are called Non-renewable resources. Examples of Non-renewable resources include fossil fuels, such as coal, petroleum and natural gas and rare minerals typically found in meteorites.

a) Natural resources and associated problems – Forest Resources -

Forest is important renewable resources. Forest vary in composition and diversity and can contribute substantially to the economic development of any country. Plants along with trees cover large areas, produce variety of products and provide food for living organisms, and also important to save the environment.

Over exploitation of forests

Forests contribute substantially to the national economy. With increasing population increased demand of fuel wood, expansion of area under urban development and industries has lead to over exploitation of forest .At present international level we are losing forest at the rate of 1.7 crore hectares annually. Overexploitation also occurs due to overgrazing and conversion of forest to pastures for domestic use.

Deforestation

1. Forest are burned or cut for clearing of land for agriculture ,harvesting for wood and timber , development and expansion of cities .These economic gains are short term where as long term effects of deforestation are irreversible
2. Deforestation rate is relatively low in temperate countries than in tropics If present rate of deforestation continues we may losses 90% tropical forest in coming six decades
3. For ecological balance 33% area should be under forest cover but our nation has only 20.6% forest cover.

Causes Of deforestation -

Forest area in some developed area has expanded. However in developing countries area under forest is showing declining trend particularly in tropical region. Main causes of deforestation are

a) *Shifting cultivation or jhum cultivation*
b) *Commercial logging*
c) *Need for fuel wood*
d) *Expansion for agribusiness*
e) *Development projects and growing need for food*
f) *Raw materials for industrial use*

Case Studies -

Jhum Agriculture or shifting agriculture has destroyed large number of hectare of forest tracts in North-Eastern states and Orissa. Jhum agriculture is subsidence agriculture in which tract of forest land is cleared by cutting trees and it is used for cultivation.

After few years, when productivity of the land decreases, cultivators abandon the land and clear next tract. As a result of this practise, combined with increasing population there is rapid deforestation as more and more cultivators clear forest to cultivate land. Also, with increase in population there is cultivators are forced to return to previous tracts.shortage of firewood and timber, due large scale tree cutting. Increased traffic volumes on these roads leads to increased pollution in the area.

Timber extraction

There has been unlimited exploitation of timber for commercial use. Due to increased industrial demand; timber extraction has significant effect on forest and tribal people.

Logging

- Poor logging results in degraded forest and may lead to soil erosion especially on slopes.
- New logging roads permit shifting cultivators and fuel wood gatherers to gain access to the logging area.
- Loss of long term forest productivity
- Species of plants and animals may be eliminated
- Exploitation of tribal people by contractor.

Mining

Major effects of mining operations on forest and tribal people are:

- Mining from shallow deposits is done by surface mining while that from deep deposits is done by sub-surface mining. It leads to degradation of lands and loss of top soil. It is estimated that about eighty thousands hectare land is under stress of mining activities in India
- Mining leads to drying up perennial sources of water sources like spring and streams in mountainous area.

- Mining and other associated activities remove vegetation along with underlying soil mantle, which results in destruction of topography and landscape in the area. Large scale deforestation has been reported in Mussoorie and Dehradun valley due to indiscriminating mining.

- **Effects of dams on forests and tribal people**

Pandit Jawaharlal Nehru referred dam and valley projects as “Temples of modern India”. These big dams and rivers valley projects have multi-purpose uses. However, these dams are also responsible for the destruction of forests.

- They are responsible for degradation of catchment areas, loss of flora and fauna, increase of water borne diseases, disturbance in forest ecosystems, rehabilitation and resettlement of tribal peoples.

  - India has more than 1550 large dams, the maximum being in the state of Maharashtra (more than 600), followed by Gujarat (more than 250) and Madhya Pradesh (130).
  - The highest one is Tehri dam, on river Bhagirathi in Uttaranchal and the largest in terms of capacity is Bhakra dam on river Satluj in Himachal Pradesh. Big dams have been in sharp focus of various environmental groups all over the world, which is mainly because of several ecological problems including deforestation and socio-economic problems related to tribal or native people associated with them.
  - The Silent valley hydroelectric project was one of the first such projects situated in the tropical rain forest area of Western Ghats which attracted much concern of the people.
  - The crusade against the ecological damage and deforestation caused due to Tehri dam was led by Shri. Sunder Lal Bahuguna, the leader of Chipko Movement.

WATER RESOURCES:

- Water is the most abundant, inexhaustible renewable resource. It covers 70% of the globe in the form of oceans, rivers, lakes, etc. Of this 70%, only 3% is available as freshwater.
- From this 3%, roughly 2% is frozen in polar icecaps and only a fraction of the remaining1% is used as drinking water (potable). 90% of the water is utilized for agricultural purposes in India.

USE OF SURFACE AND GROUND WATER

- Consumptive use: In such uses, water is completely utilized and cannot be reused. Ex:Domestic, industrial and irrigation
- Non-consumptive use: In such uses, water is not completely utilized and is reused Ex:Hydropower plant

Other uses:

1. Water is used for domestic purposes like drinking, bathing, cooking, washing. etc.

2. Water is used in commercial establishments like hotels, theaters, educational institutions, offices, etc.

3. Almost 60-70% of fresh water is used for irrigation

4. 20-30% of water is used for industrial operations by refineries, iron & steel industries, paper & pulp industries, etc.

5. Water plays a key role in sculpting the earths surface, moderating climate and diluting pollutants.

OVER-UTILIZATION OF SURFACE & GROUND WATER

The rapid increase in population and industrial growth led to severe demand on water resources. After using all available surface water resources to the maximum, human beings began using groundwater to meet their needs.

1. The increased extraction of groundwater far in excess of the natural recharge led to decreased groundwater level. The erratic and inadequate rainfall caused reduction in storage of water in reservoirs. This also led to decrease of groundwater.

2. Building construction activities seal permeable soil zone and reduce the area for percolation of rainwater thereby increasing surface runoff.

3. If groundwater withdrawal rate is higher than recharge rate, sediments in aquifers get compacted resulting in sinking of overlaying land surface. This is called land subsidence which leads to structural damage in buildings, fracture in pipes and reverses the flow of canals leading to tidal flooding.

4. Over-utilization of groundwater in arid and semi-arid regions for agriculture disturbs equilibrium of reservoir in the region causing problems like lowering of water table and decreased pressure in aquifers coupled with changes in speed and direction of water flow.

5. Over utilization of groundwater in coastal areas leads to rapid intrusion of salt water from the sea thereby rendering it unusable for drinking and agriculture.

6. Over-utilization of groundwater lads to decrease in water level thereby causing earthquake, landslides and famine.

Drought

- Water is a very basic necessity for the survival of life on earth. Imagine life with insufficient amount of water, it will be impossible to do the daily activities of cleaning, cooking, drinking etc.
- Life will turn out to be a miserable chaos. Water cycle has helped in maintaining the quantity of water on the surface of earth. About 50 litters of water is needed per day per person in order to sustain a healthy life.
- There are many areas where people do not receive this basic quantity of water. Areas that do not receive adequate amount of rainfall and have dry soil suffer from droughts. Whereas areas which receive heavy rainfall and have marshy soil generally get flooded.
- Drought conditions result from a lack of precipitation and this has many effects on the surrounding land and weather conditions. Drought conditions can worsen after prolonged periods of no rainfall, especially in areas where the water supply is short.

Causes drought?

Lack of rainfall (or precipitation): Droughts can occur when there is the lack of ‘expected’ precipitation (rain and snow).

Note that we say ‘expected’ because the lack of rain alone does not mean a drought.

FLOOD

Reasons of Flood

- Rains: Each time there are more rains than the drainage system can take, there can be floods. Sometimes, there is heavy rain for a very short period that result in floods. In other times, there may be light rain for many days and weeks and can also result in floods.
- River overflow: Rivers can overflow their banks to cause flooding. This happens when there is more water upstream than usual, and as it flows downstream to the adjacent low-lying areas (also called a floodplain), there is a burst and water gets into the land.
- Strong winds in coastal areas: Sea water can be carried by massive winds and hurricanes onto dry coastal lands and cause flooding. Sometimes this is made worse if the winds carry rains them. Sometimes water from the sea resulting from a tsunami can flow inland to cause damage.
- Dam breaking (Dams are built along the side of a river and are used to prevent high water from flooding bordering land). Sometimes, too much water held up in the dam can cause it to break and overflow the area. Excess water can also be intentionally released from the dam to prevent it from breaking and that can also cause floods.

Conflicts over water (international & inter-state).

Conflict through pollution: Rivers are also used for industrial purposes. They act as reservoirs for supply of fresh water and also a receptor of waste water and rubbish from the industry. Water crossing borders that has been polluted by wastes from one country develops into an international conflict.

Management of water conflicts

1. Concerted efforts are required to enforce laws that check these practices to control water pollution.

2. In order to overcome the problem of sharing river water in a country, the concept of interlinking of rivers has been suggested.

3. Rivers should be nationalized; the National Water Authority and River Basin Authority should be given powers to ensure equitable distribution of basin water

Food resources:

World food problems, changes caused by agriculture and overgrazing, effects of modern agriculture, fertilizer-pesticide problems, water logging, salinity, case studies.

Food Resources:

- Almost entirely from agriculture, animal husbandry and fishing. Although India is self-sufficient in food production, it is only because of modern patterns of agriculture that are unsustainable and which pollute our environment with excessive use of fertilizers and pesticides.
- The FAO defines sustainable agriculture as those which conserves land, water and plant and animal genetic resources, does not degrade the environment and is economically viable and socially acceptable.
- Most of our large farms grow single crops (monoculture). If this crop is hit by a pest, the entire crop can be devastated, leaving the farmer with no income during the year. On the other hand, if the farmer uses traditional varieties and grows several different crops, the chance of complete failure is lowered considerably.
- Many studies have shown that one can use alternatives to inorganic fertilizers and pesticides. This is known as Integrated Crop Management.

World food problems:

Our fertile soils are being exploited faster than they can recuperate.

• Forests, grasslands and wetlands have been converted to agricultural use, which has led to serious ecological questions.

• Our fish resources, both marine and inland, show evidence of exhaustion.

• There are great disparities in the availability of nutritious food.

Some communities such as tribal people still face serious food problems leading to malnutrition especially among women and children. These issues bring in new questions as to how demands will be met in future even with a slowing of population growth

Food security, loss of genetic diversity and alternate food sources

(fisheries):

Changes caused by agriculture and overgrazing:

Agriculture has both primary and secondary environmental effects. A primary effect is an effect on the area where the agriculture takes place i.e. on-site effect. A secondary effect, also called an off-site effect, is an effect on an environment away from the agricultural site. The effects of agriculture on the environment can be broadly classified into three groups, viz. global, regional and local:

(1) Global Effects: These include climate changes as well as potentially extensive

changes in chemical cycles.

(2) Regional Effects: These generally result from the combined effects of farming

practices in the same large region. Regional effects include deforestation, desertification, large scale pollution, increase in sedimentation in major rivers and in the estuaries at the mouths of the rivers and changes in the chemical fertility of soils over large areas. In tropical waters, sediments entering the ocean can destroy coral reefs.

Effects of modern agriculture - Fertilizer Pesticide problems,Water logging, Salinity

Agriculture is an art, science and industry of managing the growth of plants and animals for human use. Agriculture includes preparation of soil for cultivation of crops, harvesting crops, breeding and raising livestock, dairying and forestry. The two major

types of agriculture are:

1. Traditional agriculture

2. Modern or Industrialized agriculture

MODERN AGRICULTURE

Modern agriculture makes use of hybrid seeds of single crop variety, technologically

advanced equipment, fertilizers, pesticides and water to produce large amounts of single crop.

Problems using fertilizers

1. Micronutrient imbalance
2. Nitrate pollution
3. Eutrophication

WATER LOGGING

If water stands on land for most of the year, it is called water logging. In water logged conditions, pore-voids in the soil get filled with water and soil-air gets depleted. In such a condition the roots of plants do not get enough air for respiration. Water logging also leads to low mechanical strength of soil and low crop yield.

CAUSES OF WATER LOGGING

1. Excessive water supply to the croplands

2. Heavy rain

3. Poor drainage

MEASURES TO PREVENT WATER LOGGING

1. Avoid and prevent excessive irrigation

2. Sub-surface drainage technology

3. Bio-drainage by trees like Eucalyptus

SALINITY

Water not absorbed by soil, is evaporated leaving behind a thin layer of dissolved salts in the top soil. This is called salinity of the soil. Saline soils are characterized by accumulation of soluble salts like sodium chloride, calcium chloride, magnesium chloride, sodium sulphate, sodium carbonate and sodium bicarbonates. Saline conditions are exhibited when pH is greater than 8.0

PROBLEMS IN SALINITY

Saline soils yield less crop In order to remedy the condition of saline soils the following two techniques may be used:

1. Salt deposit is removed by flushing with good quality water

2. By using a sub-surface drainage system, the salt water is flushed out slowly.

CASE STUDIES

Canal irrigation in Haryana resulted in rising water table followed by water logging and salinity causing low crop productivity thereby huge economic losses. Similarly, the "Indira Gandhi Canal Project" in Rajasthan converted a big area into a "water soaked waste land". In Delhi, accumulation of pesticides and DDT in the body of mothers caused premature deliveries or low birth weight infants. Food centre at Centre for Science and Environment (CSE) India reported Pepsi and Coca-Cola companies sold soft drinks with a pesticide content 30-40 times higher than EU guidelines permit.

Energy resources:

Renewable and non-renewable energy sources –

Energy is broadly classified into two main groups: Renewable and Non-renewable.

Renewable Energy

Renewable energy is the energy which is generated from natural sources i.e. sun, wind, rain, tides and can be generated again and again as and when required.

Pros and Cons of Renewable energy:

• The sun, wind, geothermal, ocean energy are available in the abundant quantity and free to use.

• The non-renewable sources of energy that we are using are limited and are bound to expire one day.

• Renewable sources have low carbon emissions, therefore they are considered as green and environment friendly.

• Renewable helps in stimulating the economy and creating job opportunities. The money that is used to build these plants can provide jobs to thousands to millions of people.

• You don't have to rely on any third country for the supply of renewable sources as in case of Non-renewable sources.

• Renewable sources can cost less than consuming the local electrical supply. In the long run, the prices of electricity are expected to soar since they are based on the prices of crude oil, so renewable sources can cut your electricity bills.

Non-Renewable Energy

Non-Renewable energy is the energy which is taken from the sources that are available on the earth in limited quantity and will vanish fifty-sixty years from now. Non-renewable sources are not environmental friendly and can have serious affect on our health.

USE OF ALTERNATE RENEWABLE ENERGY SOURCES

1. Solar energy is renewable and does not cause environmental pollution

2. Energy sources that create minimum pollution, are safe not prone to security threats and have universal availability have the best chance of large-scale utilization in future.

3. Hydro-electric power generation is expected to the existing ecological balance.

4. Apart from generating heat, hydel power plants critically endanger aquatic and terrestrial biotic.

5. Radioactive pollutants released from nuclear plants are chronically hazardous. Commissioning of Boiling Water Power Reactors (BWRs) result in accumulation of large number of radionuclides in water

6. Dangerous radioactive waste cannot be buried in/land without the risk of polluting soil and underground water. The waste cannot be dumped in rivers as it poisons aquatic life and human beings.

7. Burning of coal, oil, wood, dung cakes and petroleum products have well established environmental problems. The smoke produced causes respiratory and digestive problems leading to lung, stomach and eye diseases.

CASE STUDIES

Wind energy India is generating 1200 MW electricity using wind energy. The largest wind farm is in Kanyakumari in Tamil Nadu, which generates 380 MW electricity. Hydrogen-Fuel cell car General motor company of China invented experimental cars that run on electric motors fuelled by hydrogen and oxygen. These cars produce no emission and the only waste products being water droplets and water vapour. Commonly known alternative energy sources.

LAND RESOURCES

- In India, land is generally called as "MOTHER LAND". It is because of our life depend on it for food, fibre , fuel and other basic amenities. Therefore, it is the valuable gift of nature to human beings. Top layer of the land is called soil, which is renewable resource and essential for survival of life.
- Land available for cultivation is approximately 14 million hectares. But it is reducing day by day. It is due to mismanagement. The earth is made up of three principal layers cores, mantle and crust. Cores are inner most fluid layers.
- Land is classified in to 9 categories .
  They are (i) forests,
  (ii) land put to non-agricultural use
  (iii) barren land unculturable land
  (iv) permanent pastures and other grazing lands
  (v) misc. tree crops and groves
  (vi) culturable waste
  (vii) fallow land
  (viii) current fallow
  (ix) net area sown.

LAND SUITABLE FOR CULTIVATION AND OTHER USES :

- There are four class of land which are suitable for cultivation and other purposes. Their details & limitations are as
- Soils in class I have very few or no limitations that restrict their use.
- This type of land is nearly level and the erosion hazard is low.
- soils are deep, well-drained, easily worked, hold water well and are either fairly well supplied with plant nutrients or are highly responsive to the application of fertilizers. The soils are not subject to damage because of overflow.
- Soils in this class are suited to a wide range of plants, may be used for cultivated crops, pastures, forests and wild life, food and cover.

The limitations of soils in class II may result from the effects of one or more of the following factors : (i) a gentle slope,

(ii) a slight susceptibility to erosion,

(iii) less than ideal soil depth,

(iv) occasional damaging overflow,

(v) wetness which can be corrected by drainage, but existing permanently as a moderate limitation, (vi) slight to moderate salinity or sodium, easily corrected but likely to re-occur, and

(vii) a slight climatic limitation on soil use and management.

Limitations of soils in class III may result from the effects of one or more of the following factors :

(i) moderately sloping land.
(ii) moderately susceptible to water or wind erosion.
(iii) frequent overflow accompanied with some crop damage,
(iv) very slow permeability of the subsoil,
(v) wetness or continuing water-logging after drainage,
(vi) shallow soil depth up to the bedrock, hard-pan or clay-pan which limits the rooting-zone and the water storage,
(vii) low moisture holding capacity,
(viii) moderate salinity or sodium, and
(ix) moderate climatic limitation.

The soils can be used for raising cultivated crops, pastures, forests and wild-life food and cover.

The use of these soils for cultivated crops is limited as a result of the effect of one or more permanent features, such as

(i) steep slopes,
(ii) severe susceptibility to water and wind erosion,
(iii) severe effect of past erosion,
(iv) frequent over-flow accompanied with severe crop damage,
(v) excessive wetness with a continuing hazard of water-logging after drainage,
(vi) severe salinity or sodium, and
(vii) moderately adverse climate.

These soils can be used for crops, pastures, forests and wild life food and cover.

LAND DEGRADATION

- The total land under agricultural use is around 58.4% i.e. grossed cropped area is 167.41 million hectares. The land not fit for cultivation i.e. barren land is around 9.9%. The area under forest is 21.6%, but it needs to be raised.
- land resources are the precious resources. Food security depend on conservation and proper utilization of all resources.
- Due to use and over exploitation land resources are degraded. It is due to the more & more pressure with increasing population.
- Land degradation is a real alarm. Because soil formation is a very slow process. In millions of years we have a layer crust of fertile soil. In general, formation of 1.0 cm soil crust from parent material take 300 - 400 years.

- Fertile soil have high percentage of organic matter vis-a-vis microorganisms. Each gram of fertile soil have 30 billion micro-organisms.

Significance of the problem :

- In India, green revolution brought about technological breakthrough, which led to the use of short duration high yielding varieties helping intense use of land in a year, increasing area brought under irrigation and more use of Chemicals such as fertilizers and pesticides.
- India, being vastly agriculture oriented. Development of agriculture would lead to overall development of the nation and help eradication of poverty.
- It has been of late recognised that the increasing efforts to raise agricultural growth has cost us clearly in the form of land & water degradation

LANDSLIDES

A landslide is a sudden collapse of a large mass of hillside. There are many different types of landslides where not only earth, but rock, mud, and debris flow down the side of a slope. Since the beginning of the monsoon season in June India has been hit by heavy rains and landslides affecting in particular, Arunachal Pradesh, Assam, and Bihar states

Landslides mostly occur

1. Where landslides have occurred before.

2. On steep slopes.

3. On benches.

4. Where drainage is causing a problem.

5. Where certain geologic conditions exists.

Types of landslides

1. Shallow, disrupted landslide-Example of this type is the Santa Susana Mountains and the mountains north of the Santa Clara River Valley. Here more than 75% of the slope area was denuded by landslides triggered by strong shaking,

2. Deep. Coherent Landslides. These triggered by the earthquake were far less numerous than disrupted slides, they contributed significantly to the total volume of landslide material because they tended to be much larger. Some of these landslides are

Man induces land slides:

Man can also cause slides by mining the earth, underground draining groundwater levels or overdeveloping hillsides. Man induced landslides are generally done for the development purposes i.e. industrial, forming roads, agricultural use, homes, etc. They use heavy explosives for that. In this case no serious casualties or damage occur because proper warned earlier to shift in safer places. affected

Effects :

No heavy damage occur in man induced landslides but thousands of and killed due to landslides. Many houses can be damaged and the loss of public properties is also noticed. Roads and rail communication may remain cut off from rest of the regions. Thunder storms cause debris flows on hill slopes leading to deposits of mud. Heavy rains at the same time may worsen the situation.

Soil erosion:

Soil erosion means the removal of material from the surface of the soil by the agency of running water, wind or even by gravity. Since the superficial layers of the soil are the richest in plant valuable plant nutrients and if it becomes sufficiently intense, may lead to the complete destruction of the soil as the seat of plant growth.

- Normal or geologic erosion. Geologic erosion takes place steadily but so slowly that ages are required for it to make any marked alteration in the major features of the earth's surface. There is always an equilibrium between the removal and formation of soil, so that unless the equilibrium is disturbed by some outside agency, the mature soil preserves, more or less, a constant depth and character indefinitely.
- Accelerated soil erosion. The removal of the surface soil from areas denuded of their natural protective cover as a result of human and animal interference takes place at a much faster rate than that at which it is built up by the soil-forming processes.
- Wind erosion. Wind erosion takes place normally in arid and semi-arid areas devoid of vegetation, where the wind velocity is high.
- The soil particles on the land surface are lifted and blown off as dust-storms. When the velocity of the dust-bearing winds is retarded, coarser soil particles are deposited in the form of dunes and thus fertile lands are rendered unfit for cultivation.
- Sheet erosion. Sheet erosion removes a thin covering of soil from large areas, often from entire fields, more or less, uniformly during every rain which produces a run-off.
- Rill erosion. When sheet erosion is allowed to continue unchecked, the silt-laden run-off forms a well-defined, but minute finger-shaped grooves over the entire field. Such thin channelling is known as rill erosion.
- Gully erosion. When rill erosion is neglected, the tiny grooves develop into wider and deeper channels, which may assume a huge size. This is called 'gully' erosion.

DESERTIFICATION

- Desertification is a process by which productive potential of arid or semiarid land falls. The decrease in productivity is varies from 10%-50%. Thus, desertification leads to the conversion of irrigated crop land to desert (where productivity is minimum).
- It is characterized by de vegetation loss of vegetal cover, depletion of ground water, salinization and soil erosion.
- Draught in three consecutive years in Central India in recent years has accelerated the process of wind erosion and desertification.
- In Rajasthan and Kutch-Saurashtra area, extension in the area of desert is assuming serious proportion. Climatic change and anthropogenic activities are also responsible for desertification.
- During last so many years large area has destroyed (agriculture land) by Sahara Desert. In India, also, so many places which affected by desertification.
- Deforestation is also one of the causes of desertification. The increasing cattle population heavily graze in grasslands or forests and denude the land area, which is not suitable for seed germinations. Thus, overgrazing is also one of the causes for desertification.

Role of an individual in conservation of Natural resources :

- Planning of a suitable strategy for the conservation of our natural resources and most judicious execution of planned strategies is called as Conservation Management.
- Environmental planning, evaluation, monitoring, and impact assessment are methods of conservation management. The Indian philosophy of conservation is to keep “Harmony with Nature”.

1. People should at once stop the over utilization of natural resources instead they must be properly used.

2. Instead of deforestation, representation should keep in mind. We should take help from the Govt. for plantation programmes. Everybody should take part in plantation and care the plants.

3. We should protect wildlife. Though hunting is not allowed even then the persons are doing so. For these educated young should teach the lesson of wild life act.

4. Mixed croping, crop rotation, and proper use of fertilizer insecticide, pesticides should be taught to farmers. Encourage the use of manures, biofertilizers organic fertilizers.

5. We should make habit for waste disposal, compose and to restore biodiversity.

6. Try to educate local people for the protection and judicious use of natural resources.

7. We should use light, fans and other domestic appliances when it is needed.

8. Maintain a balance between resources and human needs.

9. Maintain the essential ecological processes and the life support systems.

10. Install rain water harvesting system in houses, colonies.

We know “collecting drop-drop-drops form a big ocean”, similarly if each of us will aware about the judicious use of natural resources, all of us will conserve the nature.

Equitable use of resources for sustainable life Style:

- The equal distribution of natural resources should be for all irrespective of rich or poor. There must be balance between the need and consumption particularly for drinking water, food, fuel etc.
- The developed countries are utilizing more resources as compared to developing countries. This imbalance is responsible for rich become richer and poor gone poorer.
- This is due to sharp increase in population in developing countries. But it does not mean that people of developed countries are rich and having good life style, and less developed countries people are poor.
- Less developed countries also have rich and poor both but facing the problem of population and available natural resources.
- Developed countries like USA, Canada, Japan, Australia etc. have 22% of world's population utilising 86% of natural resources. Thus it is needed to divert the resources to poor countries to narrow down the gap between the two.

- To achieve sustainable life style, there should be equal distribution of global resources and income to meet everyone's need. But in the long process of economic development only the powerful and strong people exploited most of the environmental resources even at the cost of migration of poor people already using those resources.

Unit 3: Systems

CONCEPT OF ECOSYSTEM

Now, we can say Ecology deals with interrelationships between the biotic and abiotic compounds of an Ecosystem. The term ecosystem was first coined by A.G. Tausley 1935. It is derived by two words “eco' means environment and 'system' implies a complex of co-ordinated units.

An ecosystem concept is that the living organisms of a community not only interact among themselves but also have functional relationship with their non-living environment. This structural and functional system of communities and their environment is called an ecosystem.

FUNCTIONING AND TYPES OF ECOSYSTEMS

Depending upon the species, diversity and the manner in which they are organised, are of following types

1. Permanent and Natural ecosystem. These operate under natural conditions without any interference (even by human beings). These can be further classified in to

(i) Terrestrial ecosystem (ii) Aquatic ecosystem

Terrestrial ecosystems operate on land hence Forest, Desert and grassland and Agro-ecosystem included in this type. While Aquatic ecosystem operates in water. It can be devided in two

(a) Fresh water ecosystem

(b) Marine ecosystem

Freshwater ecosystems are usually named after the size and nature of the fresh water body such as pond, lake & river.

Marine ecosystem is largest ecosystem on earth, which consists of several sub-divisions each having its physico-chemical and Biological characteristics. For example, in the deepest ocean producers are absent but in many other organisms survive which dependent for food on the dead organic matter coming from the upper layers of the ocean.

2. **Temporary and Natural ecosystems.** These are short lived but operate under natural conditions.

3. Artificial or Anthropogenic ecosystems. These are man-made like fishery tanks dams, croplands and space ecosystems also. Fish aquarium is also come under this head.

STRUCTURE OF AN ECOSYSTEM

It is a description of the species of organisms that are present (including information on their life histories, populations and distribution in space). The structure of ecosystem provides information about the range of climatic conditions that prevail in the area, composition and organization of Biological Communities and Abiotic compounds constitute the structure of an ecosystem. According to Odum, from the trophic (Food) point of view, an ecosystem has the following components:

Ecosystem

Biotic (Living) Structure or Structure or Components

Abiotic (non-living) Components

Autotropic Components (Producers)

Heterotropic Components (Consumers)

Climative

Inorganic

Organic

Macroconsumer

Microconsumer (Decomposer)

1. Primary Consumer
2. Secondary consumer
3. Tertiary consumer
4. Quaternary consumer

1. Biotic Structure.

Producers, consumers and decomposers are components of biotic ecosystem. Living organisms exchange, expel, convert, assemble, disassembles, organise and otherwise manipulate the constituents of earth, air and water. Biotic structure includes plants, animals and microorganisms present in an ecosystem. We have identified producers, decomposers and consumers are the basic components of biotic ecosystem. These can be distinguished on the bases of their source of energy and material

(a) Autrotrophic components (Autotrophic = self nourishing)

In which the fixation of light, energy, the use of simple inorganic substances and manufacture of complex material predominates. These are also called producers.

(b) Heterotrophic Components (Heterotrophic = other nourishing)

These utilizes, rearranges and decomposes the complex materials synthesized by the autotrophs. The most intense heterotrophic activity takes place where the organic matter accumulates in the soils and sediments. These are also called consumers.

PRODUCERS

All green plants are producers. They are also called “converters" or "transformers”. “They are living members of the ecosystem that utilize sunlight as their energy source and single inorganic rich chemicals as their own food. Producers are largely photosynthetic plants and their kind varies with the kind of ecosystem. In dense forest the trees are the most important producers. In lakes and ponds, the producers are rooted or large floating and microscopic plants(phytoplankton) usually the algae.

CONSUMERS

As we have seen earlier, consumers are heterotrophs, the living organisms which ingest other organism. They derive their food directly or indirectly from the producers. The food is then digested i.e. broken down to simple substances which are metabolized in the consumers body and released the waste product to the environment. Consumers are of following types---

(1) PRIMARY CONSUMERS- These are also called 'HERBIVORES' which feed directly on the producers. They vary with the kind of ecosystem. For example a deer and giraffe is a primary consumer in forest ecosystem, while cow or a goat is in a grassland or crop ecosystem. Protozoans and certain crustaceans which feed floating algae are also primary consumers.

(ii) SECONDARY CONSUMERS- They are also called “CARNIVORES" (meat eaters). For example insects gamefish in a pond eat primary consumers.

(iii) TERTIARY CONSUMERS. - In most of ecosystem some organism that eat other carnivores like they are tertiary consumers.

(iv) OMNIVORE-- A person or animal eating plants and animals is called omnivores.

(v) **TOP CARNIVORES**- Some ecosystem have animals like lion and vulture, which are not killed or rarely killed and eaten by other animals are called top carnivores.

(vi) **DETRITIVORES**- These are the bottom living which subsist on the rain of organic detritus from autotrophic layers e.g. beetles, termites, ants crabs etc.

3. DECOMPOSERS- They are also the living components, mainly bacteria and fungi which breakdown complex compounds of dead protoplasm of producers and consumers to simple organic compounds and ultimately in to inorganic nutrients. In all the ecosystems, this biotic structure prevails.

2**. ABIOTIC STRUCTURES OR COMPONENTS**. - The physical and chemical components of an ecosystem constitute its abiotic structure. It includes two things

(i) MATERIALS OR CHEMICAL FACTOR-The materials are like water, minerals, atmospheric gases and other inorganic salts. They also include some organic matter such as amino acids, decay products, lipids, carbohydrates, proteins etc. The quantity of abiotic materials like the minerals present at any given time in an ecosystem is termed as the 'standing state' or 'standing crop.

(ii) ENERGY OR PHYSICAL FACTOR. This is in the form of light, heat and stored energy in chemical bonds. Annual rainfall, wind latitude and altitude etc. are also some physical factors, which have a strong influence on ecosystem. For proper functioning of an ecosystem there must be a continuous 'flow of energy' and 'cycling of minerals' among the organisms of the ecosystem.

ENERGY FLOW IN THE ECOSYSTEM

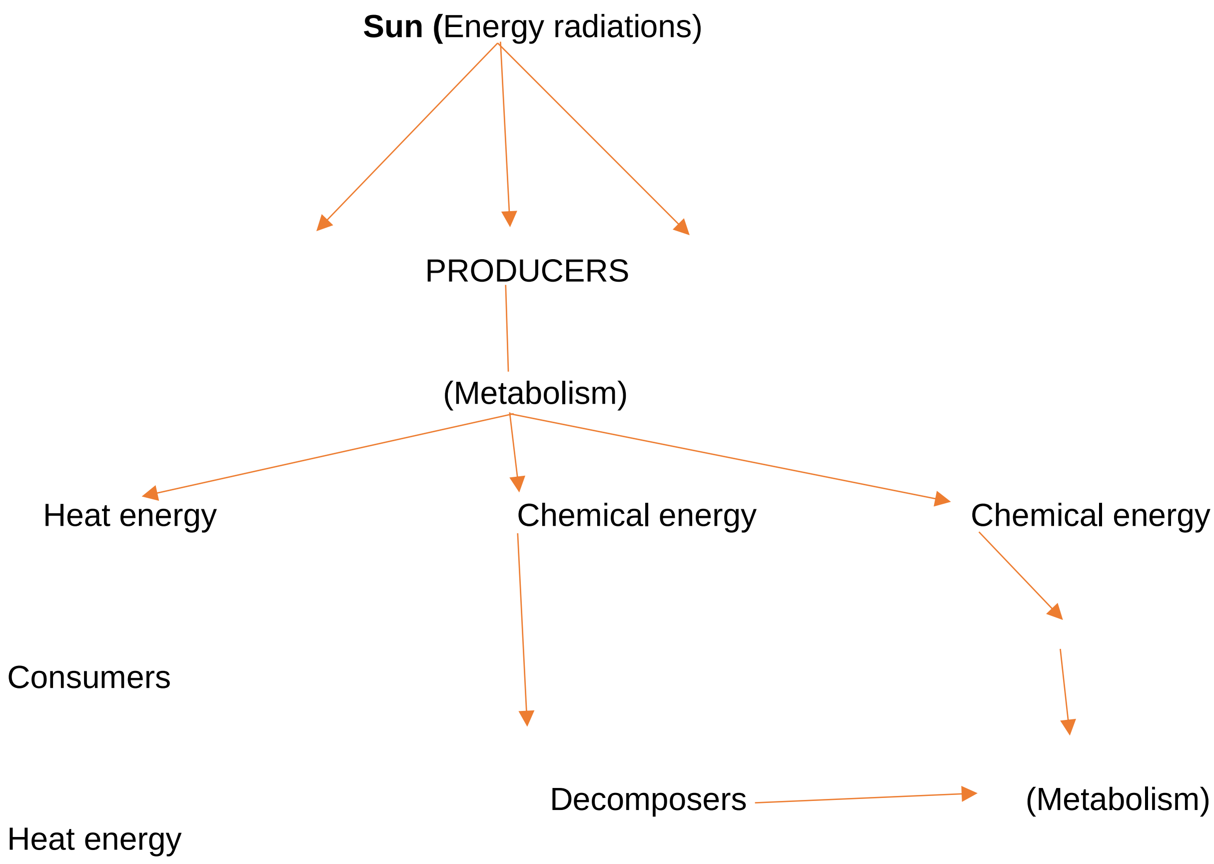
Energy is needed for every biological activity. Solar energy is transformed in to chemical energy by a process of photosynthesis. This energy is stored in plant tissue and then transformed in to mechanical and heat form during metabolic activities.

The flow of energy follows the two laws of thermodynamics.

1st law of thermodynamics: The law states that energy can neither be created nor be destroyed but it can be transformed from one form to another. Similarly , as we have read earlier Solar energy utilized by green plants in photosynthesis converted in to biochemical energy of plants and later in to that of consumers.

2nd law of thermodynamics. The law states that energy transformation involves degradation or dissipation of energy from a concentrated to a dispersed form. We have seen dissipation of energy occurs at every trophic level. There is loss of 90% energy, only 10% is transferred from one trophic level to the other.

SUN AS THE SOURCE OF ENERGY. Sun is the source of energy which extends radiations from high frequency to low frequency. Approximately 99% of total energy is in the region between UV and IR. The visible spectrum spreads over 0.38 u to 0.77 u involving about 50% of solar p radiations. Some autotrophs however utilize energy released from oxidation processes for the synthesis of organic food.



ENERGY FLOW MODELS

As we have seen that there is unidirectional flow of energy from sun to the producers and then various types of consumers. Therefore, behaviour of energy in ecosystem can be termed Energy flow. About 34% of the sunlight reaching the atmosphere is reflected back in to its atmosphere . 10% is held by ozone layer, water vapours and other atmospheric gases. Rest 56% reaches the earth surface. Out of this 1-5% is used by green plants for photosynthesis.

$$6CO_2 + 6H_20 \xrightarrow{\text{sun light and chlorophyll}} C_6H_{12}O_6 + 60_2$$

Rest is absorbed as heat by ground vegetation or water. The flow of energy in an can be explained with the help of various energy flow models ecosystem

1. ODUM'S ENERGY FLOW MODEL

E.P. Odum 1963 explained flow of energy involving three trophic levels with the help of his universal energy flow model. As the flow of energy takes place, there is gradual loss of energy at every level thereby resulting in less energy available at next trophic level.

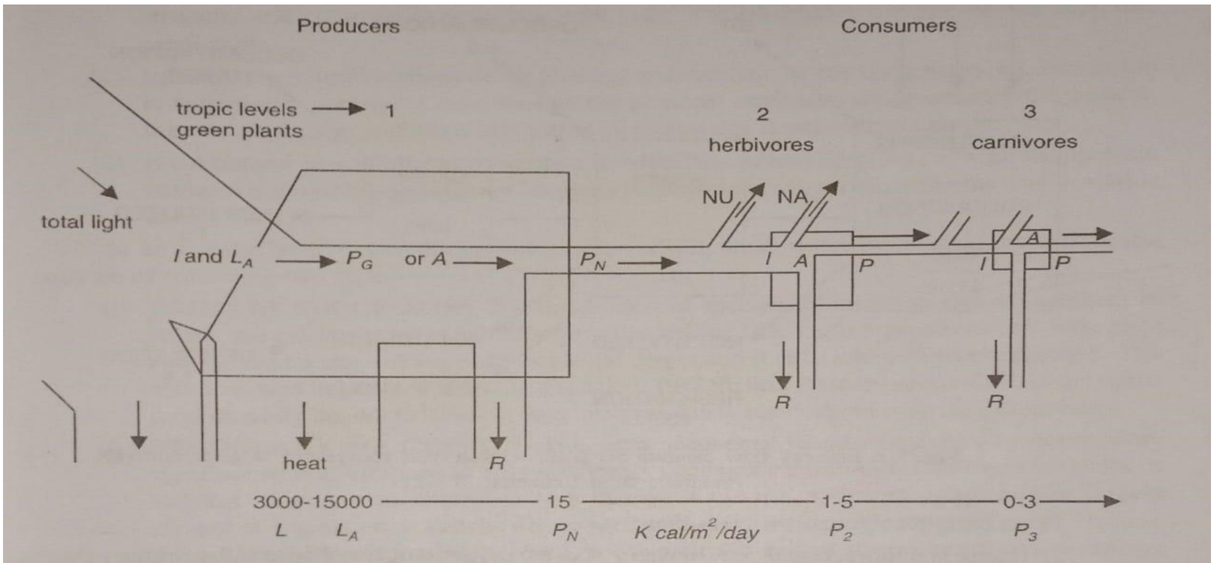


Fig. 3.2. Depicting three tropic levels (Adopted from, Odum, 1963)

Out of total 3000 K Cal of light falling (L) on producers level, only 50% i.e. 1500 KCal is absorbed by autotrophs with an efficiency of energy capture is only 0.1 - 1%. As reported 21% of this energy is consumed in metabolic reactions of autotrophs for their growth, development, maintenance and reproduction. Thus gradual decline in energy at the second trophic level i.e. herbivores and then at third trophic level i.e. carnivores in grazing food chain is observed.

2. LINDEMAN'S ENERGY FLOW MODEL

Lindeman in 1942 gave the unidirectional energy flow model of fresh water ecosystem. Model shows that out of total 118,872 g.cal/cm²/year incident solar radiations, producers can utilize only 1% (111.0 g cal/cm²/year) in their photosynthesis.

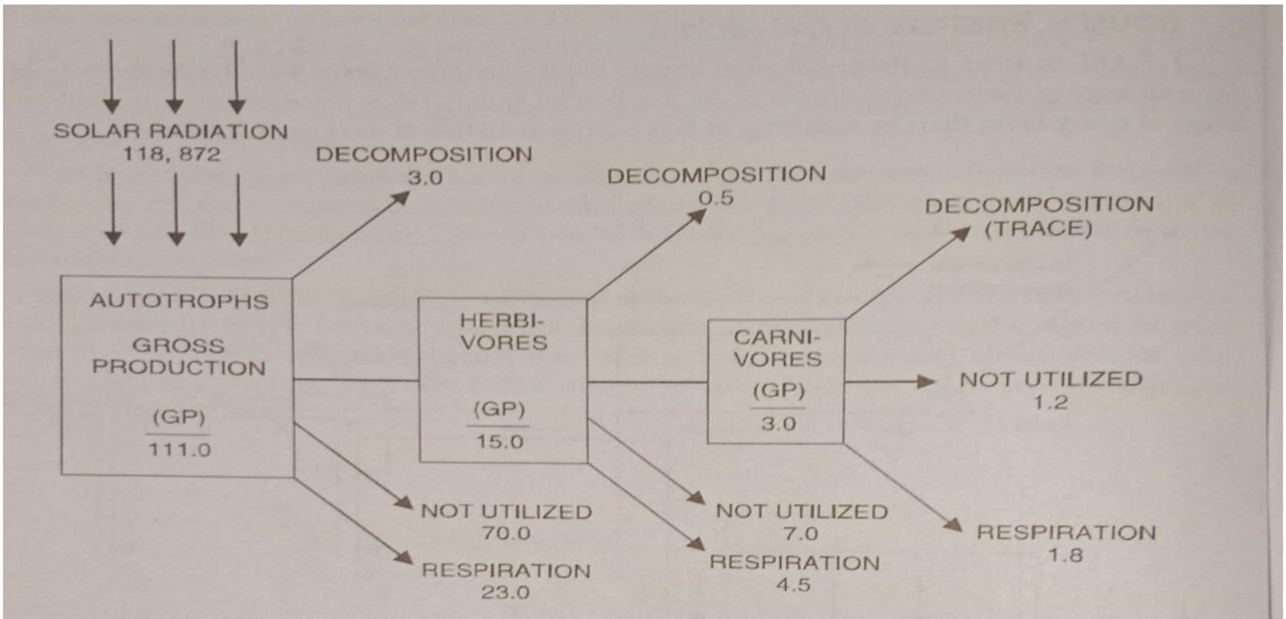


Fig. 3.3. Eneregy flow diagram for a lake (Freshwater ecosystem) in g.cal./cm^2/yr (modified from Lindeman, 1942)

- About 21% of this gross production (GP) is utilized in metabolic functions of producers, 3% is utilized in decomposition and 63% remains unutilized in decomposition and 63% remains unutilized.
- Thus only 13-14% i.e. 15 g.cal/ cmp/year of GP is available to herbivores. At this level about 30% of it (i.e.15 g.cal/cm²/year) is utilized in metabolic functions i.e. respiration, growth and reproduction etc.
- This is more than the autotrophs consumed i.e. 21%. Again 3% of it is utilized in decomposition while 47% is remains un-utilized. Thus only 20% energy of the autotrophs is available (i.e. 3 g.cal/cm²/year) to carnivorous.
- It is also reported that about 70% energy is available for carnivores, which is not utilized and only 28-6% of net production passes to carnivorous. Carnivores utilized 60% energy at this level in metabolic activities and rest is remains as un-utilized.

From both the figures it is clear that

1. There is unidirectional flow of energy i.e. the system would collapse if the primary source, the sun were cut off.

2. Progressive decrease in energy at each trophic level.

3. There is also a corresponding decrease in biomass. But there is no correlation between biomass and energy. This relationship may differ according to situations.

ECOLOGICAL SUCCESSION

Succession is the “birth" of an ecosystem, and subsequent "aging process of its abiotic and biotic features. ODUM (1971) has rightly included the following three parameters in his definition of ecological succession.

(1) It is an orderly process of community development that involves changes in species structure and community processes with time, it is reasonably directional and therefore predictable.

(2) It results from modifications of the physical environment by the community, i.e. succession is community controlled even though the physical environment determines the pattern, the rate of change and often sets limits as to how for development can go.

(3) It culminates in a stabilized ecosystem in which maximum biomass (or high information content) and symbiotic function between organisms are maintained per unit of available energy flow.

In any of the basic environments such as terrestrial, fresh water or marine, the succession may be of following two types

(i) PRIMARY SUCCESSION. It is the process of species colonization and replacement in which the environment is initially virtually free of life, i.e. the process starts with base rock or sand deme or river delta or glacial debris and it ends when climax is reached. The sere involved in primary succession is called PRESERE. Primary succession occurs when a community begins to develop on a site previously unoccupied by living organisms.

(ii) SECONDARY SUCCESSION. The term secondary succession refers to community development on locations or sites previously occupied by well developed communities. It occures where a community has been disrupted and the surface is completely or largely devoid of vegetation. It may be due to earthquake, fire or even clearing of forests by man. In each case organism modify the environment in a way that allow one species to replace another. The sere involved in secondary succession is called SUBSERE.

Depending on the moisture contents, the primary and secondary successions may be of the following types

(A) HYDRACH or HYDROSERE. The succession when starts in the aquatic environment such as ponds, lake, streams, swamps, bogs etc.

(B) MESARCH OR MESOSERE. It is an intermediate type with adequate moisture. The succession when begin in such an area is called mesarch.

(C) XERACH OR XEROSERE. The succession when starts in Xeric or dry habitat having minimum amounts of moisture, such as rocks, dry deserts etc is called xerach. A temporary community in an ecological succession on dry and sterile habitate is called Xerosere. It may be of three types

(i) LITHOSERE. i.e. succession initiating on rocks.

(ii) PSAMMOSERE. i.e. succession initiating on sand.

(iii) HALOSERE. i.e. succession initiating on saline water or soil.

Some times succession is also classified into two on the basis of community metabolism.

(a) AUTOTROPHIC SUCCESSION. It is characterised by early and continued dominance of autotrophic organisms like green plants. It begins in a predominantly inorganic environment and the energy flow is maintained indefinitely.

(b) HETEROTROPHIC SUCCESSION. It is characterised by early dominance of heterotrops such as bacteria, actinomycetes, fungi and animals. It begins in a organic environment and there is a progressive decline in energy content.

GENERAL PROCESS OF SUCCESSION

The complete process of a primary autotrophic ecological succession involves the following sequential steps which follow one another.

1. NUDATION. The process of succession begins with the formation of a base area or nudation by several reasons such as volcanic eruption, flood, landslide, erosion deposition, fire, disease etc. Some base areas are also created by man e.g. walls, burning, digging etc.

2. INVASION. The invasion is the arrival of the reproductive bodies or propagules of various organisms and their settlement in the new or base area. Plants are the first invaders (pioneers) in any area because the animals depend on them for food. It include the three steps

(1) Dispersal or migration. It is the process in which propagule leaves the parent plant and arrives the bare area. The seeds, spores or other propagule of the species reach the bare area through the agency of air, water or animals.

(ii) ECESIS. This is the successful establishment of migrated plant species in to new area. It includes germination of seeds, growth of seedlings and starting of reproduction.

(iii) AGGREGATION. This is the final stage of invasion where immigrant species increase their number by reproduction and aggregate in a large population in the area.

3. COMPETITION. As the number of individuals grows, there is competition both interspecific (between different species) and intra specific (within the same species) for space, water and nutrition. They influence each other in a number of ways known as COACTION.

4. REACTION. When living organism grow, use water and nutrients from the substratum in turn they cv have a strong influence on the environment which is modified to a large extent and known as reaction. When they become unsuitable for the existing species, favour some new one, which replace them. Thus, reaction leads to several seral communities.

5. STABILIZATION OR CLIMAX. Eventually a stage is reached when a final terminal community becomes more or less stabilised for a longer period of time and it can maintain itself in the equilibrium or steady state with climate of that area. This last seral stage is mature, self maintaining, self reproducing through development stages and relatively permanent. This final stable community of the sere is the CLIMAX COMMUNITY and the vegetation supporting it is the CLIMAX VEGETATION.

FOOD CHAINS

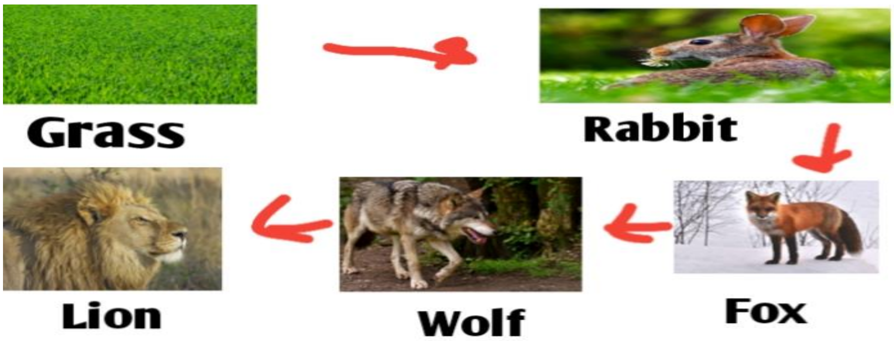
- Small herbivorous organisms such as Caterpillars field mice etc. Consume this 'vegetable material and convert it to animal material, which serve as food to meat eating animals. They are eaten by larger carnivores.
- This sequence of eating and being eaten, with the resultant transfer of energy is known as FOOD CHAIN.
- Thus in food chains organisms of an ecosystem are linked together. Each step is known as trophic level and the study of the energy flow through these steps is called trophic ecology. Food chains are not isolated from each other.
- Primary producers trap radiant energy of sun and transfer that to chemical or potential energy of organic compounds such as carbohydrates proteins and fats.
- When herbivore eats a plant and these compounds are oxidised. As we have read earlier the energy liberated is just equal to the amount of energy used in synthesizing the substances. When this animal is eaten by another one, along

with transfer of energy from a herbivore to carnivore a further decrease in energy occurs as the carnivore oxidise the organic substances for the first to liberate energy to synthesize its own cellular constituents. Such transfer of energy from organism to organism sustains the ecosystem.

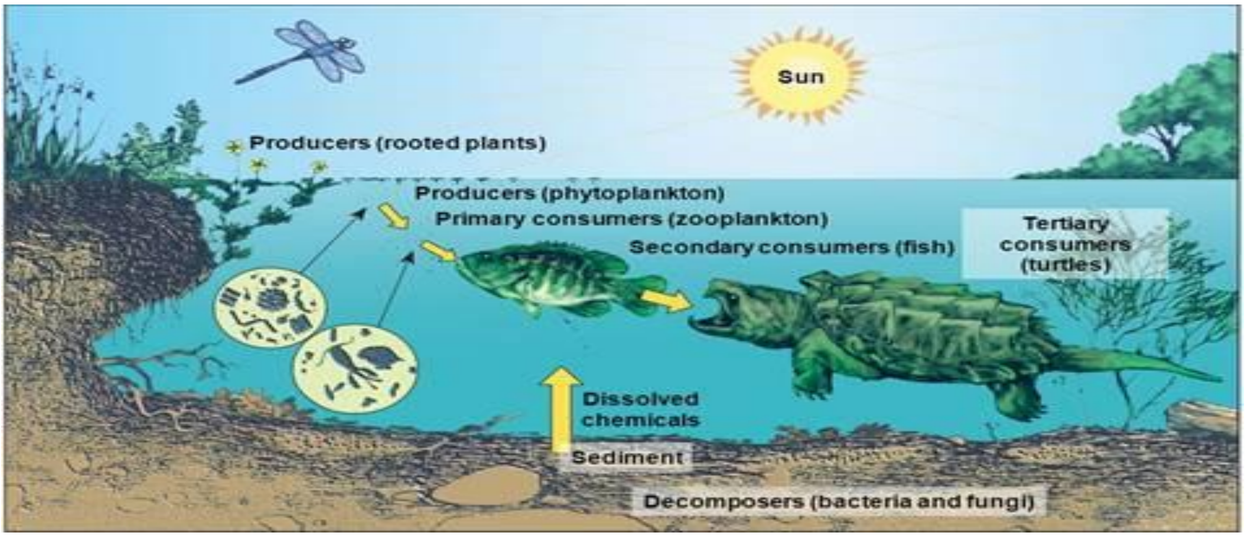
- The energy flows from primary producer to primary consumers, from primary consumer to secondary consumers and from secondary consumer to tertiary consumers and so on . This simple chain of eating and being eaten away is known as food chain.

Examples of food chains are :

1. Grass → Rabbit→ Fox→ Wolf→ Lion. (Grass land ecosystem)



2. Phytoplankton → Water fleas → Small fish → Tuna . (Pond ecosystem)



3. Litchens → Reinder → Man. (Arctic tundra)

In nature we can distinguish two types of food chains.

1.GRAZING FOOD CHAIN

This type of food chain starts from green plants and ends carnivores by passing through herbivores The primary carnivores or secondary consumers eat herbivores or primary consumers of the ecosystem. And likewise, secondary carnivores or tertiary consumers eat primary carnivores. The total energy assimilated by primary carnivores or gross tertiary production and its disposition in to respiration, decay and further consumption by other carnivores is entirely analogous with that of herbivores. Thus much of the energy flow in these chains can be described as follows

Primary producer → Primary Consumer → Secondary Consumer → Tertiary consumer

Autotroph → Herbivore → Primary Carnivore → Secondary carnivore → So on

DETRITUS FOOD CHAIN

The term detritus is given to organic wastes, exudates and dead matter derived from grazing food chain. The energy contained in this detritus is not lost to the ecosystem as a whole, rather it serves as the source of energy for a group of organisms (Detritivores), they differ from grazing food chain called the detritus food chain. Such food chains operates in the decomposing accumulated litter in a temperate forest.

In some ecosystems, considerably more energy flows through the detritus food chains than through the grazing food chains. The organisms of the detritus food chains are, algae, bacteria, slime molds, fungi, actinomycetes protozoa, insects, mites, crustaceans, molluses worms, nematodes etc. Some species are highly specific in their food requirements and some can eat almost anything. All these are detritus consumers. Heald (1969) and Odum (1971) have studied the detritus food chain of mangrove leaves of sourthen Florida. Conclusively, we ca nd detritu chain as follows.

Detritus → Detritivores → Detritivore Consumer → Small carnivore → Large carnivores

FOOD WEBS

In nature simple food chain occur rarely. The same organism may operate in the ecosystem at more than one trophic level i.e. it may derive its food from more than one source. organism may be eaten by seyeral organisms of a higher trophic level or an organism may feed upon several different organisms of lower trophic level. In this way individual food chains interconnect to form a complex network with several linkages and are known as food web. Thus food web is defined as —"**A network of food chains where different types of organisms connected at different trophic levels, so that there are a number of options of eating and being eaten at each trophic level.**

The following five types of food chains are interconnected to form food web in this figure.

(1) Grass → Grasshopper → Predatory bird (Hawk)

(2) Grass → Grasshopper → Lizard → Hawk.

(3) Grass → Rabbit Hawk (or vulture or man)

(4) Grass → Mouse/Rat → Hawk

(5) Grass → Mouse/Rat → Snake + Hawk.

This shows, food chains in natural conditions never operate as isolated sequences but are interconnected with each other forming some sort of interlocking pattern .

ECOLOGICAL PYRAMIDS

Charles Elton in 1927, noted that the animals at the base of the food chain are relatively abundant, while those at the end are relatively few in number i.e. there is progressively decrease in between the two extremes. Secondly, there is some sort of relationship between the numbers, biomass and energy content of the primary producers, consumers of the first and second orders and so on to top, Carnivores in any ecosystem.

Ecological pyramids are of three general types

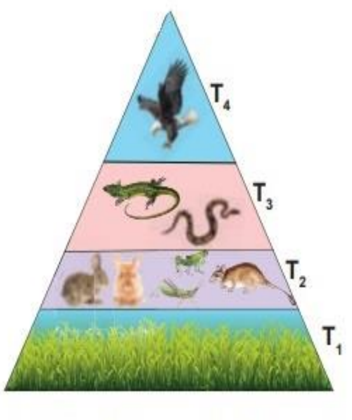
1. Pyramid of numbers **-** (Based on number of organisms at each level.)

2. Pyramid of Biomass **-** (Based on biomass of organisms)

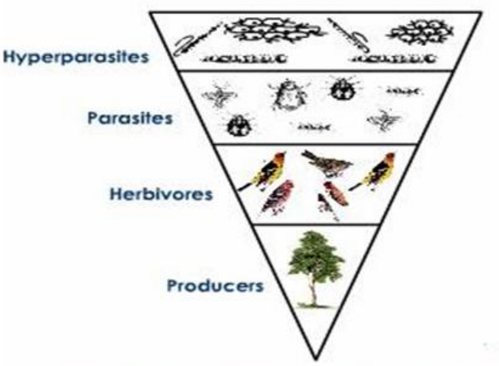
3. Pyramid of energy **-** (Showing the rate of energy flow and/or productivity at successive trophic levels.)

The pyramids of numbers and biomass may be upright or inverted depending of the food chain in the particular ecosystem whereas pyramids of energy are always upright.

1. **Pyramid of numbers.** This deals with the relationship between the number of producers, herbivores and carnivores at successive trophic levels. At the base of such figure (pyramid) is always the number of primary producers and the subsequent structures on this base are represented by the number of consumers at successive levels. a grassland ecosystem, the producers which are mainly grasses are always many in number. This number then shows a decrease towards apex, as the primary consumers or herbivores like rabbits are less in



Pyramid of numbers in grassland ecosystem

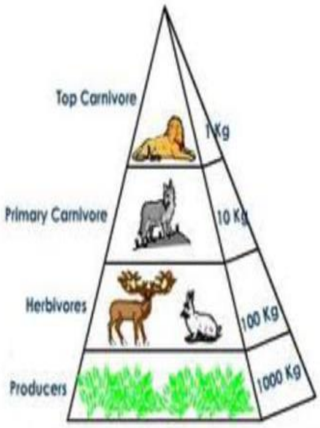


Inverted pyramid of number

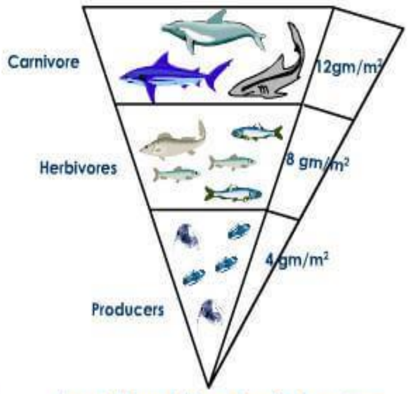
(Uprite pyramid)

number than the grasses. The secondary consumers are lesser in number than primary consumers. Finally the top consumers (tertiary)like hawks or other animals are least in number. Thus the pyramid becomes upright. In a pond ecosystem, the pyramid is also upright.

2. **Pyramid of Biomass**. Pyramid of numbers of biomass is given where the weight of primary producers forms the base. The ecosystem, where the pyramid of biomass is upright. The biomass of one tree is very high. The biomass of a number of birds feeding upon the tree is far less than that of the tree. Similarly, the biomass of even a very large number of parasite in and on the body of the birds is far less.



Upright Pyramid of biomass in a Terrestrial Ecosystem



Inverted Pyramid in an Aquatic Ecosystem

3. **Pyramid of energy**

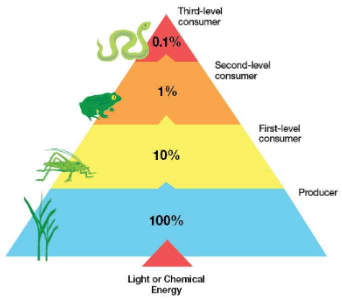
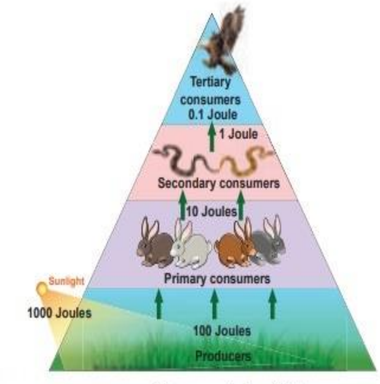


Figure 9. Energy Pyramid

- Generally three types of ecological pyramids, the energy pyramid give the best picture of overall nature of the ecosystem. As against the pyramids of numbers and biomass the shape of the pyramid of energy is always upright, because in this the time factor is always taken in to account.
- The pyramid of energy represent the total quantity of energy utilized by different trophic level organisms of an ecosystem per unit area over a set period of time. The population of phytoplanktons in aquatic ecosystem also complete sets of new generation in every few hours or days.
- The cumulative energy content of these generations of phytoplanktons trap in course of a year is certainly much more than that of only a few

generations of herbivore fishes in the corresponding time and space. The energy content of top carnivores (utilized in one year) is the least.



Pyramid of Energy

Therefore, the pyramid of energy is upright. The ratio of the amount of energy absorbed and the amount of energy which would be retained in biomass is known as ecological efficiency.

SOME MAJOR ECOSYSTEMS

There are three types of ecosystems in nature ..

1. Terrestrial ecosystem
2. Freshwater ecosystem
3. Marine ecosystem

A large geographical are with its specific and complex flora and associated fauna is called a biome. The physical factors like, nature of soil, rainfall, temperature, light etc. effects the vegetation of a biome. The ecological characteristics of some major ecosystems are given.

Terrestrial ecosystems

The terrestrial ecosystems may be Latitudinal biome or altitudinal. It consists of

(i) Forest ecosystem

(ii) Grassland ecosystem

(iii) Desert ecosystem

FOREST ECOSYSTEM

Roughly 40% of the land is occupied by forest. But in India it is one-tenth. In India, tropical rain forests are found in Western Ghats, Andamans and North-East Himalayas. So these have maximum bio-diversity. The different components of a forest ecosystem are as:

Abiotic Component : These are the inorganic & organic substances present in the soil & atmosphere. In addition to the minerals present in the forests, we find the dead organic debris. The light conditions are different due to complex stratification in the plant communities.

Biotic Component: The living organisms present in the food chain occur in the following order

1. Producers. These are mainly trees that show much species diversity and greater degree of stratification specially in tropical moist deciduous forest. In northern coniferous forest needle leaved evergreen tree, specially the spruces, firs and pines are with poor development of shrub and herb layers. Deciduous forest is greatly modified by man and much of it is replaced by cultivated and forest edge communities

2. Consumes. These are as follows

(a) Primary Consumers ; These are the herbivores that include the animals feeding leaves as ants, flies, beetles, leafhoppers bugs, spiders etc. Many of the larger herbivorous vertibrates some animals like elephants, nilgai, deer, moles, flying foxes, fruitbats, mongooses etc. are like moose, snowshoe have grouse are found on broad leaved developmental communities. Similarly on shoots and/or fruits. on tree grazing

(b) Secondary Consumers : These are the carnivores like snakes, birds, lizards, fox etc. feeding on herbivores. lion, tiger etc. that eat carnivores

(c) Tertiary Consumers: These are the top carnivores like lion,tiger etc. that eat carnivores of secondary consumers level.

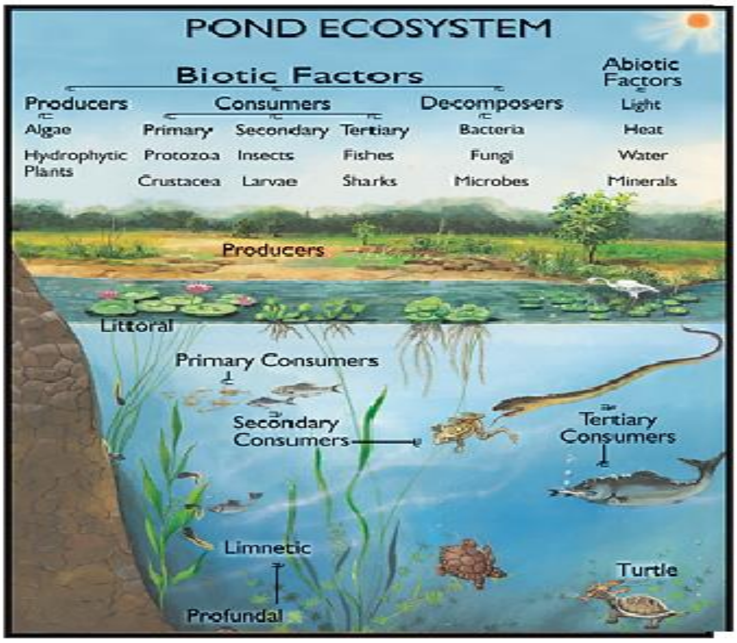
3. Decomposers. These are wide variety of micro-organisms like actninomycetes(streptomyces) , bacteria (Bacillus, clostridium, Pseudomonas etc.), Fungi (species of Aspergillus, Coprinus, Polyporus, Fusarium, Trichoderma etc.). Rate of decomposition in tropical and subtropical forests is more rapid than that in the temperate ones.

AQUATIC ECOSYSTEMS

More than 70% of the land is covered by water. The important ecosystems are….

POND ECOSYSTEMS.

Ponds are small bodies of water in which the littoral zone is relatively large and the limnetic and profundal regions are small or absent. Stratification is of minor importance . Ponds may be found in most regions of adequate rainfall . They are continually being formed, as a stream shift position, leaving the former bed isolated as a body of standing water where organic materials are accumulated.



Temporary ponds are dry for part of the year are specially interesting and support a unique community organisms in such ponds must able to survive in a dormant stage during dry period.

Ponds play an important role in the villages where most of the activities like washing clothes, bathing, swimming, cattle bathing etc. are centre around ponds. We may study the pond as an ecosystem.

Abiotic Component. Apart from heat, light the basic inorganic and organic compounds, elements are water, CO2, oxygen, calcium, nitrogen, phosphorus, amino acids etc. The amount of the minerals present at any time in the physical environment of the pond. “Standing state” may be estimated by appropriate methods. Light intensity and turbidity index of water at different depths can also be measured by lux-photometer and Sechhi disc respectively.

Biotic Components They are as follows

1. Producers. These are autotrophic, green plants and bacteria. They fix radiant energy and with the help of minerals from water & mud form complex organic substances like Carbohydrates, proteins & lipids. Producers are of the following types

(a) Macrophytes. These are mainly rooted larger plants which include partly or completely submerged floating and emergent hydrophytes. The common species of the plants are Trapa, Typha, Sagittaria, Nymphaea, Chara, Hydrilla, Utricularia, Marsilea, Azolla, Sylvinia, Spirodella, Lemna etc…

(b) Phytoplankton. These are minute, floating or suspended lower plants like Ulothrix, Spirogyra, Cladophora, Oedogonium, Cosmarium, Eudorina Pandorina, Volvox, Chlamydomonas etc. and some flagellates. Biomass is estimated as weight of standing crop per unit area or volume. Generally, biomass and energy content of the vegetation decreases from the margin of the pond towards its centre. Energy content is generally expressed in terms of cal/gm dry wt.

2. Consumers. Most of the consumers are herbivores except insects and some large fish. But generally are heterotrophs. In pond consumers are distinguished as

(i) Primary Consumers. These are herbivores, also known as “primary macro consumers” feeding directly on living plants. They may be large or in small size. They are further differentiated as

(a) Benthos. These are the animals associated with living plants labelled as 'a' in fig and those bottom forms which feed upon the plants remains at the bottom labelled as 'b' in fig. Benthic population include fish, insect larvae, mites, molluses, crustaceans etc. Besides there some animals like cows, buffaloes and birds also visit the pond.

(b) Zooplanktons. These are chiefly the rotifers, (Brachionus, Lecane etc.), protozonas (Euglena, Coleps etc.) and Crustaceans (Cyclops, Stenocypris etc.). They feed on phytoplanktons .

(ii) Secondary Consumers. These are Carnivores like insects and fish which feed on primary consumers (herbivores) like Zooplanktons.

(iii) Tertiary Consumers. These are some large fish feed on smaller fish.

In pond fish may occupy more than one trophic levels.

3. Decomposers. These are microconsumers, which absorb only a fraction of the decomposed matter. They decompose organic matter of both producers as well as microconsumers in simple forms. Thus they play an important role in return of mineral elements again to pond. The bacteria, actinomycetes and fungi (species Aspergillus, Cladosporium, Pythium, Penicillium, Circinella etc.) are most common decomposers in water and mud of the pond.

MARINE (OCEAN) ECOSYSTEM

The marine environment of seas and oceans is large occupying 70% of the earth surface. The volume of the surface area of marine environment lighted by sun is small in comparison to the total volume of water involved.

The biotic components of an ocean are as follows

1. PRODUCERS

These are autotrophs, which are mainly the phytoplanktons. They trape radiant energy from sun through their pigments. A number of macroscopic seaweeds (Brown and red algae) are also come in this category. They are in distinct zones at different depths of water.

2. CONSUMERS

These are heterotrophic macroconsumers being dependent for their nutrition on the primary producers. These are directly on producers

(i) The herbivores like Crustacions, molluscs, fishes etc. which feed are called primary consumers. called secondary.

(ii) The carnivores fishes like shad, herring etc. feeding on herbivores are secondary consumers

(iii) The top carnivores fishes like cod, haddock, halibut etc. that feed on are called tertiary consumers.

3. Decomposers. The microbes active in the decay of dead organic matter are chiefly and some fungi.

ESTUARIES (ESTUARINE ECOLOGY)

Estuarine is derived from the word aestus means tide. Pritchard in enclosed coastal body of water, which has a free connection with the open sea. It is thus strongly affected by tidal action and within it sea water is mixed with fresh water from land drainage. River mouths, coastal bays, tidal marshes and bodies of water behind barrier beaches are examples To illustrate estuaries, the different classifications will be represented based on

(1) Geomorphology
(2) Water Circulation and stratification
(3) Systems energetics.

According to Pritchard 1967, four subdivisions of estuaries are from zeomorphological point of view

(i) Drowned river valleys

(ii) Fjord type estuaries

(iii) Bar - built estuaries

(iv) Estuaries formed by tectonic processes.

River - delta estuaries found at the mouths of large livers such as Mississippi or the Nile. It is different from formers. On hydrographic basis esturaries can be placed in three broad categories.

(a) Highly stratified or salt wedge estuary.

(b) The partially mixed or moderately stratified estuary.

(c) The completely mixed or vertically homogenous estuary

The Hypersaline estuary is a special type.

Physico Chemical Aspects of Estuaries :

- Current and salinity both are important here. Estuarine currents result from the interaction of a one direction stream flow which varies with the session and rain fall with oscillation ocean tides and with wind. The salinity varies vertically and horizontally and fluctuates amazingly between 0.5 to 0.35%.
- The sessional and tidal cycles causes changes in nutrient concentration in the estuary. Any how, all estuaries have high productivity.
- The concentration of nutrients and fix carbon is The sessional and tidal cycles cause level of production within the detritus food chain.

LAKE ECOSYSTEM

Lakes are inland depressions containing standing water. They vary in size and depth (few feet to 5000 feet). Some lakes wave outlet streams. In lake there are three to five well recognized horizontal strata namely.

(i) Littoral zone

Shallow water near the shore forms this zone. - Different zone of a deep freshwater lake. It contains upper warm and oxygen rich circulating water layer, which is called epilimnion. It include rooted vegetation.

(i**) Sublittoral zone**. It extends from rooted vegetation to the non circulating cold water with poor oxygen zone i.e. hypolimnion.

(iii) **Limnetic zone.** It is the open water zone away from the shore. It is up to the depth of effective light penetration where rate of photosynthesis is equal to the rate of respiration. (iv**) Profundal zone.** It is the deep water area beneath limnetic zone and beyond the depth of effective light penetration.

(v) **Abyssal zone.** It is found only in deep lakes since it begins at about 2000 meter from the surface.

Kinds of lakes. Based on the physical factors, productivity etc. different classifications of lakes are given. Based on temperature, Hutchinson (1957) classified into dimictic, monomictic and polymictic. Based on Humic acid contents, the lakes are classified in to clear water lakes and Brown water lakes.

Physico-chemical properties of lakes

Lakes have the tendency to become thermally stratified during summar and winter to undergo definite seasonal periodicity in depth.Light too penetrates only to a certain depth,depending on turbidity.

Biotic Communities of lakes

Organisms depending on substratum are called pedonic forms and that are free from it called limnetic forms. The lakes have several type of organisms.

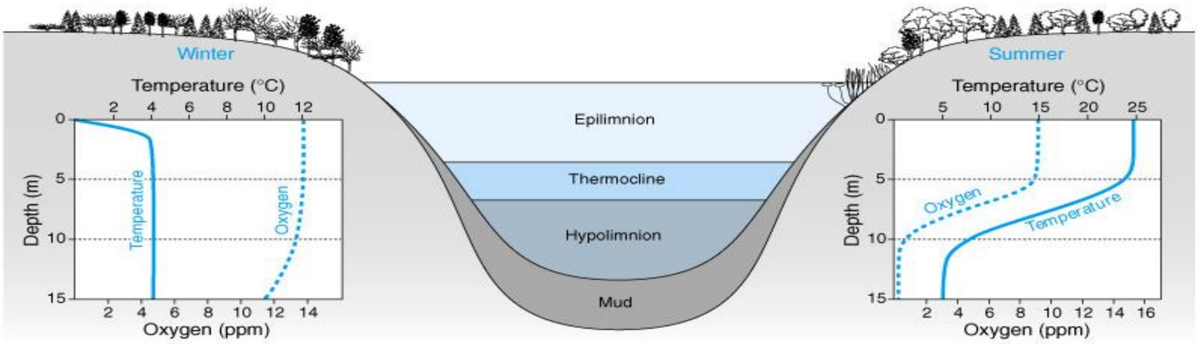
(1) **Neuston.** These including floating plants such as duckweeds and many type of animals.

Animals are called epineuston while others including insects called hyponeuston.

(ii) **Plankton**. These are small plants and animals whose powers of self locomotion is very limited. Certain zooplanktons are very active some planktons are called as nektoplanktons, (iii) **Nekton.** These animals are swimmers.

(iv) **Bethos.** These includes the organisms living at the bottom of the water mass. These living above the sediment water interface are termed benthic epifauna and those living in sediments itself are termed as infauna.

Stratification in lakes.



- ➢ During the summer the top water become warmer than the bottom waters, as a result only the warm top layer circulates and it does not mix with the more viscous colder water, called thermocline.
- ➢ The upper water layer is epilimnion. Colder noncirculating water is the hypolimnion. Subtropical lakes having surface temperatures that never fall below 4°C. In terms of water circulation patterns most of the lakes of the world can be conveniently assigned to one of the following categories (Hutchinson 1957).

(a) Dimictic (mictic = mixed) Two sessional periods of free circulation.
(b) Cold monomictic. Water never above 4°C (polar regions), seasonal overturn in summer. (c) Warm monomictic. Water never below 4°C. One period of circulation in winter.
(d) Polymictic. More or less continually circulating with only short, if any, stagnation period. (e) Oligomictic. Rarely mixed.
(f) Micromictic. Permanently stratified.

STREAMS

Biotic community in streams is quite different from that of ponds. Most streams in the vicinity of urban areas are polluted. Streams are fresh water aquatic systems where water current is a measure controlling factor, oxygen and nutrients are in water. Differences between streams and ponds revolve around a triad of conditions.

ZONATION IN STREAMS

- In streams zonation is longitudinal. In streams we find zones increasingly older stages from source to mouth. Charges are more pronounced in the upper part, because of gradient, volumes of flow and chemical composition charges rapidly.
- The change in composition of communities is likely to be more pronounced in the first mile than in the last fifty miles . The longitudinal distribution of fish in a stream may be selected as a specific example. Thompson & Hunt found that the number

Unit 4: Biodiversity and it’s Conservation

INTRODUCTION

Biodiversity may be defined as, “Biological diversity means the variability among living organisms from all sources including, interalia, terrestrial, marine and other ecosystems and the ecological complexes of which they are part, this includes diversity within species between species and of ecosystem.

GENETIC, SPECIES AND ECOSYSTEM DIVERSITY

Biodiversity is usually analysed at three levels i.e. species, genetic and ecosystem, each of which has its own significance.

1. Diversity of Biotic Communities and Ecosystems :

- Depending largely Upon the availability of abiotic resources and conditions of the environment an ecosystem develops its own characteristic community of living organisms.
- A small pond, for example, constitutes an ecosystem and possesses a set of flora and fauna different from a river which is another type of ecosystem. Different types of forests, grass-lands, lakes, ponds, rivers, wet-lands etc. represent diverse ecosystems each with a characteristic biotic community.

2. Diversity of Species Composition within a Community : The biotic component in an ecosystem may be composed of a few species only or a large number of species of plants, animals and microbes, which react and inter-act with each other and with the abiotic factors of the environment. The richness of species in an ecosystem is usually referred to as Species diversity.

3. Diversity of Genetic Organization within a Species :
Within a species there are often found a number of varieties or races or strains which slightly differ from each other in one, two or a number of characters such as shape, size, quality of their product, resistance to insects, pests and diseases, ability to withstand adverse conditions of environment etc.

BIOGEOGRAPHICAL CLASSIFICATION OF INDIA

India is one of the 12 mega biodiversity countries in the world. The country is divided in to 10 biogeographic regions. The wide variety in physical features and climatic conditions have resulted in a diversity of ecological habitats like forests, grasslands, wetlands, coastal and marine ecosystems and deserts which harbour and sustain immense biodiversity.

The following 13 biogeographical regions have been identified in India :

1. Himalaya
2. The Desert

3. Deccan Peninsula
4. Malabar
5. Andaman Islands
6. Nicobar Islands
7. Gangetic Planes
8. Laccadive Islands
9. Maldive/Chagoas Island
10. Western Ghats
11. Burman/Bangalian forest
12. Marine Coast
13. Coromondal Mahanandian

Floristic (Botanical) Regions of India

The country has been divided in to the following nine floristic regions with respect to floral diversity :

(i) Western Himalayas : It extends from Kumaon to Kashmir and has annual rainfall up to 200 cm. Correspond to three climatic belts, there are three zones of vegetation.

(a) Submontane zone. It is constituted of tropical and sub tropical parts and extends up to 1500 meters altitude. It comprises mostly of Siwalik ranges. Snowfall does not occur. The plants like Shorea robustica, Dalbergia sissoo, Cedrela toona, Eugenia jambolano, Acacia Catechu, Butea monosperma (Dhak) Zizyphus etc. are found in this region.

(b) Temperate Zone. Above submontane zone extend temprate zone forests up to 3500 meter altitude. They are dominated by plant species like Acer, Ulmus, Rhododendron, Betula, Salix, Populus, Cornus, Bumus, Pinus, Taxus, Picea etc.

(c) Alpine Zone. It extends from 3500 - 4500 metres altitudes and is characterized with alpine forest vegetation. Most common tree species are Betula, Juniperus, Rhododendrous etc. and herbs like Primula, Potentilla, Polygonum etc.

(ii) Eastern Himalayas. It includes regions of Sikkim and NEFA and is characterised by more rainfall, less snow and higher temperature. This is also divided into the following three zones altitudinally.

(a) Tropical zone. Upto 1800 metres altitudes, this zone has tropical semi-evergreen or moist deciduous forests. These forests comprise the plants like Shorea robusta, Acacia catechu, Delbergia sissoo, Terminalia, Albizzia, Cedrela, Dendrocalamus (bamboo) etc.

(b) Temperate zone. This zone extends between 1800 metres to 3800 metres altitudes and has typical montane temperate forests which are dominated by oaks like Michelia, Quercus, Pyrus, Symplocos, Eugenia, etc., at lower levels and by conifers as Juniperus, Cryptomeria, Abies, Pinus, Larix.

(c) Alpine zone. Beyond the temperate zone, extends alpine zone upto 5000 meters altitudes. It has alpine vegetation including Juniperus and Rhododendron with its other typical flora.

(iii) Indus plains. This zone includes the arid and semiarid regions of Punjab, Rajasthan, Kutch, part of Gujarat and Delhi. The rainfall is less than 70 cm. The vegetation is tropical thorn forest in semi-arid region and is typical desert in the arid region.

(iv) Gangetic plains. This region extends over Uttar Pradesh, Bihar, Bengal and part of Orissa and is characterised by moderate amount of rainfall and most fertile (i.e., alluvial) soils.

(v) Central India. It comprises Madhya Pradesh, parts of Orissa and Gujarat. The rainfall is 150–200 cm and its vegetation is thorny, mixed deciduous and teak type. The chief plants of this region are Tectona grandis, Madhuca, Diospyros, Butea, Dalbergia, Terminalia, Carissa, Zizyphus, Acafia, Mangifera, etc.

(vi) Malabar (west coast). This region include western coast of India from Gujarat to Cape Comorin and has heavy rainfall. The forests are tropical evergreen in extreme west, semievergreen towards interior subtropical or montane temperate evergreen forests in Nilgiris and mangroves near Bombay and Kerala coast.

(vii) Deccan Plateau. This region extends all over peninsular India (i.e., Andhra Pradesh, Tamil Nadu and Karnataka) and has rainfall upto 100 cm.
(viii) Assam. This region is characterised by heavy rainfall (200 to 1000 cm). The vegetation is either dense evergreen forest or sub-tropical. The evergreen forests include trees like Dipterocarpus macrocarpu, Mesua ferrca, Shorea robusta, Ficus elastica, etc., bamboos as Bambusa pallida, Dendrocalamus hamiltonii, etc., grasses like Imperata cylindrica, Saccharum sp., Themedasp., insectivorous plants as Nepenthes sp., and also epiphytes (ferns and orchids).

(ix) Andmans. This region possesses a varied type of vegetation: mangroves and beech forest at its coasts and evergreen forests of tall trees in the interior, Important plant species of this island are Rhizophora, Mimusops, Calophyllum, Lagerstroemia, etc.

VALUES OF BIODIVERSITY

Biodiversity is a valuable natural resource for the survival of man kind. Man has domesticated a number of economically important plants and animal species. Old traditional varieties and the mid relatives of domesticated plants and animals constitute a vital genetic resource for us

Consumptive value.

- Most of the developing countries obtain fuel wood from forests. Still more than 1500 million people cook their food by burning wood. About 1000 million cubic meter wood is used for fuel across the globe.
- This imposes heavy pressure on forests. Hunting of wild life, use of grass with some commercially important plants as fodder are of only comptive. fully depend on forests (biodiversity) for their habitation and livelihood.

SOCIAL VALUES : Social value is one of the instrumental values where some thing has as a means to another's end. Materialistic uses of biodiversity are the core of instrumental values by ecosystems

(1) Provision of food, fuel and fibber.
(2) Provision of shutter and building materials.
(3) Purification of air and water.
(4) Detoxification and decomposition of wastes.
(5) Generation and renewal of soil fertility, including nutrient cycling.
(6) Control of pests and diseases.
(7) Stabilization and moderation of earth's climate.
(8) Maintenance of genetic resources as key inputs to crop varieties.
(9) Live stock breeds, medicines and other products etc.

Ethical values : Ethical or religious values is also one of the indirect values of biodiversity. The ethical and religious value of biodiversity is rooted in the understanding that huminity is part of nature and that we are just one species among others. All species have an inherent right to exist. Future generations also have an inherent right to know them and to have the choice of using them or not.

Aesthetic value : The aesthetic value of biodiversity has been expressed in many ways through art, poetry, songs, literature, music and dance. Forests are closely linked with our relegion and culture. Human race has a great evolutionary attachment with forests as our ancestors lived in forests

OPTION VALUES : Biological resources existed in this biosphere are very important for human beings. The option value of biodiversity suggests that any species may prove to be a miracle species. It is the precious gifts of nature presented to us. Option value is the indirect value of a species to provide an economic benefit to human society at some point in near future.

BIODIVERSITY AT GLOBAL, NATIONAL AND LOCAL LEVELS

Biodiversity at Global level

It is estimated that there exists 5 – 30 million species of living forms on our earth and of there only 1.5 million have been identified and include 300000 species of green plants and fungi, 800000 species of insects, 40,000 species of vertebrates and 3,60,000 species of microorganisms.
The countries identified are

1. Brazil
2. Colombia
3. Venezuala
4. Peru
5. Ecquador
6. Indonesia
7. Democratic Republic of Congo (Zaire)
8. India
9. China
10. Malaysia
11. Australia
12. Mexico.

BIODIVERSITY AT NATIONAL LEVEL

- The Indian landmass extending over a total geographical area of about 3029 million hectares, is bounded by Himalayas in the north, the bay of Bengal in the east, the Arabian sea in the west, and Indian Ocean in the South. The wide variety in physical features and climatic situation have resulted in a diversity of ecological habitats.
- This richness in biodiversity is due to immense variety of climatic and altitudinal conditions coupled with varied ecological habitats.
- The Indian region having a vast geographical area is quite rich in biodiversity with a sizable percentage of endemic flora and fauna.
- These vary from the humid tropical Western Ghats to the hot desert of Rajasthan, from the cold desert of Ladakh and the icy mountain of Himalayas to the warm costs of peninsular India.

BIODIVERSITY AT LOCAL LEVEL

The biodiversity at local level can be well understand by demarcating the points, places, zones rich in biodiversity. This can be understood as compositional i.e. rich in plants & animals of same habitats and genetic make up.

We can also study the local biodiversity on following lines

1. Richness of species at a given place.

2. Physical characteristics of habitat and vegetation in particular area.
3. Change in species composition across different habitats.
4. Local diversity based on climate, geographical, ecological and other processes responsible for creation.
5. Rate of change across gradients and conditions.

It is said that environmental variables are responsible for diversity but temperature play an important role in affecting the biodiversity of an area. Thus local areas are well affected in heterogenious and homogenious habitats.

THREATS OF BIODIVERSITY

- One of the measure threat to Biodiversity is space, food and raw material for expanding human and plant establishment. Since 1600 there have been over 1000 recorded extinctions of plants and animal species.
- Probably early humans were directly responsible for extinction of many large and smaller mammals But the elimination of species is a normal process of the natural world. When species die or extinct, they will repiace by others. Due to human population and its impact on ecosystems, thousands of species and subspecies become exinct every year.
- According to E.O.Wilson, we are losing 10,000 organisms a year i.e 27 per day. It is studied that 99% of all species of fossile that ever existed are now exinct.

The following are the measure causes and issues related to threats to biodiversity.

HABITAT LOSS : Habit loss due to human activities and other disturbances are wellknown factor. Varying human disturbances are changing ecosystems and are thus threatening the biodiversity. Due to habitat degradation wild populations become more volnerable to predators and diseases. This is especially true for wild life, which suffer due to habitat loss and fragmentation.

POACHING OF WILDLIFE

Poaching is another threat to wildlife. As an ancient period, hunters, collectors, and smugglers (traders) are the measure threat to a number of species including endangered speices. They collected furs, hides, horns, tusks, and some live specimens, herbal products and smuggled to others for millions of dollars.

MAN-WILDLIFE CONFLICTS

Struggle for existance. This is applicable for both, man and wild animal. Due to habit loss animals come out of the forest and destroy the crops later on they become danger to human being. Villagers and affected people kill them.

Unit 5: Environmental Pollution

AIR POLLUTION

"Air pollution may be defined as the presence in the atmosphere of one or more contaminants in such quantities and of such duration as may be, or may tend to be injurious to human, plant or animal life, or property, or which unreasonably interfere with the comfortable enjoyment of life, or property, or the conduct of business."

CLASSIFICATION OF AIR-POLLUTANTS

The air pollutants may be classified in different ways as follows:

(a) According to origin:

(i) Primary pollutants which are directly emitted into the atmosphere and are found such as e.g., CO, NO_2, SO_2, and hydrocarbons.

(ii) Secondary pollutants which are derived from the primary pollutants due to chemical or photo-chemical reactions in the atmosphere, e.g., Ozone, Peroxy-acyl nitrate (PAN), Photo-chemical smog, etc.

(b) According to chemical composition:

(i) Organic pollutants, e.g.,-Hydrocarbons, aldehydes, ketones, amines and alcohols.

(ii) Inorganic pollutants

Carbon compounds (e.g., CO and carbonates)

Nitrogen compounds (e.g., NO_X, and NH_3)

Sulphur compounds (e.g., H_2S, SO, SO, and H2SO4)

Halogen compounds (e.g., HF, HCI and metallic fluorides)

Oxidising agents (e.g., 0_3)

Inorganic particles (e.g., fly ash, silica, asbestos and dusts from transport, mining, metallurgical and other industrial activities).

(c) According to state of matter :

(i) Gaseous pollutants which get mixed with the air and do not normally settle out, e.g., CO, NO_X, and SO_2.

(ii) Particulate pollutants which comprise of finely divided solids or liquids and often exist in colloidal state as aerosols, e.g.,- smoke, fumes, dust, mist, fog, smog and sprays.

Biochemical effects of some important air pollutants

1. Oxides of Sulphur (SO_X)

- SO_X, comprises of SO_2, and SO_3. They are Colourless, heavy water soluble with pungent and irritating odour. SO_X pollution is due to volcanic activity, combustion of fuels, Coal fired power stations, transportation, Refineries, metallurgical operations, chemical plants and other natural and human activities.
- In atmosphere, oxidation of SO_2, in to SO_3, by photolytic and Catalytic processes (in presence of O_3, NO_X, or hydrocarbons) giving rise to the formation of photochemical smog. In humid conditions of the atmosphere SO_3, reacts with water vapours to produce droplets of H_2SO_4 aerosols, give rise to the so called "Acid Rain".

$$SO_2 + 0_3 \lambda \rightarrow SO_3 + O_2$$

$$SO_3 + H_2O \, \lambda \rightarrow H_2SO_4$$

Biochemical effects: Absorbs quickly and irritates the upper respiratory tract. Reacts with cellular constituent chemicals e.g., enzymes. The H_2SO_4 formed lowers PH, impairs enzymatic functions and destroys various functional molecules. Leads to bronchial spasms, breathlessness, impaired pulmonary function via airway resistance, impaired lung clearance and increased susceptibility for infection.

2. Oxides of Nitrogen (NOx)

Characteristics: NOx mostly comprises of NO, NO_2, and N_2O. NO is colourless gas and is slightly soluble in water. NO_2, is reddish brown gas, somewhat water-soluble, oxidizing agent, can react with water to form HNO_3, which is a powerful oxidizing agent and capable of reacting with almost all metals and many organic compounds. NO_2, can travel into the respiratory system. It is also involved in the formation of ozone in the atmosphere.

Biochemical effects: Oxidises cellular lipids, Forms bonds with haemoglobin and reduces the efficiency of oxygen transport. Disrupts some cellular enzyme systems. Higher levels and prolonged exposures may cause pulmonary fibrosis, inflammation of lung tissues and lead to death. Causes nitric acid mediated effects some of which are similar to that of H_2SO_4. NO can form addition compound with haemoglobin, if it enters the blood stream.

3. Carbon monoxide (CO)

Characteristics : Colourless, odourless, toxic gas, slightly water soluble but still is extremely dangerous because it has a greater affinity for haemoglobin than that of O_2.

Biochemical effects : It competitively inhibits combination of O, and haemoglobin. It attacks haemoglobin and displaces o, to form carboxyhaemoglobin, and thus reducing the oxygen carrying capacity of blood.

(Under normal conditions): $o_2 + Hb \quad \lambda \rightarrow o_2Hb$ (oxyhaemoglobin)

(In presence of CO): $O_2Hb + CO \; \lambda \rightarrow CO\,Hb + O_2$ (Carboxyhaemoglobin)

The immediate response to CO-poisoning is loss of judgment, which is responsible for many automobile accidents. Further exposure to higher levels of CO leads to various metabolic disorders such as asphyxiation and causes death. CO-poisoning can be cured by providing fresh O_2' which reverses the above reaction.

4. Ozone (O_3) and other photochemical oxidants such as peroxyacetyl nitrate (PAN) present in photochemical smog.

Characteristics : Ozone is a pale blue gas, fairly water soluble, unstable, sweetish odour. Very reactive oxidizing agent capable of combining with many organic compounds in cells and tissues as well as with rubber and other materials. O_3 and PAN are harmful to plants, animals and humans.

Biochemical effects : Oxidize cellular constituents. PAN and ozone toxicity is produced via generation of free radicals. The free radicals produced may damage DNA and thus alter cellular genetic integrity too.

The toxic effects of ozone are manifested after inhalation and absorption in the lungs causing accumulation of fluids in the lungs (pulmonary edema), naging lung capillaries and mortality if continued or high level exposures occur

5. Hydrocarbons (and other volatile organic compounds)

Characteristics: Very reactive. React with many kinds of compounds yielding many kinds of products. Volatile hydrocarbons and other organic compounds participate in atmospheric reactions generating ozone.

Biochemical effects : Some of these compounds can react with the constituents of the cells. Carcinogenic hydrocarbons like benzopyrene can react with DNA causing mutations and cancer.

6. Particulate Matter

Characteristics : Solid particles or liquid droplets including fumes, smoke, dust and aerosols. Solid particular can adsorb various chemicals.

Biochemical effects : Effects vary with the nature of the particles. Carbon particles and other particles cause scarring of lungs via complex walling off and fibrogenic reactions leading to a disease condition known as “pneumoconiosis”. Particles carrying absorbed mutagens lead to damage of DNA in the lungs and elsewhere.

Effects of Air Pollutants on Man and his Environment

(1) Damage to materials. The materials that may be affected by air pollutants include metals; building materials, rubbers, elastomers, paper, textiles, leather, dyes, glass, enamels and surface coatings. The types of possible damage to these materials by air pollutants include corrosion, abrasion, deposition, direct chemical attack and indirect chemical attack.

(2) **Damage to Vegetation**. Air pollutants, such as sulphur dioxide, HF, particulate fluorides, smog, oxidants like ozone, ethylene (from automobiles), NO, chlorine and herbicide and weedicide sprays exert toxic effects on vegetation. The damage usually manifests in the form of visual injury such as chlorotic marking, banding, silvering or bronzing of the underside of the leaf. Retardation of plant growth may also occur in some cases.

(3) Damage to farm animals. Arsenic, lead and fluorides are the main pollutants which cause damage to livestock. These air-borne contaminants accumulate in vegetation and forage and poison the animals when they eat the contaminated vegetation.

(4) Darkening of sky and reduction in visibility. Sky darkening may be caused by heavy smoke and fog or by dust storms. The reduction in visibility may be due to smoke, fog and industrial fumes which contain particulates in the size range of 0.4 to 0.9u m that scatter light.

(5) Effect on human health and human activities. The effects of air pollution on humans, animals and vegetation has already been discussed in earlier sections. Air pollution can effect the health of workers within the industrial premises, causing absenteeism, sickness and drop in production

MEASURES TO CHECK AIR-POLLUTION

It is not easy to control/check air pollution at resonable cost, because it is not so simple. Our every life style/amentities of modern life is facing for air pollution. But we can check it or prevent by careful planning for industries, better design, operation of equipments and general awareness to do this. The following are the general methods of air pollution control :

1. Controlling the air pollution at source.

2. Site selection/Zoning

3. Controlling air pollution by devices/equipments/process modification.

4. Air pollution control by growing vegetation.

5. Air pollution control by Fuel selection and utilization.

1. Controlling of Air Pollution at Source

This is the best to check air pollution at source. This can be achieved by : (i) Modifying the process in such a way that pollutants do not form at all beyond the permissible limits.

(ii) Before release the pollutants, they should be reduced to telerable levels by methods equipments to destroy, alter, trap or so.

To control or minimised air pollution at source, the following steps should be strictly follow :

(a) This step can also be done in two ways, Ist we should select the raw material in such a way to release minimum pollutants. The supplements may also be used if needed. Secondly use suitable fuels avoiding sulphur fuels. Non-essential ingredients are removed before processing of the raw material.

(b) Air pollution can easily be checked by using modified procedure or new process. Timely it should be monitored.

2. Site Selection/Zoning

- To instal the industry, site selection is important, which results in the production of single source of pollution. Control measure based on the knowledge of the mechanics of the atmosphere is called "Zoning".
- While setting the factories the meterological and micro-meterological conditions should be considered. Other factors such as facilities for as material supply, transport labour and market for products are also important for selecting the site of industry.

Controlling of Air Pollution by Devices/Equipments/Process Modifications

Large number of factories/industries release various types of gases, along with particulates which are measure source of air pollution. In order to prevent these pollutants two types of methods are used.

(A) Methods/Equipments used to Control gaseous Pollutants

For gaseous pollutants, following methods are generally used :

(i) Absorption
(ii) Adsorption
(iii) Combustion
(iv) Cold trapping or condensers
(v) (v) Others.

But the first three are in common use.

(i) Absorption : Scrubbers are mostly used for the removal of gaseous pollutants. They have suitable liquid as absorbent to remove or modify one or more of the pollutants present in the stream. Through scrubbers gaseous effluents are passed. The efficiency of gas absorption depend upon the following factors:

(a) Chemical Activity of the gas pollutant.

(b) The extent of the surface for contact.

(c) The contact time.

(d) The concentration of the absobing medium.

This technique is used for removal of NOx, H_2S, SO_2, SO_3 fluorides etc.

(ii) Adsorption : Here, the gaseous effluents are passed through porous solid adsorbent taken in suitable containers. The efficiency of adsorption depends upon the surface area per unit weight of the absorbent. Constituents of the gas effluents are held at the interface of the adsorbent by chemisorption. When the effluents have higher concentration of Nox, Sox etc. the gases can be recovered economically and used for the manufacture of acids, i.e., HNO, & H.SO, etc.

(iii) Combustion : The flame combustion or catalytic combustion of organic gaseous pollutants convert them in to H_2O & CO_2. Flame combustion include fume incinerators, steam injection while catalytic combustion is resorted where lower temperature is needed.

(B) Methods/Equipments used to Control Particulate Emission

The particulate collection devices are based on the size, shape, properties of the particulate, which are generally originate from stationary and mobile sources.

The various methods are :

(ii) Filtration
(iii) Mechanical
(iv) Precipitators
(v) Scrubbers.

WATER POLLUTION

INTRODUCTION

Water is essential for the survival of any form of life. On an average, a human being consumes about 2 litres of water everyday.. About 80% of the earth's surface is covered by water. Some of water is available for drinking, agriculture, domestic and industrial consumption. The rest of the water is locked up in oceans as salt water, polar ice-caps and glaciers and underground. Owing to increasing industrialization on one hand and exploding population on the other, the demands of water supply have been increasing tremendously . Moreover, considerable part of this limited quantity of water is polluted by sewage, industrial wastes and a wide array of synthetic chemicals. The menace of water-borne diseases and epidemics still threatens the well-being of population, particularly in under-developed and developing countries. Thus, the quality as well as the quantity of clean water supply is of vital significance for the welfare of mankind. About 70% of all the available water in our Country is polluted

Municipal water is mainly used for drinking, cleaning, washing and other domestic purposes. The water that is fit for drinking purposes is called potable water.

Characteristics of potable water

1. It should be colourless, odourless and tasteless.

2. It should be free from turbidity and other suspended impurities.

3. It should be free from germs, bacteria and other pathogenic organisms.

4. It should not contain toxic dissolved impurities , such as heavy metals, pesticides, etc.

5. It should have a pH in the range 7-8.5.

6. It should be moderately soft, having hardness preferably in the range 50-100 PPm. Its hardness should not be above 150 PPm.

7. It should be aesthetically pleasant.

8. It should not be corrosive to the pipelines and should not cause any incrustations in the pipes.

9. It should not stain clothes.

Water Pollutants and their Sources

The various types of water pollutants are:

(a) Oxygen-demanding wastes. These include domestic and animal sewage, bio-degradable organic compounds and industrial wastes from food-processing plants, meat-packing-plants, slaughter houses, paper and pulp mills, tanneries etc., as well as agricultural run-off. All these wastes undergo degradation and decomposition by bacterial activity in presence of dissolved oxygen (D.O.). This results in rapid depletion of D.O. from the water, which is harmful to aquatic organisms.

(b) Disease-causing wastes. These include pathogenic microorganisms which may enter the water along with sewage and other wastes and may cause tremendous damage to public health. These microbes, comprising mainly of viruses and bacteria, can cause dangerous water-borne diseases such as cholera, typhoid, dysentry, polio and infectious hepatitis in humans. Hence, disinfection is the primary step in water pollution control.

(c) Synthetic Organic Compounds. These are the man-made materials such as synthetic pesticides, synthetic detergents (syndets), food additives, pharmaceuticals, insecticides, paints, synthetic fibres, elastomers, solvents, plasticizers, plastics and chemicals. These chemicals may enter the hydrosphere either by spillage during transport and use or by intentional or accidental release of wastes from their manufacturing establishments. Most of these chemicals are potentially toxic to plants, animals and humans.

(d) Sewage and agricultural run-off. Sewage and run-off from agricultural lands supply plant nutrients, which may stimulate the growth of algae and other aquatic weeds in the receiving water body. This unwieldy plant-growth results in the degradation of the value of the water body, intended for recreational and other uses.

(e) Oil . Oil pollution may take place because of oil spills from cargo oil tankers on the seas, losses during off-shore exploration and production of oil, accidental fires in ships and oil tankers, accidental or intentional oil slicks and leakage from oil pipe-lines, crossing waterways and reservoirs. Oil pollution results in reduction of light transmission through surface waters, thereby reducing photo-synthesis by marine plants. Oil pollution in Seas has been increasing due to the increase in oil based technologies, massive oil shipments, accidental oil spillages etc.

(2) Inorganic Pollutants

Inorganic pollutants comprise of mineral acids, inorganic salts, finely divided metals or metal compounds, trace elements, cyanides, sulphates, nitrates, organometallic compounds and complexes of metals with organics present in natural waters. The metal-organic interactions involve natural organic species, such as fulvic acids and synthetic organic species, such as EDTA. The heavy metals such as Hg, Cd and Lead, metalloids such as As, Sb and Se are most toxic. The water pollution by heavy metals occurs mostly due to street dust, domestic sewage and industrial effluents. Polyphosphates from detergents are also water pollutants.

(3) Suspended solids and sediments

Sediments are mostly contributed by soil erosion by natural processes, agricultural development, strip mining and construction activities. Suspended solids in water mainly comprise of silt, sand and minerals eroded from the land. Soil erosion by water, wind and other natural forces are very significant for tropical countries like India. It is estimated that 5.37 million Tonnes of NPK fertilizers are washed away in to the sea. Sediments and suspended particles exchange cations with the surrounding aquatic medium and act as repositories for trace metals such as, Cu, CO, Ni, Mn, Cr, and Mo.

(4) Radioactive Materials

The radioactive water pollutants may originate from the following anthropogenic activities:

(a) Mining and processing of ores, e.g., Uranium tailings.

(b) Increasing use of radioactive isotopes in research, agricultural, industrial and medical applications, e.g., I^{131}, P^{32}, Co^{6o}, Ca^{45},S^{35},C^{14}, Ir^{132} and Cs^{137}.

(c) Radioactive materials from nuclear power plants and nuclear reactors, e.g., Sr^{90}, Cs^{137}, Am^{241} , Pu^{248}.

(d) Radioactive materials from testing and use of nuclear weaponry, e.g. Sr^{90}, Cs^{137}.

(5) HEAT. Considerable thermal pollution results from thermal power plants, particularly the nuclear-power-based electricity generating plants. In such industries, where the water is used as a coolant, the waste hot water is returned to the original water bodies. Hence the temperature of the water body increases. This rise in temperature decreases the DO content of water, which adversely affects the aquatic life.

Some important effects of various types of water pollutants are as:

(i) Tannery effluents contain several constituents which are deleterious, irrespective of the

fact that where they are discharged viz., into river, stream, sewer, land or sea.

(ii) It imparts persistent dull brown colour to the receiving water causing aesthetic and other problems described earlier.

(iii) Highly repulsive odour is imparted to the receiving water. The dissolved constituents like proteins are purifiable.

(iv) The acidic or alkaline effluents are corrosive to concrete and metal pipes. (v) Excess NaCl in the effluent is also corrosive and renders the receiving water unsuitable for irrigation

(vi) The effluents may contain pathogenic bacteria.

(vii) The dissolved chromium present is toxic to fish and aquatic life and thus affects the natural self-purification property of the stream.

(viii) The suspended solids such as hair, flesh, CaCO,' etc. interfere with aeration and photosynthetic activities of the aquatic flora.

(ix) If the wastewater is discharged into sewer, the suspended impurities such as CaCO3, hairs etc. may choke the sewerage pipes. The sulphides present in the wastewater cause "crown corrosion" to the concrete structures, etc.

(x) The chromium and sulfides present in the waste water being toxic to microorganisms disrupt the biological treatment operation such as trickling filtration. The suspended lime etc. also interfere with the biological activities in the sewage treatment plants.

(xi) The presence of excessive salt and Cr in the wastewaters may deteriorate the quality of the ground water in the affected areas.

CONTROL OF WATER POLLUTION

The control of water pollution is difficult, but we may try for its prevention and minimisations. Industrialised and Developing countries spend a handsome amount of their GNP (Gross National Product) on pollution control measures, but the problem is going to be worsening day by day. The before water pollution control are:

1. How pure the water should be?

2. How to prohibit the effluents and discharge in to water?

3. To what extent water quality be improved?

4. How to create public opinion against water pollution? Therefore, we should adopt the respective safety measures to achieve acceptable water quality at the least cost. Some of these are :

1. Scientific techniques are necessary to be adopted for the environmental control of catchment areas of rivers, lakes, ponds or streams.

2. Industrial plants should be based on recycling operations.

3. The possible reuse or recycle of treated sewage effluents and industrial wastes should be emphasized and encouraged.

4. Instead of throwing wastes in to water, the recycling should be done for better use. Gobar gas plant, composting, manufacture of hardboard, paper etc. such examples where respective waste can be used.

5. Minimum, appropriate quantity and concentration of Fertilizers, pesticide & insecticides should be used, because excess will cause pollution.

6. There should be propaganda for water pollution control, on radio, TV, Newspapers etc. because public awareness is a must.

7. Treatment plants should be constructed and Govt should also help by funding for domestic, sewage and industrial effluents.

8. Local authorities, Industrialists, Govt officials, with public participation should co-ordinate to finds ways to control water pollution.

9. Water resources should be used in the best possible economic way.

10. To conduct seminars and training courses for helping those, who are directly or indirectly engaged in water management and water pollution control.

SOIL POLLUTION

INTRODUCTION

Soil is a very important constituents of the lithosphere. The word "Soil” is derived from a Latin word "Solum" which means earthy material in which growth of plants takes place. "Soil” may be broadly defined as the weathered layer of the earth's crust with living organisms and their products of decay.

The earth's crust basically consists of the following three rock types.

1. Igneous rocks : These are formed by cooling and solidification of molten rock material called 'Magma'. Ex:- Basalt and Diorite.

2. Sedimentary rocks : These are developed as a result of gradual accumulation, consolidation and hardening of products of weathering of mineral materials brought about by wind or waters. These rocks are characterized by the presence of distinct sedimentary layers. Ex :Lime stone, sand stone and shale.

3. Metamorphic rocks : These are formed as result of metamorphosis of igneous and sedimentary rocks under the influence of high pressure and intense heat. Ex:- Quartzite, Slate, Marble and Schist.

Sources of Soil Pollution

Soil pollution differs from water pollution or air pollution, because the pollutants remain in direct contact with the soil for relatively longer periods and hence alter the chemical and biological properties of the soil. The hazardous chemical can also enter the human food chain from soil or water plants.

EFFECTS OF SOIL POLLUTANTS

"Soil Pollution" was originally defined as the contamination of the soil system by considerable quantities of chemical or other substances, resulting in the reduction of its fertility or productivity with respect to the qualitative and quantitative yield of the crops.

The major effects of various types of pollutants are given below:

(a) Effects of modern agricultural practices:

Synthetic Fertilizers : Synthetic fertilizers are employed to increase the soil fertility and crop productivity. Excessive and indiscriminate use of chemical fertilizers may result in the following undesirable effects:

(i) Wheat, maize, corn, etc. grown on soils fertilized with NPK fertilizers may result in considerable reduction in protein content of the crop.

(ii) Excessive use of nitrogenous fertilizers leads to the accumulation of nitrates in the soil which may contaminate the ground water. Nitrate concentrations exceeding 90 ppm in drinking water may lead to diarrhoea, blue Jaundice (Cyanosis) in children, "methemoglobinemia" (or blue baby syndrome) in infants. Further, the nitrates and nitrites entering the human body may be eventually converted nitroso amines and compounds which are suspected to cause stomach cancer.

iii) Vegetation growth in nitrate-rich soils may exert toxic effects in cattle.

(iv) Excessive use of chemical fertilizers may enter the water bodies and contribute to "eutrophication". (Eutrophication is the excessive growth of algae and aquatic plants to undesirable levels).

(vi) Excessive use of chemical fertilizers may reduce the ability of plants to fix nitrogen.

(vii) Excessive quantities of potassium fertilizers in soils may reduce the quantities of valuable ascorbic acid and carotene in fruits and vegetables grown in such soils.

(vii) The large-sized fruits and vegetables grown in highly fertilized soils may be more vulnerable to attacks by pests and insects.

Pesticides

Pesticides pose potential hazard to animals, humans and aquatic life deleterious effect on soil fertility and crop productivity. Pesticides applied to crops are retained in the soil in considerable quantities. They enter into cyclic environmental processes such as absorption by soil, leaching by water, etc, and contaminate both lithosphere and biosphere. Pesticides including herbicides, fungicides and rodenticides, are persistant pollutants.

The following types of pesticides are commonly used:

(a) Chlorinated hydrocarbons (eg. DDT, Aldrin, Dieldrin, Lindane, BHC etc.)

(b) Carbamate compounds (eg. Carboryl or Sevin, Zectrion etc.)

(c) Organo-Phosphorous compounds (eg. Methyl or ethyl parathion, melathion, guthion etc.) (d) Inorganic compounds (eg. As_2O3, PbO_2, NiCl, $CuSO_2$, etc)

(e) Miscellaneous compounds (eg, Organic mercurials, 2.4D; 2.4,5T etc)

Some of the adverse effects of pesticides are given below:

(i) Some arsenic pesticides may render the soil permanently infertile.

(ii) Pesticide residues in soil may be taken up by plants and cause phyto-toxicity. They may enter the aquatic environment and enter the food chain.

(iii) Pesticides such as, endrin, dieldrin, DDT, hepachlor etc. may seep through the soil and contaminate groundwater and surface waters. They may eventually contaminate drinking water supplies.

(iv) Fruit, vegetables, rice, wheat, barley, maize etc. are known to contain considerable quantities of toxic pesticide residue such as of DDT, BHC and other organochloro pesticides.

(v) Polychlorinated biphenyls (PCB) having half-life periods of about 25 years in soil are among the most hazardous soil pollutants. They may accumulate in soil and plants when they eventually enter the animal or human body, they may cause severe health disorders including eye damage, skin problems, nervous disorders, foetus deformities and liver or stomach cancer.

(vi) Irrigated water from pesticide contaminated soils may evaporate and spread the toxic pesticide vapours in the atmosphere.

vii) DDT can enter the food chain and accumulate in human fats and may lead to disorders such as impotency.

viii) Persistant pesticides can damage human tissues and interfere with the normal metabilic activities by disturbing enzymatic functioning.

ix) Chlorinated pesticides and herbicides are hazardous soil pollutants which can affect the soil texture and damage the ecosystem.

x) Hunting birds feeding on grains contaminated with DDT are threatened of extinction.

xi) Organophosphate pesticides may cause muscular disbilities, tremors, and dizziness.

xii) Excessive use of synthetic pesticides may lead to defoliation to forests and adverse effect o fauna and flora.

xiii) Farm animals drinking stagnant water in fields sprayed by pesticides developed toxic symptoms and some mortalities were reported.

xiv) Farmers and farm workers are particularly prone to pesticide poisoning because of greater exposure while handling and spraying.

xv) Volatile pesticides may cause pollution of air in the surrounding areas.

(b) Effects of Industrial effulents

Solid, liquid and gaseous chemicals from various industries such as paper and pulp, iron and steel, fertilizers,dyes, automobiles, pesticides, tanneries, coal-based thermal power plants etc. contain a variety of pollutants such as heavy metals, solvents, detergents, plastics, suspended particulates and refractory chemicals.

(c) Effects of urban wastes

Millions tones of urban waste are produced every year from critically polluted cities. The inadequately treated or untreated sewage sludge not only pose serious health hazards but also pollute soil and decrease its fertility and productivity.Other waste materials such as rubbish, used plastic bags, garbage, sludge, dead animals, waste medicines, hospital wastes, skins, tyres, shoes, cans, etc.

Control of soil pollution

The major sources of soil pollution are the domestic wastes, industrial wastes and agricultural wastes including those toxic chemicals (eg. Pesticides) arising from modern agricultural practices. The various approaches to control soil pollution are as follows

(1) Implementing stringent and pro-active population control programmes.

(2) Launching extensive afforestation and community forestry programmes.

(3) Implementing deterrent measures against deforestation.

(4) Formulation of stringent pollution control legislation and effective implimentation with powerful administrative machinery.

(5) Imparting informal and formal public awareness programmes to educate peoples at large regarding the health hazards and undesirable effects due to environmental pollution. Mass media, educational institutions and voluntary agencies should be involved to achieve these objectives.

(6) Banning the use of highly toxic and resistant synthetic chemical pesticides or atleast

regulating/restricting their use only for special purposes under thorough monitoring.

(7) Encouraging the use of bio-pesticides in place of toxic chemical pesticides.

(8) Conservation of soil to prevent the loss of precious top soil from erosion and to maintain it in a fertile state for agricultural purposes.

MARINE POLLUTION

Seas are the main source of food and earnings for persons living in coastal areas. When the marine water is polluted it effects the animals and other food chain components. Researches shows that many marine animals secrets the medicinal chemicals which are useful to mankind and other living organisms.When water will be polluted it will effect the animals present in seas.

Sources of marine Pollution

The main sources of marine pollution are:

1. Rivers are the main source of marine pollution. They carry wastes in their drainage and joins the sea/ocean. The drainage include sewage sludge, industrial effluents, detergents, agrochemicals, plastics, metal scraps etc.

2. Many big cities and industries are situated along the coast line. Every large amount of wastes from hotels, wastes effluents mixed with detergents, sewage from corporations and industries, other wastes from human activities are mixed in sea water.

3. Ships which carry toxic substances, lubricating oil, paints heavy oils, fuels, automotive materials and other chemicals from one place to another, some times by accident or by leakages pollute the marine water.

4. Testing of atomic weapons, space aircrafts, missiles (generally developed country do this) and other radioactive wastes when dumped in seas, causes heavy loss to aquatic biota.

5. Harmful effluents from nuclear power stations or from other scientific organizations like BARC in India, chemical industries, fertilizers, Pesticide and insecticide industries when mixed in marine water causes harmful effects to marine life.

6. Marine pollution also caused by oil drilling in seas, tourism activities and heat released from industries. etc.

Effects of marine pollution:

The major effects of marine pollution are as follows:

1. Oil is most dangerous pollutant when afloat on sea or mixed with water a great threat to marine life specially fish, birds, invertebrates and algae. Thousands of birds killed every year because once they oiled, seldom survived despite efforts to clean themselves.

2. Oil of sea also effects sensitive flora and fauna, phytoplankton, zooplankton and other animals. In Alaska, Brittany (France), Elbe (Germany) thousands of birds died by oil spillage.

3. Plastic or plastic materials when dumped into sea by commercial ships or from drainage, animal take it through their food in stomach. It causes ulcer and reduces hunger.

4. Marine pollution effects the food chain in seas. Serious diseases like cancer are the caused when affected animals are taken by man from ocean.

5. Detergents, either from cleaning up the spills or from drainage, also responsible for high mortality of marine life.

6. Heavy metals (like lead and mercury), factory materials, mineral oils, acids and other biocides are also measure threat to marine life when mixed with sea water.

Control of marine pollution:

The control of marine pollution can be studied in following two steps:1. Steps already in operation pollution

(i) Port authorities are alert and introduced antipollutant measures by creating pollution cell. But deeper check the in sea coastal guards are doing this job.

(ii) Various research organizations, institutions are working in this field to marine pollution

(iii) In most of the countries (India too), the monitoring and survey in operation to control the marine pollution.

(iv) Authorities are taken care of effective measures to check the oil leakage from ships and tankers.

(v) Urban and coastline corporations are trying to check the dumping of wastes from human activities & Municipal etc. solid waste management is helping to recycle or reuse.

Suggesting steps to control marine pollution

(1) Dumping of oil ballest, hazardous and toxic substances, gases from radioactive labs into sea, should be banned or should be properly treated before dumping.

(2) Drainage, sewage sludge and effluents from industries should not be discharged in to rivers which joins sea.

(3) Developmental activities on coastal areas should be minimised.

(4) Toxic pollutants from industries and treatment plants should not be discharged into sea.

(5) Ships and ports should have certain facilities for reducing pollution.

(6) Certain biological and other methods should be followed to restore species diversification and ecobalance in the water body to prevent pollution.

(7) Effective measures should be developed to check the leakage in ships and oil tankers.

(8) Nuclear explosions and other nuclear activities in sea should be minimized.

(9) Wastes from municipal, industries, sewage and thermal power stations should be recycled for reutilization. Such plants should be developed. Some are in operation.

(10) We should develop awareness in people to reduce the amount of waste in their daily life.

(11) Drilling should not be allowed in coastal areas.

NOISE (SOUND) POLLUTION

The term 'noise may be defined as an unwanted sound at a wrong time and a wrong place. Wheather a given sound is wanted or unwanted may depend upon the person involved, the loudness, the rhythm, and the length of time for which one is exposed to it.

Sound intensity measured Decibel (dB) = 10 log $\frac{Sound\ intensity\ measured}{Reference\ sound\ intensity}$

Effects of Noise

(a) Physiological Effects:

The acute effects caused by noise depend upon the pressure and frequency about. At high levels of about 150 dB, immediate permanent hearing impairment may be caused. At sound levels in the range of 120-150 dB, effects on respiratory system, dizziness, disorientation, loss of physical control, other physiological changes resulting from stress, nausea and vomiting may be caused.

(b) Psychological effects

Although there is little specific evidence regarding the onset of mental or nervous illness caused by noise, some reports are available to indicate temporary effects such as deterioration in concentration and even mental disorientation at high noise levels.

(C) Hearing Loss

Prolonged exposures to loud noise can cause temporary or permanent loss of hearing. People working in noisy places such as industrial establishments, factories etc. often suffer from temporary loss of hearing. If the loudness of noise is moderate or the duration of exposure is short, the damage is only temporary.

(d) Other health effects of noise pollution: Loud noise is affects sleep, concentration and work or performance of an individual. Work which needs a high degree of skill and precision is considerably affected. It may cause headache, irritability and fatigue. It is interesting to note that our optical system is considerably affected by noise pollution.

Prevention and Control of Noise Pollution

Loud noise is the form of pollution which often causes much public concern. Therefore, necessary steps have to be taken to control the noise pollution. Some of these are :

1. Reduction of noise at the source of its origin: Often a little precaution can reduce much of the noise pollution caused by loud noise. This can be achieved by replacement of noisy devices or machines with quieter ones. Noise level can be reduced effectively by replacement of noisy and rattling parts, providing better cushioning to check the vibrations, proper oiling and greasing to ensure smooth running and using effective silencers etc.

2. Application of sound proofing techniques to muffle down loud noises: Sound waves are absorbed by porous material such as perforated sheets and other objects. Just as putting cotton plugs in the ears reduces noise level for the individual concerned, sound barriers placed around the source of origin of loud noises drastically reduce the intensity of sound on the other side of the obstacle.

3. Keeping residential localities free of noisy industries, busy highways, aerodromes etc. Residential localities should be established away from noisy industries, busy highways, aerodromes or else these noisy establishments should be developed away from quiet residential areas. Industrial units can be displaced to some industrial area whereas by passes may be developed to divert busy railway tracks and highways away from domestic establishments. Only that part of traffic should be allowed to get into a residential area which is barely necessary.

4. Enactment of strict legislation and its effective compliance: In most of the countries our own, legal framework against noise pollution has been developed. However, in most of the cases little efforts are made to enf only effective compliance of these rules much of the nuisance of noise pollution shall automatically be curtailed.

5. Noise control methods in industrial plants

Excessive noise is produced from various types of machines, petrol and diesel engines, electric motors, construction site equipment, pumps and pumping systems, compressed air systems, hydraulic systems, air distribution system, industrial fans, etc. It is always advantageous, economical and effective to identify the noise sources and noise problems right in the design and erection stages and incorporate the necessary noise control measures rather than attending to the problems at a later stage.

The following four approaches are available for noise control :

Approaches Noise Control

(1) Modifying some of the present practices and procedures in order to minimize the noise. Ex:Reducing automobile traffic, outlaying sirens, discouraging stereos without headsets, using glue instead of rivets, etc.

(2) Shielding the sources of noise generation.

Ex: Use of sound-absorbing motor mountings, better installation, better design, use of motor enclosures, use of vibration damping or absorbing materials in automobiles and dishwashers, etc.

(3) Shielding the noise receiver.

Ex: Using earplug, control booths, etc. (4) Shifting noisy sources and things away from people Ex: Isolating airports, industrial complexes, etc. Obviously, some of the above measures can be implemented successfully only if they are mandatory.

THERMAL POLLUTION

The term Thermal Pollution has been used to indicate the detrimental effects of heated effluents discharged by various power plants. It denotes the impairment of quality and deterioration of aquatic and terrestrial environment. Various Industrial plants like thermal, atomic, nuclear, coal fired plants, oil field generators and mills utilize water for cooling purposes.

Thermal Pollution: It can be defined as:

1. The warning up of an aquatic system to the point where desirable organisms are adversely affected.

2. Addition of excess of undesirable heat to water that makes it harmful to man, animal, plant or aquatic life or other wise causes significant dangers to the normal activities of aquatic communities in water.

3. Heated effluents either from natural or man made sources, contaminated with water supplies, may be harmful to life because of their toxicity, reduction in Dissolved Oxygen (D.O.), aesthetically unsuitable and spread diseases.

4. It reduces the number of aquatic species and destroys the balance of life in streams as is evidenced by the biological indices of community and diversity. 5. It is a by-product of rapid and unplanned industrial progress and over population.

SOURCES OF THERMAL POLLUTION

The accelerated pace of development, rapid industrialization and extensive population density have increased demand of thermal power plants. Human activities, today, are constantly adding pollutants to air and water at a higher rate. The following sources contribute to thermal pollution:

1. Nuclear Power Plants: Nuclear power plants, including nuclear experiments and explosions, discharge a lot have unutilized heat into nearby water streams. Emissions from nuclear reactors and processing instruments are also responsible for increasing the temperature of water bodies. Heated effluents from power plants at 10°C higher than the coolant receptor and severely affect the aquatic flora and fauna discharges effluent having drainage from hospitals, institutes,discharged

2. Coal-fired Power Plants: Some thermal power plants ultimately temperature difference of 15°C between effluent and water body. The Thermal power plants utilize coal as fuel and they constitute the major source of thermal pollutants. The heated coils are cooled with water from nearby like or river and discharge the hot water back to the receptor water body and thereby increasing the temperature of the nearby water. The heated effluent decreases the content of dissolved oxygen of water. It results into killing of fish and other marine organisms.

3. Industrial Effluents: Industries generating electricity, like coal as fuel and Nuclear powered thermal plants, require huge amounts of cooling water for heat removal. Other industries like textiles, paper and pulp as well as sugar also release heat in water but to a much lesser extent.

4. Hydro-electric Power: The generation of hydroelectric power, sometimes, results in negative loading in water systems. Apart from electric power industries, various factories with cooling contribute to thermal loading. It has been reported that about 18% more heat is given to cooling ponds in nuclear power plants than any other plant of equivalent size.

5. Domestic Sewage: Domestic sewage is commonly discharged into rivers, lakes and canals with or without waste treatment. The municipal sewage normally has a higher temperature than receiving water. The discharged water not only raises the stream temperature to a measurable extent but also creates numerous deleterious effects on aquatic biota.

EFFECTS OF THERMAL POLLUTION:

The various effects of the thermal pollution

1. Reduction in Dissolved Oxygen: Concentration of dissolved oxygen decreases with increase in temperature of water. For example, the D.O. content is 14.6 ppm in water at a temperature of 32°F and 6.6 ppm at 64°F. Thus cold-water fish, which requires about 6 ppm to survive, would not tolerate the high water temperatures. If they remained in the area they would die of oxygen starvation. Since the aquatic biota live acrobically, so a healthy stream should have an adequate supply of dissolved oxygen.

2. Change in Water Properties: A rise in temperature changes the physical and chemical properties of water. The vapour pressure increases sharply , while the viscosity of water decreases. The decrease in density, viscosity and solubility of gases increases the settling speed of suspended particles, which seriously affect the food supply of aquatic organisms.

3. Increase-in Toxicity: The rising temperature increases the toxicity of the poison present in water. A 10°C rise in temperature doubles the toxic effect of Potassium cyanide, while an 80°C rise in temperature triples the toxic effect of O-Xylene causing massive mortality of fish. In

digestion, excretion and overall development of aquatic organisms. The temperature changes totally disrupt the entire ecosystem. Sharp changes in temperature are often destructive. Because, the life of aquatic animals involves several chemical reactions and the rate of these reactions vary according to changes in temperature.

5. Interference with Reproduction: In fishes, several activities like nest building, spawning, hatching, migration and reproduction etc. depend on some optimum temperature. For instance, the maximum temperature at which lake trout will spawn successfully is 8.9°C. The warm water not only disturbs spawning but also destroys the laid eggs.

6. Variations in Reproductive Rate: The increase in temperature triggers deposition of eggs by female. The triggering is particularly dramatic in estuarine fish, which spawn in four hours after the water temperature reaches critical level.

7. Changes in Metabolic Rate: Fishes show a marked rise in basal rate of metabolism with temperature to the lethal point. The respiratory rate, oxygen demand, food uptake and swimming speed in fishes increase.

8. Increased Vulnerability to disease: Activities of several pathogenic microorganisms are accelerated by higher temperature. Hot water causes bacterial disease in certain fishes such that they fail to develop eggs above critical temperature.

9. Invasion to destructive organisms: Thermal pollutants may permit the invasion of organisms that are tolerant to warm waters and highly destructive e.g. invasion of ship worms into New Jersey's Oyster Creek.

10. Undesirable Changes in Algae Population: The life in an ecosystem is greatly influenced by the algal growth. Excess nutrients from the washout waters from farmlands, thermal plants cause an excessive algal growth with consequent acceleration of eutrophic and other undesirable changes.

11. Destruction of Organisms in Cold Water: The volume of water required for cooling purposes from a stream is enormous. Unfortunately many of plankton, small fish, insect larvae that are sucked into the condenser along with cooling water are killed by the thermal shock, increased pressure and water viscosity.

12. Biochemical Oxygen Demand: When the temperature of stream carrying biodegradable organic matter rises, the intensified action of aquatic organisms causes B.O.D. to be accomplished at a lower temperature. When the temperature of stream carrying biodegradable organic matter rises fish death may occur due to synergistic action, which is caused due to accelerated chemical or biochemical action.

13. Effect on Marine Life: Temperature plays an important role in affecting the physiology, metabolism, growth and development of marine animals. Sea organisms are poilkilothermic i.e. their body temperature varies with the surrounding water. Some marine creatures cannot tolerate wide changes of temperature, so they die at higher temperature.

14. Effect on Bacteria: Due to the heated discharges from the industries and plants (industrial), the bacteria are severely damaged. The effect includes coagulation of body Protein, melting of cell fats, toxic action of metabolic products etc.

CONTROL OF THERMAL POLLUTION

Heat must be removed from the condenser cooling waters prior to their disposal into water bodies. The major principles involved in the process of heat loss are:

1. Conduction

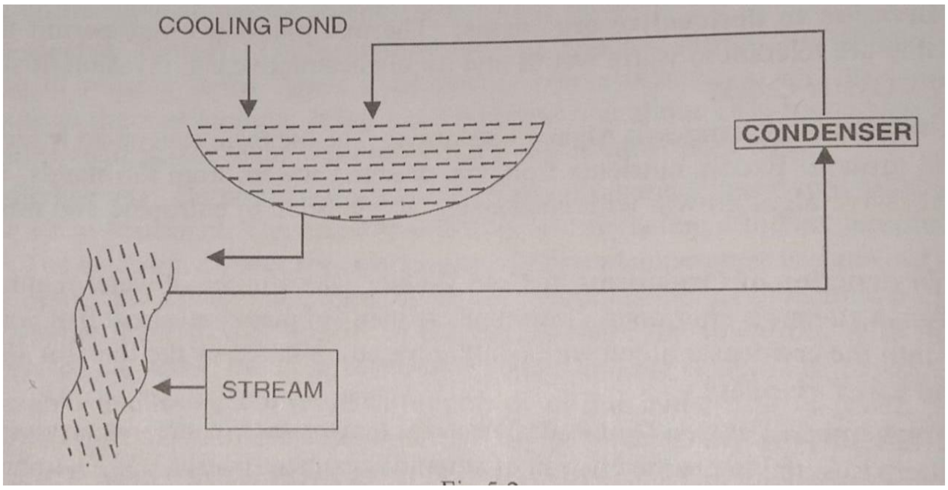
2. Convection

3.Radiation

4.Evaporation

The following methods can be adopted to control high temperature caused by thermal discharges:

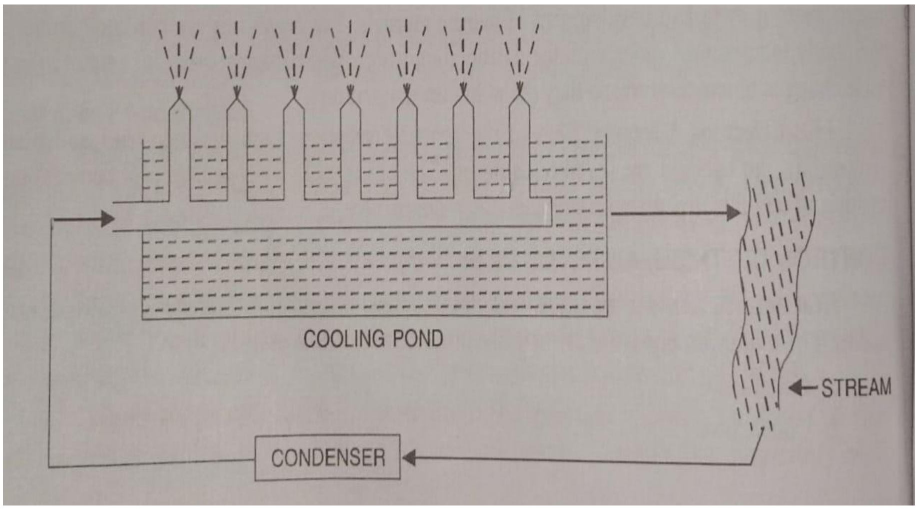
(1) COOLING PONDS :



The water from the condensers is stored in the earth like ponds where natural evaporation brings down the temperature. The water is recirculated again.

(2) SPRAY PONDS:

In spray ponds, the water is sprayed in the cooling ponds with the help of spray nozzels to convert it into fine droplets which provide more surface area to facilitate efficient heat transfer to atmosphere.



(3) **Cooling Towers:**

WET COOLING TOWERS:

In wet cooling towers, the heated water is brought in direct contact with continuously flowing air. The evaporation brings down the temperature. To increase the surface area of contact, the water is broken down into droplets by use of spray nozzles or by splashing it on the packing or baffles in the cooling towers.

(4) To handle large quantities of heated effluents, large tanks or reservoirs should be constructed to retain the water for a little longer time. When water cool down to a tolerable temperature, it may be released.

(5) The heated effluents discharged from the chemical industries and thermal power plants can be put in to certain beneficial uses like green house, frost protection during colds, aquaculture, heating the buildings etc.

NUCLEAR HAZARDS

- A number of atoms possess the ability to emit radiations and thereby cause radioactive pollution. Radiations originate from instability of the nuclei of an atom which loses sub-nuclear particles and energy to acquire a stable state i.e radioactivity. It is the state of nuclei which is responsible for the phenomenon. Neutrons and protons constitute the nucleus while electrons revolve round the nucleus (units outer orbits).
- When the number of protons are equal to number of electrons, the chemical properties shall remain the same. Neutrons and protons constitute the mass while electrons constitute charge to the element.
- Thus Radioactive element is defined to be the collection radioactive mass with the same charge of the nucleus. The radioactive atom has the same charge of the nucleus and the same mass is called Radioactive isotope. The Radioactivity of a radioactive substance is expressed by the number of nuclear transformations in unit time.

A radio isotope is characterized by the following properties:

(i) Half life period.
(ii) Mode of decays.
(iii) Energy of radiations.
(iv) Definite energy state

Radiation is the emission of rays and particles or release of energy from the source (atom). There are two types of radiations ionizing and non-ionizing radiations. These radiations destroy the organic molecules of which the body cells are composed. If ion pairs enter into a living protoplasm, they damage it and the damage is proportional to the number of ion-pairs absorbed. The following types of radiations are given out when an element transmutates or decays.

(1) Emission of alpha (α) particles. Alpha particles are nothing but Helium nuclei. Emission of alpha particle will change into elements of lower atomic number. These are deflected by electric and magnetic fields. They are to show moving, strongly ionizing, weakly penetrating and stopped by 80 mm of air.

(ii) Emission of Beta particles (β) :- Emission of Beta particle changes into another element with a higher atomic number. Beta particles are high velocity electrons. Strongly deflected in electric and magnetic fields. The penetrating power of Beta particles varies with the energy of particles.

(iii) Emission of Gama rays (γ):- These are high energy electromagnetic radiations. Can penetrate several cm. of Lead sheet depending upon the energy. These are undeflected in magnetic fields.

Radioactive decay is a spontaneous process arising from nuclear instability.

Sources of Radio Active Pollution

The two main sources of radioactive pollution are, natural and man made.

NATURAL SOURCES

- The natural sources of radioactivity are considered mainly of the cosmic from the space, and the naturally occurring radio isotopes present in the environment and those contained within the body of the organisms.
- The cosmic radiations are of extra terrestrial origin, which probably arise from the sun or even beyond it. They are consisted of particles of very high energy, primarily of protons and some heavy nuclei.
- These cosmic particles collide with the gas molecules of the upper atmosphere bringing about intense ionization in gases accompanied with the formation of secondary cosmic rays composed mainly of neutrons, mesons, and gamma rays. Eventually a complex mixture of particles reaches the earth as cosmic rays. These particles also form substantial quantities of ^{3}H and ^{14}C in the atmosphere.

Man-Made Source

Man causes radioactive pollution by testing of nuclear weapons, establishment of nuclear power plants, mining and refining of plutonium, and thorium, and preparation of radioactive isotope.

1. Nuclear weapons

Testing of nuclear arms comprises:

(a) The use of Uranium 235 and Plutonium 239 for fission.

(b) Hydrogen or lithium as fusion material.

Atomic explosions are uncontrolled chain reactions. They give rise to very large neutron flux conditions that cause other materials in the surrounding environment to become radioactive. Huge clouds of fine radioactive particles and gases are thrown up in the environment and are carried away to distant areas by the agency of wind. Gradually they settle down on earth as fall out or are brought down by rain.

2. Atomic Reactors and Nuclear Fuel

The most common fuel used for fission in the nuclear power plants are uranium, thorium and plutonium. Uranium undergoes several processes, right from its mining to its inception into the reactors. The spent materials obtained from the reactors, after the energy has been utilized, are reprocessed to recover unburnt uranium, plutonium and some other important isotopes, which can be used in medicine or for some other useful purposes.

3.**Radioactive Isotopes**

Radioactive isotopes such as 125, 14c and 32, and their compounds find wide usage in scientific research institutions contain varying amounts of radioactive materials. When this waste water reaches the different water sources such as rivers, streams, lakes etc. through the sewers they cause water pollution. Radioactive iodine and phosphorus also enter the food chain through water and may finally reach man through fish etc.

4. Other Sources

During different medical treatments, varying concentrations of radiations enter the human body for instance, X-rays are common for detecting skeletal disorders, and therapy for cancer patients often includes radium and other isotope radiations.

Damages to a Biological System

Most of the damages caused by radioactive pollutants stem from their capacity to produce high energy radiations, which are very harmful to a living system. There are two main modes in which radioactive pollution can be dangerous to a biological system.

- **(i)** **Damages caused by radiations from outside source.**
- **(ii)** Damages caused by radiations from sources inside the body.
- **(iii)** Damages caused by Radiations at different levels

(i) Damages at Molecular level

Damages to macromolecules such as enzymes, DNA, RNA etc. through ionization crosslinkages within and between two affected molecules.

(ii) Damages at sub-cellular level

Damages to cell-membranes nuclei, chromosomes such as fragmentation, mitochondria etc. **(iii) Damages at cellular level**

Inhibition of cell division death, decay and transformation to malignant state.

(iv) Damages to Tissues and Organs

Disruption of such systems as central nervous system, loss of sight, inactivation of bone marrow activity resulting in blood cancer malignancy and ulceration of intestinal tract.

(v) Damages to an Individual and whole population

- Death or shortening of life due to radiations changes in characteristics due to mutations. In human beings exposure of radiations results in little visible effects in early stages. But after 12-24 hours injury symptoms manifest themselves.
- This includes reddening of skin, anemia, anorexia. Vomiting, and diarrhoea and with heavy doses, blister formation, pigmentation of skin, burning sensation all over the body, loss of sight etc. It must be noted that for all this there is no cure available. Once a person is exposed to radiation he has to bear its consequences. Medical aid can do little.

HAZARDS ASSOCIATED WITH RADIO ACTIVE POLLUTION

Major hazards associated with radio-active pollution can be summed up as follows:

(1) No physical, chemical or biological process can influence the process emissions. The unstable nuclei have to decay and acquire a stable state.

(2) A number of radio-active isotopes have a very long half-life takes 14,0000,000,00 years to lose half of its radio-activity . Half of Uranium-235 (92 U23) takes 710,000 years to disintegrate. Half of Neptunium-237 (93 Np237) decays in 21,00,000 years. This makes these radio-active wastes almost a permanent hazard for the biosphere.

(3) Most of the radiations have a high penetrating power. Thick sheets of steel, cement concrete walls etc, can not contain them. They can easily penetrate to deep seated organs and cause injury.

(4) Nucleic acids (DNA and RNA) effectively absorb these radiations. Even low level radiations which do not cause any visible damage are completely absorbed by nuclear material which causes carcinogenic, mutagenic and teratogenic effects.

(5) A biological system is unable to distinguish between a radio-active and a normal isotope of an element as their physical and chemical properties are similar. Radio-active isotopes are therefore, absorbed and incorporated within the bodies of living organisms as normal isotopes are. This lodges a radio-active source within the body of the organism itself.

(6) Like any other element radio-active isotopes are also absorbed, accumulated and biomagnified thousands of times. Thus the entire food chain becomes contaminated. Organisms at higher trophic levels may, therefore, receive a highly concentrated source of radio-active material through their food supply.

(7) There is no other way to dispose off these hazardous wastes except to store them for thousands or millions of years away from living beings. This is too long a period on human scale of time. Even the safest burial places for radio-active wastes, which represent the best of human efforts, have shown signs of leakage. At present it appears very difficult, though not impossible to store radio-active wastes away from the biosphere for such long periods.

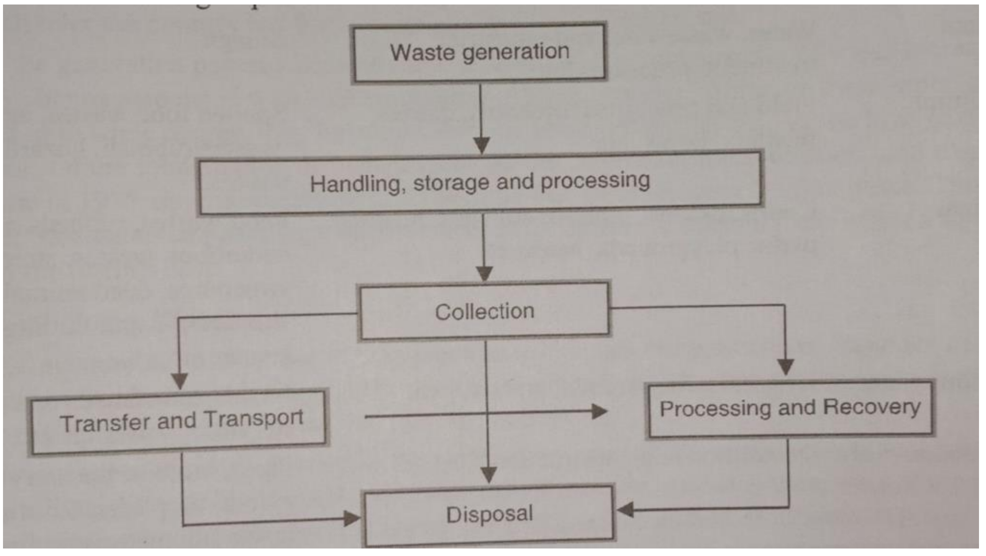
(8) In spite of all these hazards, nuclear reactors and tests are still continuing and an increasingly large amount of radio-active wastes is accumulating every day while no solution to the problem of their safe disposal is in sight till date

SOLID WASTE MANAGEMENT

Any material that is thrown away or discarded as useless and unwanted by human or animal activities is considered as solid waste. In earlier period, the disposal of solid waste was simple but now a days it is a great challenge. The management of waste is the fundamental concern of the activities encompassed in solid waste management. The purpose of the study of solid wastes

(i) Identify the various types of solid wastes and their sources.
(ii) Examine the composition of wastes.
(iii) Consider the elements involved in their management.

The activities involved with the management of solid wastes from the point of generation to have been grouped in to six Functional Elements



‘The total quantum of solid waste generated in an area depends upon its population and urbanization. Solid wastes generation is directly related with income. Higher the income greater is the waste generation.

Sources of solid wastes

Sources of solid wastes can be clarified in to following categories:

1. Residential

2. Commercial

3. Municipal

4. Industrial

5. Open areas

6. Treatment plants

7. Agriculture

8. Hazardous wastes

9. Construction sites

TYPES OF SOLID WASTES:

Garbage: Food wastes are the animal, fruit, or vegetable residues resulting preparation, cooking, and eating of foods. It is also known as garbage. Rubbish: Rubbish consists of combustible and non-combustible solid wastes of households, institutions, commercial activities, etc, excluding food wastes or other highly pursuable materials. Paper, Cardboard, Leather etc.,

Ex, Combustible- Non-Combustible -Aluminium cans, tin cans, glass etc. Ashes and Residues:Materials remaining from the burning of wood, coal coke and other combustible wastes are categorized as ashes and residues.

Demolition and Construction wastes:

Wastes from buildings and other structures are classified as demolition wastes. Wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures are classified as construction waste.

Wastes such as street sweepings, roadside litter, catch basin debris, dead animals and abandoned vehicles are classified as special wastes.

Agricultural Wastes

Wastes and residues resulting from diverse agricultural activities-such as the planting and harvesting of roe, field, and tree and vine crops, the production of milk, the production of animal for slaughter, and the operation of teed lots are collectively called agricultural wastes. **Hazardous wastes:**

Chemical, biological, flammable, explosives, or radioactive waste that are harmful to human, plant or animal life are classified as hazardous wastes.

Collection of Solid Wastes:

Collection of solid wastes in urban areas is difficult and complex because the generation of residential and commercial-industrial solid wastes is a diffuse process that takes place in every home, every apartment building, and every commercial and industrial facility as well as in the streets, parks, and even the vacant areas of every community. The mushroom like development of suburbs all over the country has further complicated the collection task.

Effects of Solid Wastes

- The accumulation of waste at any place is a bad and risky situation. Varieties of microorganisations like bacteria, fungi, viruses, worms etc creep in to the accumulated waste and start its decomposition. Later on they grow and increase in number.

- Various types of germs develop in the waste. They reach us through air, water and food. Most of the infectious diseases like cholera, diarrhoea, dehydration etc. spread in these ways.
- Air pollution, water pollution and soil pollution are caused due to the accumulation of different types of wastes. Harmful fumes from industries and other waste effects eyes, skin, historical moments etc. Asbestos particles from Asbestos Industry causes Asbestosis. Accumulation of heavy metal particles cause serious health hazards. Mercury can cause Mina Mata disease.
- Wastes material when accumulated here and there disturbs the drainage system. Decomposing wastes reach underground and contaminate underground water and soil.

Special Wastes:: Management of solid waste Waste management is the collection, transport, processing or disposal of waste as to reduce their effects on local environment and community . Because it can not be stopped absolutely materials so

Methods of solid waste disposal.

There are following methods:

(a) Physical removal.- It is generally done by manual activities like, collection of wastes and sorting out in to reusable, decomposable and non decomposable. Then disposal becomes easy. Dustbins should be used in homes, offices and dispose accordingly i.e. to kabadi or for reuse, recycle. Some Municipals are also doing such jobs.

(b) Dumping- Transfer of solid waste from place of collection to the site of disposal is called dumping. Corporations and Municipal bodies collect and dump them on some suitable and safe site located far away from human habitation.

(C) Compaction and Bailing- The solid wastes are often spread on a plane and hand surface and later pressed by bulldozer. This is called compaction. These compacted layers are rolled and piled. This is called bailing. Now such compacted and bailed solid wastes are dumped for decomposition.

(2) 3R or Reduce, Reuse and Recycle of solid waste

(A) Reduce of waste material- We should reduce the household waste by using maximum part of the goods. Before throwing out side, we should select the parts for Reuse/Recycle. When we purchase the things, avoid polythene and heavy packages.

Hazardous waste can be controlled by reduction at source. We should suggest friends, relatives to save all clean papers and other various means to save paper. Gaseous wastes are generally removed through combustion, absorptions and adsorption techniques. There should be proper cooperation and co-ordination among individuals, local bodies and Govt Institutions for proper waste management in an area. Reduced demand for any metallic product will decrease the mining of their metal and cause loss production of waste. Thus, every individual has a responsibility of creating less waste and managing its properly.

(B) Reuse of waste materials.

After selecting the waste (which can be reused) use after the proper treatment. We should not use, cups, plates, utensils, napkins etc of paper. If they are of permanent nature, therefore, they can be reused after washing. Plastic bags, wrap, foils, rotten articles should not be used.

We should use refillable lighters, containers, and other usable items. We should discourage use and throw policy. Sell or donate goods instead of throwing them out. Furniture, clothes and other repairable articles should be reused after repair instead of throwing. We should develop quality of borrow, share and rent in ourselves.

(C) Recycling of waste materials. Sewar and other drainage systems are associated with sewage treatment devices that centralize toxic effects of sewage before releasing it to the local water systems. Principal operations of solid waste disposal incorporate composting, senitary, land filling, thermal process or incineration.

(1) Sewage treatment.
It is done through following steps:

(a) Neutralized sewage

(a)The sewage is sent through setting chambers, where lime is mixed with it. Thus it becom neutralized and most of the sediment is removed.

(b)Neutralized sewage is passed through Upflow Anaerobic Sludge Blanket (UASB). Here, decomposable material is decomposed through bacterial activities in absence of oxygen. After that water is passed through aeration tanks where air and bacteria are mixed.

(c) Dissolved substances are removed by processes like chlorination, evaporation, exchange technique and absorption.

The treated water is used accordingly.

ii) Pulverisation:- The volume of solid waste is reduced through grinding or smashing for easy handling to transport and disposal.

(iii) Composting :-The process of making manure of decomposable waste with the help of microbial activities is called as composting. It is of two types Aerobic i.e. in presence of air and Anaerobic i.e. in absence of air. For this different size pits are dug in the ground and all the biodegradable solid, semi solid wastes are dumped and fully filled pits are covered with a layer of soil. Water is added time to time. The average time for composition is 1-6 months.

Sanitary Landfilling: In this process solid wastes are scientifically filled in to low lands. As all this wastes can not be recycled or burnt, these will be always a need for land fill. In sanitary landfills, garbage and other waste is spread out in their layers, compacted and covered with clay or plastic foam. The process of filling is done in such a way that wastes can not create any type of hazard to public health.

(IV) Thermal process : Burning of solid waste under controlled conditions is called as thermal process. The heat produced in this process may be utilized. It is carried out in both the presence and absence of air.

ROLE OF AN INDIVIDUAL IN PREVENTION OF POLLUTION

Pollution and poverty are complimentary to each other. Some time people forced to go with the path of pollution. Illiteracy is another factor in the prevention of pollution. Unlimited desires, selfishness, urbanization, industrialisation, deforestation, to increase the life style etc. are some of big factors which are main cause of pollution. For that the need is to understand first, apply then be a lesson for others. Gandhiji was not an environmentalist but was for the concept of sustainable development

In short, an individual can do as following safety measures to prevent the pollution –

(1) One should start first in the field of environmental awareness to protect the pollution.

(2) We should go place to place to teach the lesson of awareness and prepare volunteers. (3) Give the message to save environment through papers, magazines, T.V. and radio.

(4) To promote for plantation and conservation of forest.

(5) To organize seminars, on the subject related to pollution.

(6) One should go in rural areas during festivals, functions, local gatherings, and religious occasions to convince people for prevention of pollution.

(7) Awareness is very effective in childhood, hence we should go to schools, organize rallies to teach the lesson of environment.

(8) World forest day, world environmental day and other such function should be organized for general awareness. On these functions, Govt. should also take interest in this regard but we should not depend on Govt.

(9) Population growth should be reduced.

(10) We should use and promote mass transport system. If possible go on foot or use bicycle for short distances.

(11) We should not use materials containing CFC eg Refrigerators, Cups, etc.

(12) We should discourage the use of more fertilizers insecticides and pesticides but should encourage the use of bio fertilizers.

DISASTER MANAGEMENT

FLOOD

- As floods are one of the very few well recorded natural phenomena, the catastrophic damages caused by them attracted focused attention in recent decades. With increasing population pressure and accelerated economic development, the adverse effects of floods are being increasingly felt now.
- The term Flood is generally defined as a relatively high flow or stage in a river and the inundation of low land which might result therefrom. In a broader sense

the term flood is used to convey all their outfalls into main rivers, outflow due to jamming or blocking of rivers by landslides and inadequate drainage to carry away surface water speedily. Coastal floodings are also covered.

- In India vast stretches of land are submerged under water and other adverse effects are caused, such as destruction or damage to houses, property, bridges roads and other means of communication lives lost etc. year after year.
- The disastrous floods of 1954 and the immediate succeeding years resulted in the initiation of organized and coordinated flood management efforts to mitigate the problem.

CAUSAL PHENOMENA AND CHARACTERISTICS

- Flood are natural phenomena characteristic of all rivers. As is known, the rainfall in India is largely dependant on the monsoons and cyclonic depressions. Most of the rainfall is received during the southwest monsoon season during which heavy spells of rain are often experienced in the catchment over the period of a few days at a time.
- It could therefore be said that high rainfall coupled with inadequate channel capacity leads to flooding. Choking of rivers beds by natural causes or artificial obstructions aggravate the problem.

VULNERABILITY

- An extreme natural phenomenon capable of causing disaster (leading to loss of lives or damage to property) is known as a natural hazard. The process of identifying the probability of occurence of a natural hazard of a given intensity at a specific location, based on an analysis of natural processes and site conditions is termed Hazard assessment.
- Vulnerability indicate the conditions (physical, socioeconomic/political) which increase the community's susceptibility to disaster or which adversely affect its ability to respond to events. It thus gives an idea of the expected degree of damage to a construction or an economic activity when exposed to a natural hazard of a given intensity.
- Risks are the probable losses in a given area or to an infrastructure system caused when the hazard materializes.The type and degree of flooding is influenced by many factors. The principal factors can be classified to fall under three groups.

(1) climatological conditions.

(2) hydrological and environmental conditions

(3) local geomorphology off the flood plain In addition, coastal flooding also depends on the coastal configuration and tidal

ADVERSE EFFECTS OF FLOODS

All over the world, and throughout history, natural disasters have imposed human suffering and extracted heavy toll of losses. Recent instances have revealed that it is not merely the developing countries that have so suffered. The loss in some of the highly developed Nations is mind boggling notwithstanding the high standards of construction and extensive protection measures that they had undertaken.

Apart from the casualties, injuries and disablement, many sections of the population get affected by the floods. Cropped area gets submerged, eroded and strewn with sand leading to loss of crop production and consequential disruptions. Many houses are destroyed completely; others are damaged. Damage and loss to public and private utilities and industrial disruptions occur. Breakdown of economic activities occurs with corresponding loss of wealth.

The statistics compiled suffer from one disabilities and many suggestions for better compilation of flood damages have been also offered. Moreover damage figures compiled by interested parties or even the Govt. for other purposes may not indicate the precise picture of losses. However the broad figures as indicated above serve the purpose of indicating the order of losses. In any case the exact assessment of the comprehensive loss to the economy of the Nation or to the individuals is a near impossible task.

EARTHQUAKE

- ➢ Earthquakes are considered to be one of the most dangerous and destructive natural hazards. The commencement of this phenomenon is usually sudden with little or no warning.
- ➢ It is not yet possible to predict earthquakes and to make preparation against damages and collapse of buildings and other man-made structures.
- ➢ Actually earthquake consists of a sudden shaking (vibrations) of ground caused by disturbances in the earth's crust.
- ➢ An earthquake generates a set of horizontal and vertical vibrations of the ground which are random in character.
- ➢ Earthquakes may be defined as a natural phenomenon which tends to create panic due to the trembling vibrations of sudden undulation of a portion of earth's crust caused by splitting of a mass of rock (Tectonic) or by volcanic or other disturbances.

GENERAL CHARACTERISTICS

Impact of Earthquakes is sudden with little or no warning. However, following a major Earthquake, the after-shocks may give warning of a further earthquake. On some occasions, an earthquake may be preceded by a less intense tremors or foreshocks.

. It is not yet possible to predict magnitude, time and place of occurrence of an earthquake.

• The onset is usually sudden.

• Earthquake prone areas are generally well identified and well known on the basis of geological features and past occurrences of earthquakes.

• Major effects arise mainly from ground movement and fracture or slippage of rocks underground. The obvious effects include damage (usually very severe) to buildings and infrastructures alongwith considerable casualties.

. On the average about 18000 people die each year due to this disaster throughout the world.

• About 200 large magnitude earthquake (M>6.0) occur in a decade. a

• The world's earthquake problem seems to be increasing with the increased population, high rise buildings and crowded cities.

PRE-CURSORS INSTRUMENTAL AND NON-INSTRUMENTAL

- We have already stated that it is not yet possible to predict earthquakes. However, sometimes there are some indication that would indicate that perhaps an earthquake would occur. Such indications are called "precursors".
- There could be either instrumental, i.e., those that are measured by instruments or non-instrumental, i.e. those which can only be perceived and not measured. Needless to say, the non-instrumental precursors are more subjective.

VULNERABILITY

- Disasters result from vulnerable societies being exposed to a hazard. There can be physical vulnerability, social vulnerability and economic vulnerability on account of an earthquake disaster.
- Physical vulnerability relates to buildings, infrastructure and agriculture. The vulnerability of buildings is dependent on their sets, shape, materials used, construction techniques, maintenance and proximity of buildings to others. The weightage attached to each factor will vary according to the characteristics of the particular earthquake.
- Infrastructure may be considered in three broad groups: transport systems (roads, railways. bridges, airports, port facilities): utilities (water, sewerage and electricity); telecommunications; dams and flood protection embarkments.

Social Vulnerability

Records of past earthquake disasters suggest that the following groups of people are particularly at risk and require special attention:

• Single parent families:

• Women, particularly when pregnant or lactating.

• Mentally and physically handicapped people:

• Children, and

• The elderly.

Poor people are less concerned with infrequent hazards. If there are groups whose livelihoods are at risk, living or working in densely populated areas, with low perceptions of risk and without institutional support, the cumulative effect would be high social vulnerability.

ECONOMIC VULNERABILITY

- It measures the risk of hazards causing losses to economic assets and processes. It focuses only valuating the direct loss potential (i.e. damage or destruction of physical and social infrastructure and its repair or replacement cost, as well as crop damage and losses to the means of production); indirect loss potential (i.e. the impact on cost production, employment, vital services and incomeearning activities); and secondary effects (epidemics, inflation, income disparities and isolation of outlying areas).
- With the insights provided by economic vulnerability analysis, it is possible to estimate direct and indirect losses and to design ways and means to mitigate them in relation to the estimated costs of relief/recovery actions and mitigation measures required.

IMPACT AND EFFECTS

In general terms, typical impacts and effects of earthquake disasters tend to be :

• Loss of Life.

• Injury

• Damage to and destruction of property.

• Damage to and destruction of subsistence and cash crops.

• Disruption of production.

• Disruption of lifestyle.

• Loss of livelihood.

• Disruption to essential services.

•Damage to national infrastructure and disruption to administrative and organizational systems.

• National economic loss.

• Sociological and psychological after-effects.

The following problem areas need particular attention in case of Earthquake disasters: Severe and extensive damage, creating the need for urgent counter measures, especially search and rescue, and medical assistance.

• Difficulty of access and movement.

• Widespread loss of or damage to infrastructure, essential services and life support systems. • Recovery requirements (i.g., restoration and rebuilding) may be very extensive and costly.

. Occurrence of earthquakes in areas where such events are rather rare may cause problems due to lack of public awareness.

NATURE OF DAMAGE

Damages due to earthquakes are the related terms and depends upon various factors listed below:

(a) Nature of earthquake.

(b) Geological and soil conditions

(c) Quality of construction.

(d) Sociological factors.

CYCLONE

- Cyclones are one of the most disastrous natural hazards in the tropics and are responsible for deaths and destruction more than any other natural calamities. Cyclones bring with them extremely violent winds, heavy rain causing floods and storm tides causing coastal inundation.
- Cyclones form over the warm ocean waters (sea surface temperature of the order of 26°C or 27°C) little away from the equator within the belt of 30°N and 30°S. In our area, cyclones form in the Bay of Bengal and the Arabian sea. As they move westward or northwestward, those forming in the Bay of Bengal come to the Indian territory while those forming in the Arabian Sea generally go away from India but sometimes they turn around to hit Gujarat.

RISK REDUCTION PROCESSES

- The prevention of tropical cyclone formation is not within the realm of possibility. However, the loss of human lives and destruction of properties can be minimized by adopting prescribed short and long term measures for risk reduction.
- While cyclone warning system is the most important constituent of short term risk reduction measures against cyclone disaster, the risk assessment of tropical cyclone falls under long term measures.
- As prevention of formation of tropical cyclone is not in the realm of possibility, some structural and non-structural preventive measures of long term nature can be undertaken to mitigate the suffering of cyclone affected people.
- Structural measures like construction of cyclone shelters, embankments, dykes, reservoirs and coastal afforestation are some of the long-term risk reduction measures for cyclone disasters. Creation of proper awareness, training and education of people in the vulnerable communities, introduction of insurance can be some of the non-structural measures.

EFFECTS

Severe tropical cyclones are responsible for large casualties and considerable damage to property and agricultural crop.

The destruction is confined in the coastal districts and the maximum destruction being within 100 km from the centre of the cyclones and on the right side of the storm track. Principal dangers from a cyclones are:

(i) very strong winds

(ii) torrential rain, and

(iii) high storm tides. Most casualties are caused by coastal inundation by storm tides.

(iv) Maximum penetration of storm surges varies from 10 to 20 km inland from the coast.

(v) Heavy rainfall and floods come nest in order of devastation.

LANDSLIDES

- Often it is not realized that a large part of India consists of mountainous terrain. In the north, there is the extensive Himalayan mountain system extending all along from the west to the east. Its lofty peaks rise to more than 8000 metres height.
- The middle ranges of the Himalayas 5000 metres high on the average while the foothills rise to about 6000 metres. The Himalayas abound in glaciers and are the origin of many rivers and streams. There is abundant rainfall and snowfall often accompanied by strong winds.
- The peninsular region of India starts from the Vindhyachal ranges and consists of the Deccan Plateau which slopes eastwards.
- On its edges, this great plateau is bound by the mountain the Eastern Ghats and the Western Ghats. The Nilgiri mountains are in the southern parts of the ranges plateau. The west-central parts of the country have the of ranges of the Aravali mountains.

LANDSLIDES IN INDIA

- Landslides affect the remotely located, often isolated, small communities in villages or hamlets in the mountain regions of the country where external assistance takes time to reach in times of emergency when the normally difficult terrain and tracks may become almost impossible to negotiate.
- Many a times, even the information about the occurrence of such events and the damage done takes days to reach the district and state headquarters. Because of these reasons, landslides and snow avalanches assume the status of major natural disasters even though the affected area and population may be rather small.

Incidence of landslides in India

Region	Incidence of Landslides
Himalayas	High to very high
Northeastern Hills	High
High Western Ghats and the Nilgiris	Moderate to high
Eastern Ghats	Low
Vindhyachals	Low

Kind and Magnitude of Damage

There is no doubt that anything that comes in the ways of a landslide will suffer severe damage and may even by totally buried or wiped out . Anything located on top of a landslide will also not survive when the rock or mud slips out from below it.

Landslides : More often, the major landslides are combinations of rockslide and rockfall. They all involve movement or mass (soil , debris or rock). The process of movement of mass may vary from slow soil creep to abrupt and sudden rockfall. Landslides, also known as landslips, range from low angle and rather slow slides to sudden vertical falls.

Based on the type of movement, relative rate of movement and kind of material involved, landslides can be designated into 5 kinds as follows:

- Slump with earthflow
- Debris slide
- Debris fall
- Rock slide
- Rock fall

Landslides are also known to result in blocking of streams or overflowing of lakes thus causing flash floods because large volumes of debris falling in a lake or reservoir cause its water to overflow or the temporarily blocked stream may suddenly release the huge quantity of impounded water to cause a devastating flash flood downstream.

Relief and Rehabilitation

Essentially, the relief steps comprise the following:

(1) Search and Rescue

(2) Medical assistance to the injured

(3) Disposal of the dead

(4) Food and water

(5) Emergency shelter for the homeless

(6) Opening up access roads if blocked; and restoration of communication channels

(7) Psychological counseling of the survivors who have lost their close relatives

(8) Repair of houses and facilities

(9) Assistance (technical and financial) to restart economic activity to restore regular work and income

(10) Reconstruction through proper planning.

We have already discussed the relief steps in the preceding section. As regards the long-term measures, these will comprise the following:

(1) Reducing the hazard proneness of the site through engineering measures such as strengthening or modifying the slopes, removing fragile and unstable portions, securing snow accumulations by snow fences, snow nets or by cribbing, and improvement of drainage.

(2) Stopping indiscriminate quarrying and mining in mountain areas.

(3) Afforestation of zones prone to landslides so that trees and vegetation provide a binding force to prevent slippage of debris, rock, and snow.

(4) Creation of a voluntary, community based preparedness system of watch, monitoring and alert. This will not only be useful in times of a disaster but will provide enough self confidence (and thereby self reliance) which is an essential objective of an effective rehabilitation programme.

(5) Provision of assistance for economic rehabilitation by arranging work, employment loans, and grants.

In the extreme case of severe damage to a community by a landslide or snow avalanche, the site may be rendered totally unusable. In that case, rehabilitation takes the form of relocation and reconstruction. In such an event, the new site should be carefully chosen so as to minimize vulnerability and risks.

Unit 6: Social issues and the Environment

UNSUSTAINABLE TO SUSTAINABLE DEVELOPMENT

- More and more natural resources were consumed in the process of satisfying the rapidly growing needs of the habitat. Every development activity has some impact on the environment.
- For meeting the needs, the human cannot live without the developmental activities. Consequently, there is need to continue developmental activities in such a way that environment should not polluted at least.
- Unsustainable development means the development of a few privileged nations both in science and technology. Such developments are at the cost of our life supporting systems like air, water, soil and over exploitation of our natural resources which may lead to the collapse of the inter-related systems of the earth.

There are two aspects of sustainable development:

(i) Inter-generational equity - This emphasizes that we should stop over-exploitation of resources, reduce waste discharge and emissions and maintaining an ecological balance. It expects to hand over a safe healthy and resourceful environment to the future generations.

(ii) Intra-generational equity - This emphasizes that technological development should support economic growth of the poor countries so as to reduce the weather gas within and between the nations.

Measures for sustainable development - There are following major measures for sustainable development:

1. To promote environmental education and awareness - From childhood, we should develop a feeling of belongingness to earth. This can be possible by introducing environment as a subject in education from primary stage. Media can also be helpful in developing such feelings.

2. Three 'R' approach - Three 'R' means, Reduce, Reuse and Recycle. We should reduce the excessive use of natural resources, but use them again and again instead of passing it on to the waste stream. Recycle the materials to reduce pressure on our existing natural resources.

3. Appropriate technology - The technology should use less resources and produce minimum waste. It is over which locally adaptable, eco-friendly, resource efficient and culturally suitable.

4. To utilize resources as per carrying capacity of the environment - Sustainability of a system depends largely upon the carrying capacity of the system. If carrying capacity of a system crossed, environmental degradation status and continues till it reaches a point of no return. Carrying capacity has two basic components.

(i) Supporting Capacity - It is formed of productive and protective systems

(ii) Assimilative Capacity - It is formed of the systems which utilize the wastes produced by human activities.

Urban Problem Related to Energy

- Urban areas are developing very fast. In most of cities there is influx of populations from surrounding areas, mostly in search of employment and better living conditions. Therefore, it is difficult to accommodate all the industrial, commercial and residential facilities within limit. As a result, cities are spreading in to sub-urban or to rural areas. Uncontrolled population, irregular development are the main factor for receding facilities in urban areas.
- Energy is required in every walk of life like industry, transport, defence, agriculture, trade, education, domestic etc. Cities are the main centres of economic growth. Hence, energy is the most important input for development.
- The energy requirements of urban population are much higher than that of rural ones. Energy problems become more severe due to the limited amount of non-renewable resources of energy.

There are following main causes of energy problems.

1. Increasing use of energy for domestic and commercial purposes (due to increased population and industrialization).

2. Industrial plants using big proportion of energy.

3. Non-renewable resources of energy like coal, petroleum and natural gas are decreasing.

4. Increasing of transport means.

5. Decreasing production of Hydroelectricity due to insufficient rains.

6. Transmission loss due to defected power distribution system.

There are following steps to solve the energy related problems.

1. To control urbanization.

2. To develop renewable resources of energy like solar radiation, wind power, hydel power, nuclear power, bio mass etc. These are pollution free also.

3. Non-renewable energy resources should be used only when no non-conventional source of energy is available.

4. Welcoming the awareness programs to save energy.

5. Effective measures for transition loss and energy theft.

WATER CONSERVATION

- Water is needed in almost every sphere of human activity. Without water life is not possible. In many aspects the properties of water are unique. It is called universal solvent. No other liquid can replace

- it. The global distribution of fresh water on earth's crust including ground water and water present as its vapours in atmosphere.

Water is required for direct consumption or indirectly for washing, cleaning, cooling, transportation or even for waste disposal. Important sectors of human activity, which require water can be grouped as:

1. Irrigation

2. Industries

3. Live stock management

4. Thermal power generation

5. Domestic requirements

6. Hydroelectric generation, fisheries navigation and recreational activities.

The following steps should be taken for conservation of water.

1. Water economy, Re-use and Recycling. If water meters are installed and charged properly, the consumption of water in domestic establishments, livestock management and industries shall drastically decline. The heated water from thermal power plants, where large amount of water is needed, may be utilized elsewhere after proper cooling. The same is true for many industries, water used once may be used again for another purposes.

2. Agricultural runoffs from fields. This can be used to irrigate cropland down the stream, while an efficient use of water with conditions of proper drainage can significantly reduce the agricultural runoffs.

3. Efficient distribution system. Water resources are not distributed evenly. Some localities have plenty of water and others have little. Many river basins have plenty of water, which flows down un-used to the sea. Surplus of one basin can be used to make up the deficit at another.

4. Enhancement of surface storage capacity. About 27000 Cubic kms of fresh water which rush down to the oceans through stream and rivers are of no use to the mankind. We can store this water in tanks, reservoirs, dams for further use in drier seasons.

5. Reduce evaporation losses. Water losses through evaporation and seepage are enormous both from the reservoirs and distribution system. It should be reduced.

6. Improvement of underground storage capacity. The fresh water is stored in underground deposits. Every year about 10-15% of the total precipitation enters the ground water table. These deposits regularly feed streams and rivers during the drier periods. These deposits are cheap and easily obtainable.

7. Desalination of Sea Water. A huge store of water exists in our oceans. If the salt content of the sea water is removed, we can use it. This can be done by desalination plants.

8. Afforestation and Reforestation of hill slopes to check loss of water in floods.

9. Artificial rain making and precaution of water pollution.

RAIN WATER HARVESTING

- Water is an essential natural resource for sustaining life and environment. So Conservation and preservation of water resources are urgently required to be done. Water management has always been practiced in our communities since ancient times, but today this has to be done on priority basis.
- The ministry of Water resources in India is endeavouring to make rain water harvesting a part of every day life in our villages and cities as a people's movement, and this will go a long way in the management of ground water as a sustainable resource.
- Government and the people join hands for creating awareness of the importance of rain water harvesting with the main objective of adopting these measures and techniques throughout the country.
- A judicious mix of ancient knowledge, a modem technology, public and private investment, and above all, people's participation will go a long way in reviving and strengthening water- harvesting practices throughout the nation.

Rainwater harvesting is categorized into domestic rain water harvesting and rain water harvesting for agriculture, erosion control, flood control and aquifer replenishment.

Domestic rain water harvesting, also known as roof water harvesting or roof top rain water harvesting is the technique through which rain water is captured from roof catchments and stored in tanks or reservoirs.

Rain water harvesting systems, both small and large, consists of six basic components.

(a) Catchment area/roof, the surface upon which rain falls.

(b) Gutters and downspouts, the transport channels from catchment surface to storage.

(c) Leaf screens and roof washers, which are systems that remove contaminants and debris.

(d) Cisterns or storages tanks, where rain water is stored.

(e) Water treatment, the filters and equipment as well as additives to settle, filter and disinfect.

The main causes of fall in ground water levels are:

(a) Overexploitation or excessive pumping either locally or over large areas to meet increasing water demands.

(b) Non-availability of other sources of water. Therefore, sole dependence is on ground water.

(c) Unreliability of municipal water supplies both in terms of quality and quantity, driving people to their own sources.

(d) Misuse of ancient means of water conservation like village ponds, baolis, percolation tanks and therefore, higher pressure of ground water development.

The main effects of overexploitation of ground water resources are:

(a) Drastic fall in ground water levels in some areas.

(b) Drying up of the wells/bore wells.

(c) Enhanced use of energy.

(d) Deterioration in ground water quality.

(e) Ingress of sea water in coastal areas.

The method and technique include:

(a) Roof top rain water harvesting and its recharge to underground through existing wells or bore wells or by constructing new wells, bore wells, shafts, spreading basins, storm water drains etc.

(b) Harnessing runoff in the catchments by constructing structures such as gabions, check dams, percolation trenches, sub-surface dykes etc.

(c) Impounding surplus runoff in the village catchment and water sheds in village ponds and percolation tanks.

(d) Recharging treated urban and industrial effluents underground by using for direct irrigation or through recharge ponds or wells etc.

The main objectives of rain water harvesting are :

(a) To restore supplies from the aquifers depleted due to over exploitation.

(b) To improve supplies from aquifers lacking adequate recharge.

(c) To store excess water for use at subsequent times.

(d) To improve physical and chemical quality of ground water.

(e) To reduce storm water run-off and soil erosion.

f) To prevent salinity ingress in coastal areas.

(g) To increase hydrostatic pressure to prevent or stop land subsidence.

(h) To recycle urban and industrial waste waters etc. ponds,

(i) To rehabilitate the existing traditional water harvesting structures like village percolation tanks, baolis, tanks etc.

(j) To convert the traditional water harvesting structures into ground water recharge facilities with minor scientific modifications and redesigning.

(k) To use the existing defunct wells and bore wells after cleaning and also the operational wells as recharge structures.

The expected advantages of rain water harvesting are:

(a) Rise in ground water levels in wells.

(b) Increased availability of water from wells.

(c) To prevent decline in water levels.

(d) Reduction in the use of energy for pumping.

(e) Reduction in flood hazards and soil erosion.

(f) Improvement in water quality.

(g) Arresting sea water ingress.

(h) Assuring sustainability of the ground water abstraction sources and consequently the village and town water supply systems.

(i) Mitigating the effects of droughts and achieving drought proofing.

WATERSHED MANAGEMENT

- Watershed is a drainage area on earth's surface from which runoff, resulting from precipitation flows past a single point in to a large stream, a river, a lake or the ocean. It is a geo-hydrological unit and drains at a common point, has been accepted world over as a scientific unit for area development.
- The watershed can range from a few square kilometre to few thousand square kilometre in size. Damodar Valley Corporation in 1949 adopted first Integrated Watershed Management. Watershed development is the rational utilization of natural resources of soil water and vegetation for increasing and stabilizing the productivity of land on a sustainable basis.
- The development of watershed will result in increase in sub soil water regime, recharge of wells.
- The watershed based development approach is undoubtedly an agreeable concept to set the goal. But this demands a massive people's movement to make the village community self reliant.
- The watersheds are very often found to be degraded due to uncontrolled, unplanned and unscientific land use activities like over grazing, deforestation, mining, soil erosion, industrialization etc.

Objectives of watershed management.

Watershed management is the rational use of land and water resources for optimum production causing minimum damage to the resources.

The main objectives of watershed management are as :

1. To increase agricultural production i.e. increasing the availability of fodder, fuelwood, timber and raw materials for industries.

2. The rational utilization of natural resources like water soil and vegetation. 3. To minimize the risks of floods, droughts and landslide.

4. To Manage the watershed for developmental activities like domestic water supply, irrigation, hydropower generation.

5. To develop the rural areas and their lifestyle.

Under the development of national policy, the watershed management was included in fifth Five Year Plan. Now a days, a number of national watershed development programmes are in progress. Various measures are necessary for watershed management.

Some of them are :

1. Scientific mining and quarrying must be done in the watershed areas because hills loose stability and get disturbed by improper mining.

2. Water harvesting in the watersheds to be used in dry season .

3. Afforestation and agro forestry (crop plantation) should be promoted to prevent runoffs loss and soil erosion and increase soil moisture. Woody trees like Eucalyptus and Lencaena should be grown in between crops to reduce the runoffs and loss of fertile soil in high rainfall areas.

4. some mechanical measures like terracing, bunding, bench terracing, contour cropping etc. are used to minimize runoff and soil erosion in the slopy regions of watersheds. 5. To promote soil binding plants like Vitex.

6. People's participation should be ensured including farmers and tribals in the water shed management programmes. This can be done by properly educating people about the campaign or paying some incentives.

The Himalayas are one of the most critical watersheds in the world. Most of the watersheds of our country lie in this region. Successful watershed management has done at Sukhomajri and Panchkula with the active participation of the local people.

Resettlement and rehabilitation of people: Its problems and concerns

- Some times for the development of projects like construction of dams, mining, creation of parks etc. and during natural calamities like Earthquake, Landslides, Volcanos, Floods, Droughts, Cyclones, the problems of resettlement and rehabilitation arise. For example recently the Tsunami cyclone affected thousands of families and during construction of Indira Sagar dam in Khandwa district of Madhya Pradesh thousands of families were displaced and rehabilitated near Chanara and other places.
- This caused permanent loss of the benefits and facilities. This disturbed Socio-economic and ecological base of local community which are generally forest and tribal people.

Families are disintegrated and also lost ancestral link between people and the environment. Various types of projects result in the displacement of native people are :

1. Displacement due to Dams. Universe without energy is not imaginable. The most easily accessible and eco-friendly form of renewable energy is hydropower. Water is scarce natural resource and India is blessed with it. Hence it has to judiciously harnessed and managed for welfare of all living beings. India's exploitable hydropower potential is 84044 MW.

Case Study

INDIRA SAGAR PROJECT (ISP) - Indira Sagar Project (1000 MW) is in Khandwa district of MP. It is constructed, operate and maintain by Narmada Hydroelectric Development Corporation (NHDC). Narmada is bestowed with rich potential of 29 major, 135 medium and 3000 minor projects. The reservoir of ISP Dam is largest reservoir in India with storage capacity of 12.22 BM of water for irrigation of 2.70 lakh Ha. A total of villages and people affected by this project. They were given plots, transportation grant, shifting facilities, agricultural land and other compensation. A separate township CHANERA was developed for displaced people. Under this project 26000 Ha area is proposed for irrigation, 564 villages to be benefited by irrigation. This will cause the production of 4.00 lakh tonnes of food grains and 10.55 lakh tonnes of other crops every year additionally.

REHABILITATION.

- The United Nations Universal declaration on Human Rights (Article 25(1) has declared that "Right to housing is basic human right".
- This suggest better rehabilitation, adequate compensation, job opportunities, civic amenities and religious and cultural benefits. Therefore, National Rehabilitation Policy is needed to honour the human rights of the displaced people. Govt. under Land Acquisition Act 1894 has power to vacate the land from people by giving notice for Govt. use.

For displaced persons in case of Indira Sagar Dam, the following compensations for resettlement and rehabilitation were given :

1. Developed plot or Rs 20,000 for purchase of plot for one family.

2. Rehabilitation grant of Rs 18700/- or 9350/- as per status of PAFs.

3. Transportation grant Rs 5000/- for shifting of one family.

4. Allotted 2-8 hectares of agriculture land per family or land compensation.

5. Attractive compensation for house, trees, wells and other structures.

6. At the plot sites, developed roads, water supply to lights, schools, health centres, worship places, panchayats, community centres, shops etc.

7. R and R work is being executed smoothly.

8. Additionally more benefits were given.

9. Professional training being given to project affected families at I + 1 Narmada Nagar.

10. Central school (Kendriya Vidyalaya started in June 01)

11. Different socio-economic upliftment programmes such as free medical check up, vaccination, training programmes are being organized.

ENVIRONMENTAL ETHICS

Issues and possible Solutions

- The issues, principles and guidelines relating to human interaction with their environment OR human obligations towards the environment and living beings are called Environmental Ethics or Earth Ethics.
- Ethics constitute the basic codes of civilized behaviour, without which our environment as we know would be impossible. Such rules embody the basic constraints each of us agrees to practice in relationship with others. Ethical codes can be of help in most instances that confront us, but dilemmas do arise in which it seems there are no suitable alternatives.
- We can see that our acts will follow what we think i.e. human-centric thinking or earth centric thinking. The first view urges us to march ahead gloriously to conquer the nature and establish our supremacy over nature through technological innovations, economic growth and development, while second urges us to live on this earth as a part of it, like any other creation of nature and live sustainably.
- Human beings are over exploiting the natural resources and polluting the environment. These human acts are very dangerous and may lead to environmental crisis.

In relation to environmental protection or in need of environmental ethics two world views

1. Eco-centric worldview. This states that earth resources are limited, and they are not for human beings alone but for all species. So we have to draw our requirements from environment, but not to that extent it degrades the environment. A healthy economy depend upon the healthy environment, therefore, success of mankind depend upon how we cooperate with nature while trying to use the resources of nature.

2. Anthropocentric World view. It states that man is the most important species of nature. Earth has an unlimited supply of resources. Most of the industrial societies believe in this view. So the success & healthy economy of mankind depend upon how nicely man derives benefits from nature.

To check the environmental crisis, we must follow the certain environmental ethics for better future. Some of them are -

1. One should love and honour the earth.

2. We should celebrate the turning of the seasons of the earth.

3. Do not waste or exploit the natural resources.

4. To bring about awareness regarding conservation of life support systems.

5. Our should be fair in sharing of resources.

6. We should respectful to plants and animals which provide us food.

7. We should conserve the ecosystem and promote appropriate sustainable development.

8. We should not do anything at the cost of nature.

CLIMATE CHANGE

- Though climate is an average weather of an area or environmental factors of an area. These include quantity of light, temperature, humidity, wind, gases, water etc which average for about 30 yrs.
- Thus the changes in environmental conditions of an area over long period of time is called climate change. These changes effect the agriculture, migration of animals, hydrological cycle, thermal gradient between the poles and equator, wind pattern, distribution of rainfall etc.
- The scientific and technological revolution has given multiple facilities to mankind, but at the same time man-made (Anthropogenic) activities are responsible for depletion of resources and upsetting the delicate balance between the various components of the environment.
- They are, excessive use of fossils fuels, deforestation, desertification, loss of fertility of soil, rapid industrialization, increase of automobiles. Changes in the atmosphere conditions resulting in to serious problems like green house effect, depletion of ozone layer and rise of world temperature etc.
- The global change in temperature will not be uniform everywhere and will fluctuate in different regions. The places at higher latitudes will be warmed up more during late autumn and winter than the places in tropics. Poles may experience 2 to 3 times more warming than the global average, while warming in tropics may be only 50 to 100°C on an average. The increased warming at poles will reduce the thermal gradient between the equator and high latitude regions, decreasing the energy available to the heat engine that drives the global weather machine. This will disturb the global pattern of winds and ocean currents as well as the timing and distribution of rainfall. Shifting of ocean currents may change the climate of iceland and Britain, it may result in cooling at a time when rest of the world warms.

GLOBAL WARMING

- The average global temperature is 15°C. The lower most layer of atmosphere i.e., troposphere, traps the heat by a natural process due to the presence of certain gases called Greenhouse gases.
- They are carbon dioxide, ozone, methane Nitrous oxide, Chlorofluorocarbons (CFCs) and water vapours. In absence of these gases the temperature (15°C) would have been - 18°C. Thus warming of the earth's climate owing to the increased concentration of green house gases is called Greenhouse effect.
- Therefore, this effect contributes a temperature rise to the tune of 33°C. These gases act like the glass in the botanical greenhouse trapping the reradiated heat near the earth's surface and warming the planet.

- These gases along with water vapour and clouds absorbs the infrared radiation, trapping heat near the earth's surface. The two predominant green house gases

(1) the water vapours whose level in the troposphere has relatively remained constant is controlled by hydrological cycle while

(2) CO_2 whose level has increased is controlled by the global carbon cycle. Other gases whose levels have increased due to human activities are methane, NO and CFCs. Deforestation has also elevated levels of CO_2.

GREEN HOUSE GASES

The green house gases present in the troposphere and resulting in an increase in the temperature of air and the earth are discussed here.

CARBON DIOXIDE (CO_2) - The CO_2 is considered as the most dominant factor responsible for the green house effect. The troposphere contains only 0.0375% CO_2 (by volume) and its amount is controlled by carbon cycle .

CHLORO FLUORO CARBONS (CFCs) - The main source of CFCs include leaking air conditioners and refrigerators, evaporation of industrial solvents, production of plastic foams, aerosols, propellants (CFC-11) etc.

The concentration of CFCs is rising nearly 5% per year. CFCs trap heat 20,000 times more efficiently than CO_2 and also destroy ozone layer, thus posing a serious twofold environmental problem.

METHANE (CH_4) - It is produced in a number of ways including the action of anaerobic bacteria on vegetation, decomposition of organic matter, incomplete combustion of vegetation, natural gas pipeline leaks, burning of biomass during production and uses of oil and natural gas and petroleum oil etc. It is rising approx. 2% every year. It absorbs 20-25% times more heat than CO_2.

NITROUS OXIDE (N_2O) –

- It is released from nylon products, from burning of biomass and fuels (specially coal). From breakdown of fertilizers in soil, livestock wastes and nitrated contaminated ground water, nylon products etc.
- It is responsible for about 6% of global warming. Besides trapping heat in the troposphere it also depletes ozone in the stratosphere. It absorbs about 250 times more heat than CO_2. The N_2O concentration in atmosphere is 0.3 ppm and is increasing 0.2% annually

OZONE - It comes mostly from hydrocarbons and nitrogen oxides. It causes irritation to eyes and respiratory organs. It decreases the resistance power to infections and aggravates illness.

IMPACT OF GLOBAL WARMING

(i) Climatic change (Increase in global temperature) - Increase the level of Green house gases causes the global warming have affected the global climate. This effect will increase in future. According to IPCC (1996) the world climate has warmed from 0.3 to 0.6°C during the last century.

(ii) Effect on Sea levels - Rising temperatures will cause glaciers to melt and the polar ice caps to shrink . As a result sea level may rise by 0.2 - 1.5 m over the next 50 - 100 yrs It is proved that sea level have already risen by 10 - 25 cm. If it continues, many low lying areas may be submerged in near future, and it is possible to destroy 20% - 80% of the coastal wetland..

(iii) Reduction of Biodiversity - As we have discussed, increased temperatures, inundation of some coastal biological communities and changes in the pattern of distribution of many species over a long period of time are likely to cause reduction in biodiversity in aquatic and terrestrial ecosystems.

(iv) Effect on Agriculture - There are different views regarding the effect of global warming on agriculture. It may be positive or negative. However, the effects of this change will vary for C_3 (i.e. wheat, rice and beans) and C_4 (e.g. maize, millet and sugarcane) plants.

(v) Effect on human health - The global warming will lead to changes in the rainfall pattern in many areas, thereby effecting the distribution of vector borne diseases like malaria filariasis, elephantiasis etc. Warmer temperature and more water stagnation would favour the breeding of mosquitoes, snails and some insects, which are vectors of such diseases.

(vi) Effect on Arctic ecosystems - Global climate change will have profound effects on arctic ecosystems. Tundra is more sensitive to global climate change than most other ecosystems on earth. According to Shaver et al 1992 warmer temperature may increase primary production, thereby increasing Carbon input and soil respiration hence increasing carbon output.

(vii) Ecological disturbance - Global warming increases the desert. It increases temperature in North America, South Africa, Mexico, India and other countries. Changes of hurricanes, cyclones and floods will be more which will damage the lagoons, estuaries and coral reefs. Global warming may cause extinction of more than one million species of animals and plants by 2050 A.D.

MEASURES TO CHECK GLOBAL WARMING

To check the global warming following steps are necessary –

(1) Plant more trees (Afforestation)

(2) Control population growth.

(3) Cut down the current rate of CFCs and fossil fuel.

(4) Use of non-conventional source of energy.

(5) Shift from coal to Natural gas.

(6) To trap and use methane as a fuel.

(7) Reduce beef production.

(8) Efficiently remove CO, from smoke

(9) Use photosynthetic algae to remove atmosphere CO2

(10) Adopt sustainable agriculture.

(11) Use energy more efficiently.

ACID RAIN

Normal rain water is always acidic because of the fact that CO_2 present in the atmosphere gets dissolved in it forming carbonic (H_2CO_3) acid. Because, the presence of SO_2 (Sulphur Dioxide) and NO_2 (Nitrogen Oxide) gases as pollutants in the atmosphere, the pH of the rain water is further lowered (as low as 2.4). This is known as Acid rain.

How does acid come from

- Acidification of environment is a man-made phenomenon. No doubt that most acid come from human activities i.e. cars, houses, factories, power stations etc.
- There has always been some acid in rain, coming from volcanos, swamps and planktons in the oceans, but scientists know that it has increased very sharply over the past 200 years.
- The acidity is mainly associated with the transport and subsequent deposition of oxides of sulphur, nitrogen, and these oxidative products. These oxides are produced by combustion of fossil fuels, smelters, power plants, automobile exhausts, domestic fires etc.

How acid rain is formed

In high temperature combustion processes most of the nitric oxide originates from atmosphere and some Nitric oxide also released by burning of wood and as a result of microbial nitrification in the soil. Lightning is another source of Nitric oxide.

In day time Nitric oxide is oxidized by oxygen, ozone

$$\mathbf{NO + O_3 \rightarrow NO_2 + O_2}$$

$$\mathbf{H_2O \rightarrow H^+ + OH^-}$$

$$\mathbf{NO_2 + OH^- \rightarrow HNO3}$$

Similarly, formulation of H_2SO_4 acid in the atmosphere can take place with a wide range of reduced as well as partially oxidised Sulphur compounds, H_2S, CS_2 etc. These compounds are released from oceans and soil under reducing conditions. The production of H_2SO_4 from SO_2 may take place homogeneously in the gas phase as :

$$\mathbf{SO_2 + OH^- + X \rightarrow HSO_3 + X}$$

Where X = O_2 or N_2 in atmosphere.

The HSO_3^- so formed can undergo a number of reactions, some of which produce sulphuric acid.

$$HSO_3^- + O_2 + X \rightarrow HOO^- + SO_3 + X$$

$$SO_3 + HO_2 \rightarrow H_2SO4$$

The hydroperoxy radical HOO^- can also react to give HNO_3

$$NO + HOO^- \rightarrow NO_2 + OH^-$$

$$NO_2 + OH^- \rightarrow HNO_3 + X^-$$

Thus a number of reactions are taken place, forming different acids.

Effects of acid rain

Acid rain exerts both direct and indirect effects on the organisms and materials it comes in contact with. The dry deposition attacks building material, steel and other metals. Some of the effects may be described as :

1. A significant reduction in fish population accompanied by decrease in the variety of species in food chains have been observed.

2. Adirondack ponds having high acidity levels, were among the first to lose fish population.

3. Different species reacts differently to acidified lakes. Adult fish can survive in more concentration aluminium than dry fish.

4. Many bacteria and blue green algae are killed due to acidification, disrupting the whole ecological balance.

5. In 1958 at Europe pH of rain water was 5.0 and in Netherland (1962) was 4.5. It damaged the leaves of plants and trees.

6. Forests of West Germany, Switzerland, Czechoslovakia, Swedish were severely affected by acid rain.

7. In North America and Europe, acid rain destroyed crops and forests, reducing agricultural productivity

8. Acid rain has retarded the growth of pea, beams, radish, potato, spinach, carrots etc.

9. Modern researches show that acid rain leaches Potassium, Calcium, Magnesium etc essential elements from the top soil.

10. Acid lakes have low levels of phytoplankton.

Lime stone attacked as :

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$$

The attack on marble is termed as Stone-leprosy.

14. The Taj Mahal in agra is suffering from SO_2, H_2SO_4 and other fumes, pollutants released from Mathura refinery.

15. Acid rain corrodes houses, monuments, statues, bridges, fences, railways etc.

16. Acidification can play havoc with human nervous, respiratory and digestive systems by making the person an easy pray to neurological diseases.

OZONE LAYER DEPLETION

Stratosphere - Troposphere is the part of atmosphere where humans live and other life processes also occur. The stratosphere is the region of space between approximately 15-50 kms above the earth's surface. The gas molecules in the stratosphere act as absorbing centres, moderating the transmission of the solar radiation to the earth. The qualitative as well as quantitative effect of this is an important determining factor with respect to life processes.

CREATION OF OZONE LAYER

- Ozone is naturally occurring gas found through out atmosphere, with a maximum mixing ratio at the altitude ranging from 15-30 km above the earth. This region is known as ozone layer.
- Ozone can be toxic to plants and animals but increased concentration has a profound beneficial effect. Both, atmosphere and earth surface are subjected to radiation from sun.
- These certain radiations are absorbed by atmospheric gases leading to ionization or dissociation of gases. In the lower mesosphere, atmospheric oxygen gets dissociated and subsequently combines with molecular oxygen forming ozone in stratosphere.

FORMATION OF OZONE

- In the lower mesosphere, the atmospheric oxygen absorbs UV radiation < 240 nm and photo dissociates in to two oxygen atoms.
- These atoms subsequently combine with molecular oxygen of upper stratosphere producing ozone. Ozone is also capable of absorbing short wave length UV radiations releasing oxygen atoms.

$$O_2 + hv\ (\lambda < 240\ nm) \rightarrow O + O$$

$$O + O_2 \rightarrow O_3$$

Decomposition 03 + hv (λ = 230 - 320 nm) O_2+O

$$O + O_2 \rightarrow O_2 + O_2$$

- This mechanism does not necessarily upset the ozone equilibrium because ozone (loss) is compensated by creation of ozone. As a result ozone occurs in 10 ppm concentration in the form of layer in stratosphere.
- The thickness of ozone layer is measured in Dobson units (DU), where 1 DU = 0.01 mm of the compressed gas 0°C and 760 mm mercury pressure. The average thickness of ozone layer in stratosphere has been estimated to be about 230 DU. It varies marginally with latitude.

MECHANISM OF OZONE DEPLETION

There are two processes

1. Natural process

2. Anthropogenic process

1. Natural process: A dynamic equilibrium existing between the production and decomposition of ozone molecule constitutes one of the most important mechanism. The heat generated during the reaction causes a rise in temperature. Secondly, the photochemical process absorbs most of the harmful solar UV radiations.

2. Anthropogenic process - Some of the natural species moving in to stratosphere has been augmented in recent years by a number of human activities. Many of the processes, which are responsible for ozone layer depletion share a general mechanism of the type –

$$X + O_3 \rightarrow XO + O_2$$

$$XO + O \rightarrow X + O_2 \qquad \text{Where } X = \text{reacting species}$$

Net reaction $$O + O_3 \rightarrow O_2 + O_2$$

The most of the common species (above x) have been identified to be free radicals like HO_X, NO_X and ClO_X

EFFECTS OF OZONE DEPLETION

(1) With the ozone layer depletion, there is danger of the increase in the flux of ultraviolet radiation over earth's biosphere. They are harmful for man's life.

(2) UV radiations effects biological systems in two ways - one is confined to patches of skin while the other develops in the immune system as a whole.

(3) These kinds of skin cancer, Basal cell carcinoma, squamous cell carcinoma and melanoma caused by UV rays.

(4) UV radiations cause sun burns, leukaemia and breast cancer.

(5) UV radiations absorbed by cornea and lens in the eye leading to Photokeratitis and cataracts.

(6) Ozone at ground level of low concentration) exerts its toxic effects directly on the lungs.

(7) Ozone exposure has been shown to be associated with lung cancer, DNA breakage.

(8) Photochemical smog is the measure cause of ozone exposure causing urban air pollution posing a threat to human health.

(9) Many micro- phytoplankton's would die because of their exposure to UV solar radiation. The marked reduction in the productivity of phytoplankton's would in turn adversely effect zoo planktons.

(10) The loss of fish population would directly effect the inhabitants of coastal areas.

NUCLEAR ACCIDENTS AND HOLOCAUST

- Japanese towns of Hiroshima and Nagasaki . The first atom bomb was exploded about 580 metres in the atmosphere over ill fated Hiroshima on August 6, 1945. the second atom bomb was detonated 507 metres high in air over Nagasaki.
- At least 100,000 people were reported killed, severely injured and missing in Hiroshima alone, where the bomb virtually demolished all structures and buildings in about 15 square km. area. In Nagasaki 49000 civilians were killed, injured and disappeared while an area of 6 to 7 km. was devastated.
- The atom bomb exploded on Hiroshima used Uranium (U – 235) with a half life period of 8.5×10^8 years, while the Nagasaki bomb had plutonium (Pu - 239) as an explosive man-made radio-nuclide with half life of 24,000 years.

Case study

CHERNOBYL ACCIDENT

- Chernobyl was the first officially acknowledged nuclear accident in USSR and first reported to the world. April 26, 1986 was a sad day for nuclear power generation when a major accident occurred at 1.23 A.M. in the nuclear reactor at Chernobyl, in the Ukraine area of the Soviet Union.
- It resulted in clouds of radioactive smoke over a large area in Scandinavian countries which are 2000 km. away in the Russian region itself. There was a devastating fire in the reactor which caused few casualties and severe damage to the nuclear plant.
- On finding the fire uncontrollable the soviet authorities sought the help of West Germany and other nuclear nations to tackle the situation. Presumably, the core of the nuclear reactor had melted.
- The explosion at the Chernobyl power plant in Soviet Ukraine, USSR confirmed the worst nuclear disaster. Poor design of the reactor magnified with operator negligence caused the havoc. The operators ignored warnings from various sensors and even disconnected the emergency core cooling systems.

Neutrons went out of control and enormous steam built up in pipes. The explosion sent the graphite slabs of the reactor core through the roof, setting it a fire and spewing radioactive materials around the world.

THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT 1981

- With increasing industrialization and the tendency of the majority of industries to congregate in areas which are already heavily industrialised, the problem of air pollution had begun to be felt in the country.
- The various pollutants discharged from certain human activities connected with traffic, heating, use of domestic fuel, refuse, incinerations etc. also have detrimental effects on the health of the people as also on animal life, vegetation and property.

- In view of decisions taken at the June 1972 United Nations Conference hold at Stockholm, the Govt. decided to implement those decisions related to the preservation of the quality of air and control of air pollution.
- Accordingly the Air (Prevention and Control of Pollution) Bill was introduced in the parliament and passed by both the houses of parliament.
- It came into force on the 16th day of May 1981 as THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT 1981 (14 of 1981). Its amendment act 1987 (47 of 1987) came into force.

THE AIR (PREVENTION AND CONTROL OF POLLUTION) ACT, 1981 (14 OF 1981) [29TH MARCH 1981]

An Act to provide for the prevention, control and abatement of air pollution, for the establishment, with a view to carrying out the aforesaid purposes, of Boards, for conferring on and assigning to such Boards, powers and functions relating thereto and for matters connected therewith.

(v) the form and the manner in which appeals may be preferred, the fees payable in respect

CENTRAL AND STATE BOARDS FOR THE PREVENTION AND CONTROL OF AIR POLLUTION

Central pollution control board - The Central Pollution Control Board constituted under section 3 of the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974), shall, without prejudice to the exercise and performance of its power and functions under the Act, exercise the powers and perform the functions of the Central Pollution Control Board for the prevention and control of air pollution under this Act.

State Pollution Control Boards - In any State in which the water (Prevention and Control of Pollution) Act, 1974 (6 of 1974), is in force and the State Government has constituted for that state a State Pollution Control Board under section 4 of that Act, such State Board shall be deemed to be the State Board for the Prevention and Control of Air Pollution constituted under section 5 of this Act, and accordingly that State Pollution Control Board shall, without prejudice to the exercise and performance of its powers and functions under that Act, exercise the powers and perform the functions of the State Board for the prevention and control of air pollution under this Act].

POWERS AND FUNCTIONS OF BOARDS

Functions of Central Board –

(1) Subject to the provisions of this Act, and without prejudice to the performance of its functions under the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974), the main functions of the Central Board shall be to improve the quality of air and to prevent, control or abate air pollution in the country.

(2) In particular and without prejudice to the generality of the foregoing functions, the Central Board may

(a) advise the Central Government on any matter concerning the improvement of the quality of air and the prevention, control or abatement of air pollution;

(b) plan and cause to be executed a nation-wide programme for the prevention, control or abatement of air pollution;

(c) co-ordinate the activities of the State Boards and resolve disputes among them;

(d) provide technical assistance and guidance to the State Boards, carry out and sponsor investigations and research relating to problems of air pollution and prevention, control or abatement of air pollution;

(e) plan and organize the training of persons engaged or to be engaged in programmes for the prevention, control or abatement of air pollution on such terms and conditions as the Central Board may specify;

(f) organize through mass media a comprehensive programme regarding the prevention, control or abatement of air pollution;

(g) lay down standards for the quality of air;

(h) collect and disseminate information in respect of matters relating to air pollution;

(i) perform such other functions as may be prescribed.

(3) The Central Board may establish or recognize a laboratory or laboratories to enable the Central Board to perform its functions under the section efficiently.

(4) The Central Board may

(a) delegate any of its functions under this Act generally or specially to any of the committees appointed by it;

(b) do such other things and perform such other acts as it may think necessary for the proper discharge of its functions and generally for the purpose of carrying into effect the purposes of this Act.

Functions of State Boards - (1) Subject to the provisions of this Act, and without prejudice to the performance of its functions, if any, under the Water (Prevention and Control of Pollution) Act, 1974), the functions of a State Board shall be

(a) to plan a comprehensive programme for the prevention, control or abatement of air pollution and to secure the execution thereof;

(b) to advise the State Government on any matter concerning the prevention, control or abatement of air pollution;

(c) to collect and disseminate information relating to air pollution;

(d) to collaborate with the Central Board in organising the training of persons engaged or to be engaged in programmes relating to prevention, control, or abatement of air pollution and to organise mass-education programme relating thereto;

(e) to inspect, at all reasonable times, any control equipment, industrial plant or manufacturing process and to give, by order, such directions to such persons as it may consider necessary to take steps for the prevention, control, or abatement of air pollution;

(f) to inspect air pollution control areas at such intervals as it may think necessary, assess the quality of air therein and take steps for the prevention, control or abatement of air pollution in such areas;

(g) to lay down, in consultation with the Central Board and having regard to the standards for the quality of air laid down by the Central Board, standards for emission of air pollutants into the atmosphere from industrial plants and automobiles or for the discharge of any air pollution into the atmosphere from any other source whatsoever not being a ship or an aircraft;

PREVENTION AND CONTROL OF AIR POLLUTION

(i) Power to declare air pollution control areas.

(ii) Power to give instructions for ensuring standards for emission from automobiles.

(iii) Restrictions on use of certain industrial plants.

(iv) Persons carrying an industry etc, not to allow emission of air pollutants in excess of the standard laid down by State Board.

(v) Power to take samples of air or emission and procedure to be followed.

(vi) Reports of analysis.

(vii) Appeals,

PENALTIES AND PROCEDURE

Failure to comply with the provisions of section 21 or section 22 or with the directions issued under section 31A –

(1) Whoever fails to comply with the provisions of section 21 or section 22 or directions issued under section 31A, shall, in respect of each such failure, be punishable with imprisonment for a term which shall not be less than one year and six months but which may extend to six years and with fine, and in case the failure continues, with an additional fine which may extend to five thousand rupees for every day during which such failure continues after the conviction for the first such failure.

(2) If the failure referred to in sub-section (1) continues beyond a period of one year after lhe date of conviction, the offender shall be punishable with imprisonment for a term which shall not be less than two years (but which may extend to seven years and with fine.]

Penalties for certain acts - Whoever -

(a) destroys, pulls down, removes, injures or defaces any pillar, post or stake fixed in the ground or any notice or other matter put up, inscribed or placed, by or under the authority of the Board, or

(b) obstructs any person acing under the orders or directions of the Board from exercising his powers and performing his functions under this Act, or

(c) damages any works or property belonging to the Board , or

(d) fails to furnish to the Board or any officer or other employee of the Board any information required by the Board or such officer or other employee for the purpose of this Act, or

(e) fails to intimate the occurance of the emission of air pollutants into the atmosphere in excess of the standards laid down by the State Board or the apprehension of such occurrence, to the State Board and other prescribed authorities or agencies as required under sub-section (1) of section 23, or

(f) in giving any information which he is required to give under this Act, makes a statement which is false in any material particular, or

(g) for the purpose of obtaining any consent under section 21, makes a statement which is false in any material particular, Shall be punishable with imprisonment for a term which may extend to two to three months or with fine which may extend to (ten thousand rupees) or with both.

THE WATER (PREVENTION AND CONTROL OF POLLUTION) ACT, 1974

- As a result of growth of industries and the increasing tendency to urbanization the problem of pollution of rivers and streams had assumed considerable importance.
- It had become essential to ensure that the domestic and industrial effluents are not allowed to be discharged in to the water courses without adequate treatment. To draw a draft enactment for the prevention of water pollution a committee was set up in 1962. Later on a draft bell was prepared and put up for consideration at the joint session of Central Council of local sell Govt., ministers of Town and Country planning hold in 1965.
- After long discussion, some resolutions were passed by the legislatives of some states. To give effect to these resolutions, the Water (Prevention and Control of Pollution) bill was introduced in the parliament, and having been passed by both the houses, received the assent of the President on 23 March 1974.
- It came on the Statute book as THE WATER (PREVENTION AND CONTROL OF POLLUTION ACT 1974 (6 OF 1974). Later on, it was amended twice (44 of 1978) and (53 of 1988).

POWERS AND FUNCTIONS OF BOARDS

Functions of Central Board - (1) Subject to the provisions of this Act, the main function of the Central Board shall be to promote cleanliness of streams and wells in different areas of the States.

In particular and without prejudice to the generality of the foregoing function, the Central Board may perform all or any of the following functions, namely:

(a) advise the Central Government on any matter concerning the prevention and control of water pollution;

(b) co-ordinate the activities of the State Boards and resolve disputes among them;

(c) provide technical assistance and guidance to the State Boards, carry out and sponsor investigations and research relating to problems of water pollution and prevention, control or abatement of water pollution;

(d) plan and organize the training persons engaged or to be engaged in programmes for the prevention, control or abatement of water pollution on such terms and conditions as the Central Board may specify;

(e) organize through mass media a comprehensive programme regarding the prevention and control of water pollution:

(f) collect, compile and publish technical and statistical data relating to water pollution and the measures devised for its effective prevention and control and prepare manuals, codes or guides relating to treatment and disposal of sewage and trade effluents and disseminate information connected therewith;

(g) lay down, modify or annual, in consultation with the State Government concerned, the standards may be laid down for the same stream or well or for different streams or wells, having regard to the quality of water, flow characteristics of the stream or well and the nature of the use of the water in such stream or well or streams or wells;

Functions of State Board - (1) Subject to the provisions of this Act, the functions of a State Board shall be

(a) to plan a comprehensive programme for the preventions, control or abatement of pollution of streams and wells in the State and to secure the execution thereof;

(b) to advise the State Government on any matter concerning the prevention, control or abatement of water pollution;

(c) to collect and disseminate information relating to water pollution and the prevention, control or abatement thereof;

(d) to encourage, conduct and participate investigations and research relating to problems of water pollution and prevention, control or abatement of water pollution;

(e) to collaborate with the Central Board in organizing the training of persons engaged or to be engaged in programmes relating to prevention, control or abatement of water pollution and to organize mass education programmes relating thereto;

(f) to inspect sewage or trade effluents, works and plants for the treatment of sewage and trade effluents and to review plans, specifications or other data relating to plants set up for the treatment of water, works for the purification thereof and the system for the disposal of sewage or trade effluents or in connection with the grant of any consent as required by this Act;

(g) to lay down, modify or annul effluent standards for the sewage and trade effluents and for the quality of receiving waters (not being water in an inter-State stream) resulting from the discharge of effluents and to classify waters of the State;

(h) to evolve economical and reliable methods of treatment of sewage and trade effluents. having regard to the peculiar conditions of soils, climate and water resources of different regions and more especially the prevailing flow characteristics of water in streams and wells which render it impossible to attain even the minimum degree of dilution:

(i) to evolve methods of utilization of sewage and suitable trade effluents in agriculture:

(j) to evolve efficient methods of disposal of sewage and trade effluents on land, as are necessary on account of the predominant conditions of seant stream flows that de no provide for major part of the year the minimum degree of dilution;

(k) to lay down standards of treatment of sewage and trade effluents to be discharged into any particular stream taking into account the minimum fair weather dilution available in that stream and the tolerance limits of pollution permissible in the water of the stream, after the discharge of such effluents;

(l) to make, vary or revoke any order -

- (i) for the prevention, control or abatement of discharges of waste into streams or wells;
- (ii) requiring any person concerned to construct new systems for the disposal of sewage and trade effluents or to modify, alter or extend any such existing system or to adopt such remedial measures as are necessary to prevent, control or abate water pollution;

(m) to lay down effluent standards to be complied with by persons while causing discharge of sewage or sullage or both and to lay down, modify or annul effluent standards for the sewage and trade effluents;

(n) to advise the State Government with respect to the location of any industry the carrying on of which is likely to pollute a stream or well;

(o) to perform such other functions as may be prescribed or as may, from time to time, be entrusted to it by the Central Board or the State Government.

The Board may establish or recognize a laboratory or laboratories to enable the Board to perform its functions under this section efficiently, including the analysis of samples of water from any stream or well or of samples of any sewage or trade effluents.

PENALTIES AND PROCEDURE

1. Failure to comply with directions under sub-section (2) or sub-section (3) of section 20, or orders issued under clause (C) of sub-section (1) of section 32 or directions issued under sub-section (2) of section 33 or section 33A -

(1) Whoever fails to comply with the direction given under sub-section (2) or sub-section (3) of section 20 within such time as may be specified in the direction shall, on conviction, be punishable with imprisonment for a term which may extend to three months or with fine which may extend to ten thousand rupees or with both and in case the failure continues , with an additional fine which may extend to five thousand rupees

for every day during which such failure continues after the conviction for the first such failure.

(2) Whoever fails to comply with any order issued under clause (C) of sub-section (1) of section 32 or any direction issued by a court under sub-section (2) of section 33 or any direction issued under section 33A shall, in respect of each such failure and on conviction, be punishable with imprisonment for a term which shall not be less than one year and six months but which may extend to six years and with fine, and in case the failure continues, with an additional fine which may extend to five thousand rupees for every day during which such failure continues after the conviction for the first such failure.

(3) If the failure reffered to sub-section (2) continues beyond a period of one year after the date of conviction, the offender shall, on conviction, be punishable with imprisonment for a term which shall not be less than two years but which may extend to seven years and with fine.

2. Penalty for certain acts -

(1) Whoever -

(a) destroys, pulls down, removes, injures or defaces any pillar, post or stake fixed in the ground or any notice or other matter put up, inscribed or placed, by or under the authority of the Board, or

(b) obstructs any person acting under the orders or directions or the Board from exercising his powers and performing his functions under this Act, or (c) damages any works or property belonging to the Board, or

(d) fails to furnish to any officer or other employee of the Board any information required by him for the purpose of this Act, or

(e) fails to intimate the occurrence of any accident or other unforeseen act or event under section 31 to the Board and other authorities or agencies as required by that section, or

(f) in giving any information which he is required to give under this act, knowingly or wilfully makes a statement which is false in any material particular, or

(g) for the purpose of obtaining any consent under section 25 or section 26, knowingly or wilfully makes a statement which is false in any material particular, shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to [ten thousand rupees) or with both.

(2) Where for the grant of a consent in pursuance of the provisions of section 25 or section 26 the use of meter or gauge or other measure or monitoring device is required and such device is used for the purposes of those provisions, any person who knowingly alters or interferes with that device so as to prevent it from monitoring or measuring correctly shall be punishable with imprisonment for a term which may extend to three months or with fine which may extend to [ten thousand rupees] or with both. or wilfully

3. Penalty for contravention of provisions of section 24 - Whoever contravenes the rovisions of section 24 shall be punishable with imprisonment for a term which shall not be less an one year and six months) but which may extend to six years and with fine.

4. Penalty for contravention of section 25 or section 26 - Whoever contravenes the provisions of section 25 or section 26 shall be punishable with imprisonment for a term which all not be less than [one year and six months] but which may extend to six years and with fine.

5. Enhanced penalty after previous conviction - If any person who has been convicted of offence under section 24 or section 25 or section 26 is again found guilty of an offence involving contravention of the same provision, he shall, on the second and on every subsequent conviction, *punishable with imprisonment for a term which shall not be less than (two years] but which may seven years and with fine;

Provided that for the purpose of this section no cognizance shall be taken of any conviction made more than two years before the commission of the offence which is being punished.

6. Penalty for contravention of certain provisions of the Act - Whoever contravenes any of the provisions of this Act or fails to comply with any order or direction given under this Act, for which no penalty has been elsewhere provided in this Act, shall be punishable with imprisonment which may extend to three months or with fine which may extend to ten thousand rupees or with both and in the case of a continuing contravention or failure, with an additional fine which may extend to five thousand rupees for every day during which such contravention or failure continues after conviction for the first such contravention or failure.]

7. Publication of names of offenders.

8. Offences by companies.

9. Offences by Govt. Departments. Cognizance of offences. servants.

10. Cognizance of offences. servants.

11. Members, officers and servants of boards to be the public servants.

PUBLIC AWARENESS

Environmental pollution, environmental degradation, environmental deterioration, environmental crisis etc. are few words which becoming day by day a subject of concern in every walk of life. This is all due to industrialization, rapid population growth, urbanization, changing life style etc. The formulation of various acts and legislations to control pollution and conserve or protect environment, underlines the will and concern of the Government.

Methods -

To protect and conserve the environment is the basic duty of all sections of people because environment belongs to all and every individual matters. Instead of searching the solution, it is necessary to find the permanent solution of environmental and ecological problems. It can be done by following means.

(1) Through mass-media - There are various means of mass communication to educate, entertain & give information's, instructions etc. to people. Radio was the first. Next is T.V. in terms of its reach to the masses.

(2) Through Education - Students are the back bone of a country. If environmental education is started from grass root level i.e. from childhood stage, it will give good results. It will be done through formal and informal environmental education. A welcome step to introduce environmental studies paper at collage level by Government by the directive of Supreme Court is good in the direction of awareness.

(3) Through rallies, orientation and training programmes: - To promote environmental awareness, environmental rallies with posters, handbills, programmes may be organized on certain occasions like 5th June as world environmental day and is week of October as wild life week. Some training programmes, orientation, workshops, seminars, meetings based on environment awareness may be organized for decision makers, planners, leaders also, so that they can also spread the message to protect & conserve the environment.

(4) Through voluntary organizations and NGOs - Due to having link between people and Government some voluntary organizations and non-Government organizations can play an important role in the direction of environmental awareness in people by organizing educational, religious, plantation, musical, competitions (essay, drawing, oral) etc. programmes. These organizations can also advise the government to implement effective programmes for environmental awareness.

(1) Bombay Natural History Society (BNHS).

(2) Wild Life Preservation Society of India. (WPSI)

(3) Worldwide Fund for Nature - India (WWF - India).

(4) Centre for Science and Environment (CSE)

Unit 7: Human population and the environment

POPULATION GROWTH

The most important features of population is the growth i.e. the capacity of increase in individual members. By measuring the size or density of a given population from time to time, we can get rate of increase and can also predict future changes in its size. It can be defined in following

(a) Logistic growth : When a population is allowed to grow in a limited space (environment) it shows logistic growth. If we plot a graph between number of bacteria or cells against time, we typical S shaped sigmoid curve called population growth curve.

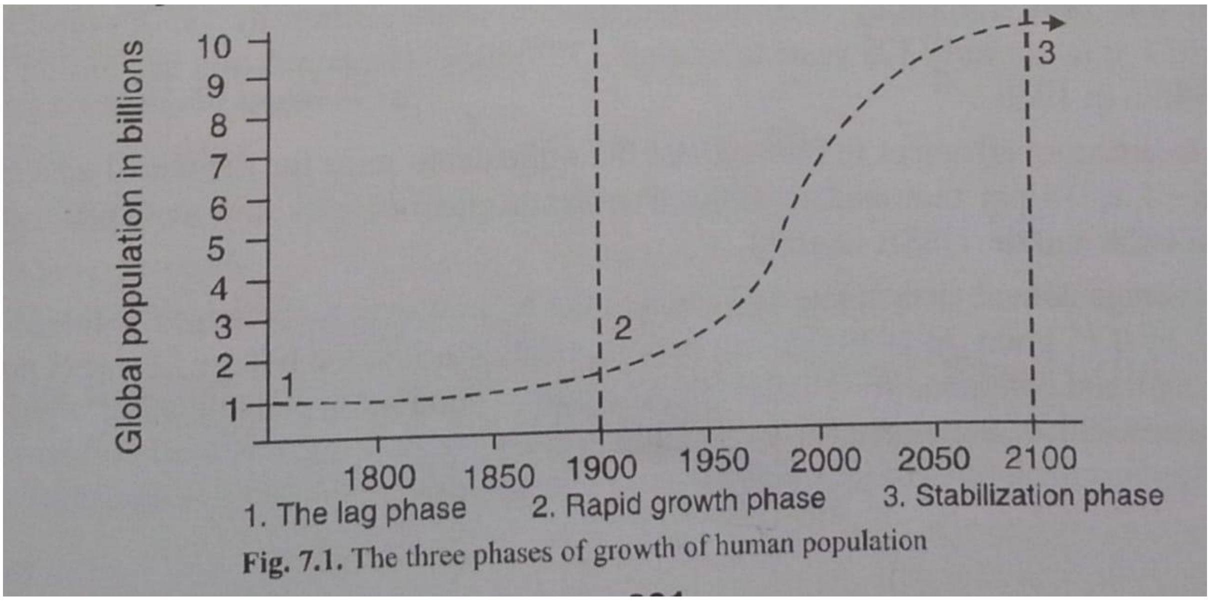


Fig. 7.1. The three phases of growth of human population

It has four phases i.e. Ist phase shows slow rate called lag period, second is accelerating stage followed by a phase of extremely rapid population. The last phase is accelerating multiplication followed by equilibrium phase where is essentially no net change in population called saturation level or carrying capacity. It is represented by letter K.

The logistic equation shows density dependent growth i.e. growth of a simple population in a limited space with limited resources. It may be written as

$$dN / dt = \gamma N(1 - N/K)$$

where dN/dt rate of growth of population

γ= intrinsic rate of increase (per individual of population)

N = Population size (No. of organisms in population at time t)

K = Carrying capacity of population

(1 - N/K) = density-dependent factor.

(b) Exponential Growth : When a population growth curve quickly begins to rise very steeply, the population shows exponential growth. It is I shaped (Fig. 7.1). A population growing exponentially increases accordingly to the equation

$$N_t = N_0 e^{rt}$$

Where N_t = The number of individuals in the population after t units of time

N_0 = initial population size (t = 0)

r = exponential growth rate

e = the base of the natural logarithm

(c) Geometric Growth : Geometric growth may be defined as the population growth in which the rate of increase is proportional to the number of individuals in the population at the beginning of the breeding session. When young ones are added to the population only at specific times of the year during well defined reproductive periods, the population is said to have geometric growth. The equation for this is

$$N_t = N_0 \lambda$$

Where λ= the geometric growth rate.

POPULATION EXPLOSION FAMILY WELFARE PROGRAMME

- Previously this programme was known as National Family Planning Programme. In the year 1977 the name was changed to National Family Welfare Programme. Family planning programme was launched in India in 1952. India was the first country to do so.
- Beginning of the programme was modest, i.e., establishment of few FP clinics, distribution of FP educational material, training of health functionaries and research. During the third 5-year-plan (1961-66) family planning was declared as centre of planned development.
- Then the emphasis was shifted from clinic approach to extensive education approach (i.e., motivating people about small family norm). A separate Department of Family Planning was created in 1966 in the Ministry of Health.
- In 1972, the MTP Act was passed. In April 1976, National Population Policy was framed. During the emergency period (1976), forcible sterilisation campaign led to the defeat of Congress in 1977 elections.
- In June 1977, new Janata Government formulated a new population policy and made family planning as voluntary and renamed it as Family Welfare Programme.

Importance of Family Welfare Programme

1. The family welfare programme occupies an important position in the nation's socioeconomic development.

2. Indian population which was 34 crores in 1947 has crossed 100 crore mark by 2000 AD. India has only 2.4% of world's land area but it supports about 15.5% of world's population.

3. India's population is increasing by 1.8 crores every year. To check this galloping growth, the country has laid down long-term demographic goal of achieving an NRR of one by the year 2000 AD.

4. Acceptance of the family welfare services is made voluntary.

5. The programme was 100% centrally sponsored scheme. FP programme was integrated the MCH services.

ORGANISATIONAL SET UP

1. Central level

At central level Central Cabinet Subcommittee is present. It is headed by Prime Minister. Next level is Population Advisory Council. This is headed by Union Minister of Health and Family Welfare. Members are representatives of various professional bodies and some technical persons. Next level is Central Family Welfare Council, which is headed by union minister and ministers of and family welfare of all states. It coordinates the work of the programme.

2. State level

Ministry of Health and Family Welfare is the apex organization at the state level. This is headed by the minister of health and family welfare of the respective state. At the state level the family welfare work is organised by State Family Welfare Bureau. The State Family Welfare Bureau has three wings:

(a) Administrative wing (headed by state family welfare officer and associated by some officers)

(b)Education and information wing (headed by mass media information officer)

(c)Field operation and evaluation wing (headed by statistical officer).

3. District level

- At district level the work of family welfare is organized by District Family Welfare Bureau. has three wings like the state level.
- At some districts Regional Family Welfare Training Centres are present. These will undertake training of medical officers and para-medical staff. 4. Peripheral level
- In rural areas the family welfare work is looked after by rural family welfare centres attached to PHC while in urban areas urban family welfare centres will took after this work.

At village level the MPHA(F) and MPHA(M) are mainly responsible for the programme. They will take the assistance of CHG, TBA and anganwadi workers.

5. Village level

At village level the MPHA(F) and MPHA(M) are mainly responsible for the programme. They will take the assistance of CHG, TBA and anganwadi workers

Goals of National Population Policy

1. NRR 1 (which implies two-child norm)
2. Birth rate 21/100 population
3. Death rate 9 per 1000 population
4. Raising couple protection rate to 60%
5. Reduction of family size to 2.3 live births.
6. Decrease the IMR to 60 per 1000

Programme Strategies

1. Integrated approach
2. Cafetaria approach
3. Welfare approach
4. At risk approach

VALUE EDUCATION

- Man acts to satisfy his needs or wants. Anything which satisfies human need becomes thereby a thing of Value. It is the element of desirability and satisfaction that is common to all values, material or non-material.
- In psychology the term value is generally employed to designate a dominant interest, motive or broad evaluative attitude. Value has been defined variously by different educationists, but on the whole, it is interpreted to be either a set of feeling or an action. Human behaviour is governed by his values. These are socially approved desires or goals, conceptions or standards by which things are approved or disapproved.
- Value is a dynamic term used in different aspects. Indian philosophy has used it in sense of state free from pleasure and pain, psychologists in the sense of “psychic energy", sociologists in the sense of “use of time, energy and money for certain ends. The last theory is named as “Integral theory”.
- The progress and development of a nation depends upon the quality of the values cherished by its citizens. One of the serious criticism against our educational system is that it lacks value orientation. Our 1986 National Policy on Education and its modifications have strongly advocated value education.

IMPORTANT VALUES

Important values may be described as follows

(i) Religious Value : It is defined in terms of faith in God. The outward acts of behaviour expressive of this value are going on pilgrimage, is linking in simple life, having faith in religious leaders, worshipping God and speaking the truth. Students (Higher studies) prefer least the religious value.

(i) Social Value : It is defined in terms of cherity, kindness, love and sympathy for the people, efforts to serve God through the service of mankind, sacrificing personnel comforts and gain to relieve the needy and affected of their misery.

(iii) Democratic Value : This value is characterized by respect for individuality, absence of discrimination among persons on the basis of sex, language, religion, caste, colour, race and family status, ensuring equal social, political and religious rights to all and respect for all democratic institutions.

(iv) Aesthetic Value : It is characterized by appreciation of beauty, from proportion and harmony, love for fine arts, drawing painting, music, dance, sculpture, poetry and architecture, love for literature, decoration and the surroundings. It is also the least preferred values in schools.

(v) Economic Value : This value stand for desire for money and material gains. A man with high economic value is guided by consideration of money and material gain in the choice of his job.

(vi) Knowledge Value : This value stand for love of knowledge or theoretical principles of an activity and love of discovery of truth. A man with this value considers a knowledge of theoretical principles underlying a work essential for success in it. He values hard work in studies.

(vii) Hedonistic Value : It is the conception of desirability of loving pleasure and avoiding pain. For a hedonist the present is more important than the future. He indulges in pleasure of senses and avoids pain.

(viii) Power Value : It is defined as the conception of desirability of ruling over others and also of leading others. A man with this value prefers a job where he gets opportunity to exercise authority over the others.

(ix) Family Prestige Value : It is defined as the conception of desirability of such items of behaviour roles, functions and relationship as would become one's family status. It implies respect for roles which traditionally charateristic of different castes of Indian society.

(x) Health Value : It is the consideration for keeping the body in a fit state for carrying out one's normal duties and functions. It also implies the consideration for self preservation.

Role of Information Technology in Environment and Human Health

- Just as chemical or metallurgical or electrical technologies enable the processing of raw materials in to usable goods, to satisfy man's and societies needs, so does information technology (IT) help the storage, processing, transmission and exploitation of information to satisfy a person's, company's, society's or Govt's needs for information. Information covers voice as in telephony, text as in fax, images as in video and data as between computers.

- Information is knowledge and knowledge is power. Knowledge plus experience is wisdom and it is the wise use of information that gives advantage to those who have information. in extending man's mind or
- Information technology as commonly picturised by computers brain or intellectual power. Information technology devices like microprocessors and becoming mass appliances from pace makers for the heart, hearing aids and efficiency enhances in automobile engines and devices to steer space vehicles on the moon. Like banking, trading, learning and teaching, sectors of human activity, Information technology has tremendous use in the

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

PRODUCTION TECHNOLOGY

3RD SEMESTER

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PRODUCTION TECHNOLOGY

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METAL FORMING

- Metal forming process is the process in which the metals are deformed to get desired shape and size. Necessary deformation in metal can be achieved by application of large amount of mechanical force or by heating the metal and then applying comparatively less force.
- On the basis of heat applied forming process are classified into two types:

i) **Hot working process: -** If the working temperature is above the recrystallisation temperature then the process is known as hot working process.

ii) **Cold working process: -** If the working temperature is below the recrystallisation temperature then the process is known as cold working process.

Recrystallisation temperature: - It is the temperature at which entirely new crystals or grains are formed in the metal and old grain structures are destroyed.

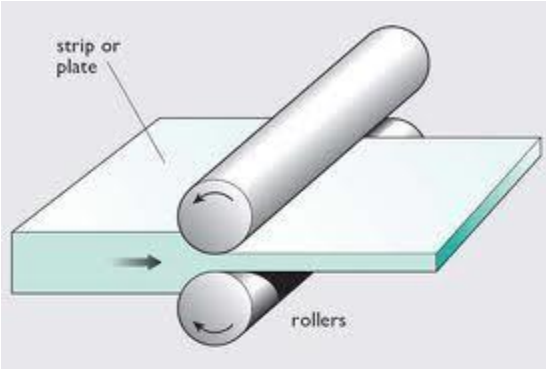
- The metal forming processes are: -

i) Rolling
ii) Extrusion
iii) Forging
iv) Deep drawing etc.

Fundamentals of rolling and extrusion: -

Fundamentals of rolling: -

- Rolling is the process of compressing the metal by passing it between two revolving cylinders called rolls. As the metal is compressed its cross-sectional area is reduced and length is increased.
- Rolling normally a hot working process unless specifically mentioned as cold working.
- The starting material is the molded ingot which is rolled into intermediate shape likes blooms, billets and slabs. These intermediate shapes are rolled further into plates, sheets, bars, structural shapes, I, L, T, or channel section.
- Rolling consist of passing the metal between the two rollers which grip the hot plate and so reduce it in size, and after each pass the rollers are brought closer together and the metal passed through until required reduction in its section has been attainted.



Applications: -

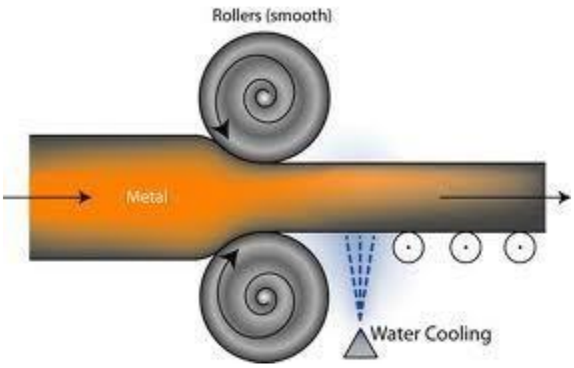
Billets are used for making: -

i. Forgings
ii. Extruded Section
iii. Hot rolled sections, bars, flats, rods, etc., which can be further used to cold roll rods and bars or for cold drawing rods, bars, wires and seamless tubes.

Hot Rolling: -

- The hot rolling process is the most rapid method of converting large section into desired shapes. The forming of bars, plates, sheets, rails and other structural sections are made by hot rolling.
- The operation consists of passing the hot ingot through at least two rolls rotating in opposite direction at the same speed.
- The space between the rolls is adjusted to conform to the desired thickness of the rolled section. The rolls, thus, squeeze the passing ingot to reduce the cross-section and increase its length.
- The ingots are casted in mould of suitable form and are used in rolling mills as raw material for preparing desired section. The first operation to the ingot is carried out at the blooming mill where it is rolled to blooms. The bloom has a square cross-section with a minimum size of 150 mm×150mm. The blooms are cut up in lengths convenient for the subsequent reducing process into billets. The billet is smaller than a bloom and has a minimum size of 50mm×50mm.
- The successive stages in the reduction of a billet to a round bar. The billet is rotated at 90^0 after each pass.
- When the final product of the rolling mill is to be sheets, plates or strip, the ingots or blooms are rolled to slabs. The slabs have rectangular cross-sections with a minimum width of 250 mm and thickness of 50 mm.

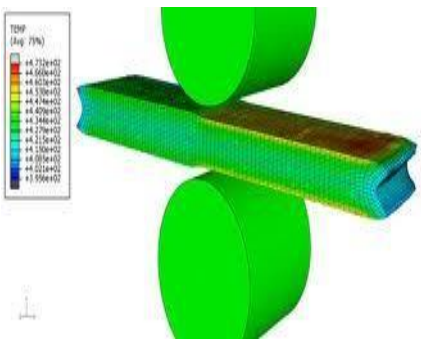
➢ The materials commonly hot rolled are aluminum, copper, magnesium, their alloys and many grades of steel.

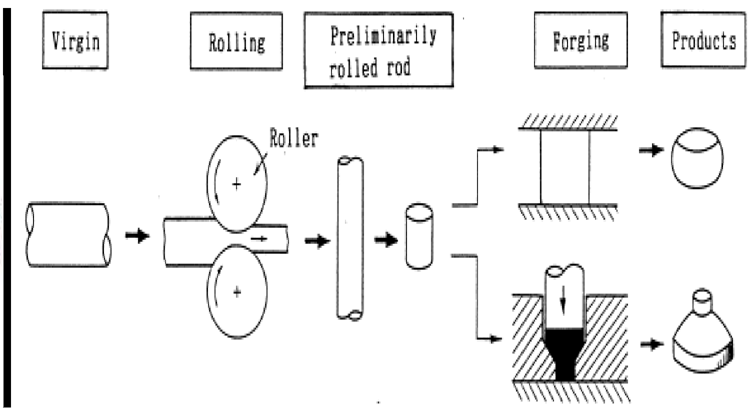


Cold Rolling: -

The rolling of metal below its recrystallisation temperature is called cold rolling:

1. Cold rolling is generally done to provide a smooth and bright surface finish to previously hot roll steel.
2. Cold rolling is done to improve the hardness and strength of previously hot worked metals.
3. It is also used to finish the hot rolled components to close tolerances.
4. Before cold rolling hot rolled metal surface should be thoroughly clean removing all scale. This is usually done by picking in an acid salutation. Most cold rolling is performed in four high rolling mill and cluster type rolling mill.
5. This is because at lower temperature metals having high strength and backup rolls in 4 high rolling mills and cluster rolling mill provide better support.
6. Cold rolling may cause the metal to become hard and brittle and if it is continued too long cracks may be developed in metal. The metal piece may have to be annealed more cold rolling can be done.





Types Of Rolling Mills: -

Rolling mills may be classified according to the number and arrangement of the rolls: -

a) Two-high rolling mills.
b) Three-high rolling mills.
c) Four-high rolling mills.
d) A tandem mill of three four high stands.
e) Cluster rolling mill.

Hot rolling

Cold rolling

a) Two-high Rolling Mills: -

- A two-high rolling mill may further be classified as a reversing mill and a non-reversing mill.
- A two-high rolling mill has two rolls only.
- In a two high rolling mill the rolls rotate first in one direction and then in the other so that the rolled metal may pass back and forth through the rolls several times. This type is used in blooming and slabbing mills and for roughing working plate, rail, structural and other mills.
- The two non-reversing mills have two rolls which revolve continuously in the same direction. Therefore, smaller and less costly motive power can be used. However, every time, material to be carried back over the top of the mill for again passing it through the rolls. Such an arrangement is used in mills through which the bar passes once and in open-train plate milling.

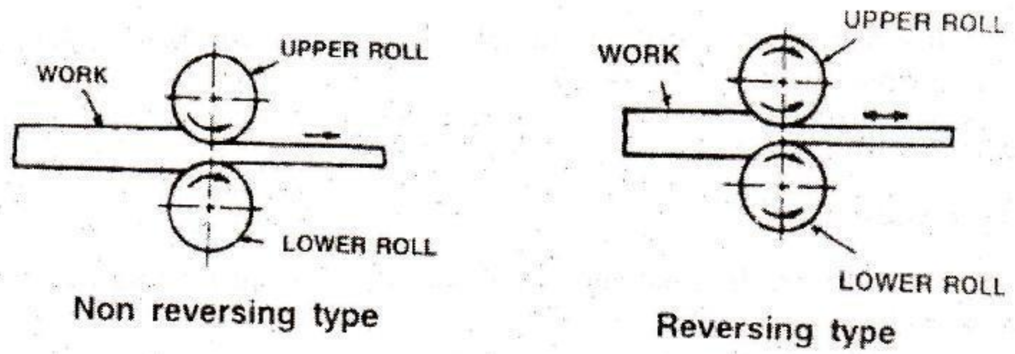
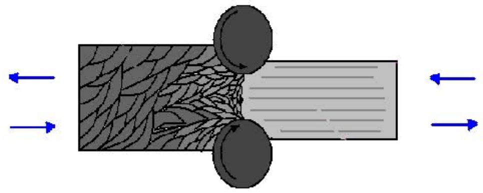
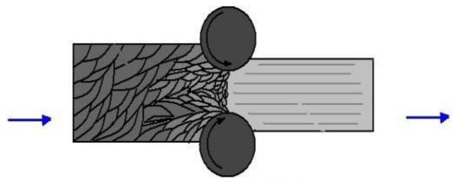


Fig 5.51 Two High Rolling Mill



Reversing Mills



Non Reversing Mills

b) <u>Three High Rolling Mills: -</u>

- It consists of a roll stand with three parallel rolls one above the other.
- Adjacent rolls rotate in opposite directions so that material may be passed between the top and middle rolls in one direction and the bottom and middle rolls in the opposite one.
- In three high rolling mills the work piece is rolled in both the forward and the return passes. First of all, the work piece passes through the bottom and the middle rolls and then returning between the middle and top rolls so that thickness is reduced at each pass. Mechanically operated lifting tables are used which moves vertically on either side of the stand, so that the work piece is feed automatically into the roll gap.
- Since the rolls run in one direction only, a much less powerful motor and transmission system is required.
- The rolls of a three-high rolling mill may be either plain or grooved to produce plate or sections respectively.
- Three-high rolling mill may be used as blooming mills or for subsequent rolling operations, such as billet rolling and finish rolling.

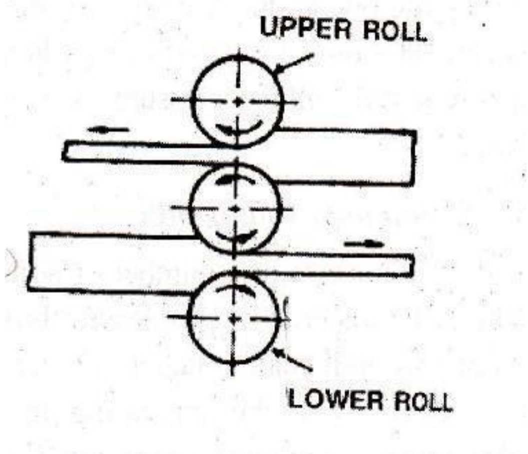
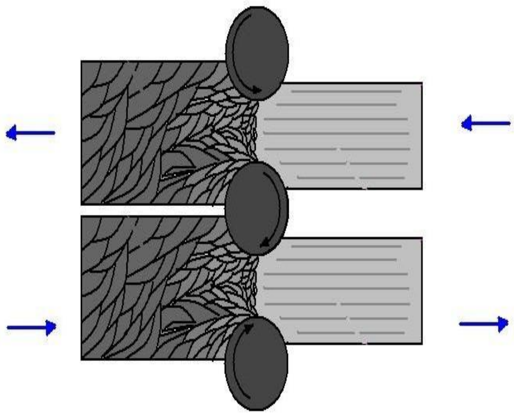


Fig. 5.52 Three High rolling Mill



Three High Rolling Mills

c) Four-high Rolling Mill: -

- It has a roll stand with four parallel rolls one above the other.
- The top and bottom rolls rotate in positive directions, as do the two middle rolls.
- The two middle rolls are known as work rolls as the work piece is fed between them.
- The two middle rolls are similar in size then the top and bottom rolls which are called back-up rolls because they reinforce the smaller work rolls to minimize roll deflection, which otherwise would cause plates and sheet to be thicker at the center than at the two outer edge.
- The four-high rolling mill is used for the hot rolling of armour and other plate, as well as the cold rolling of plates, sheets and strips.

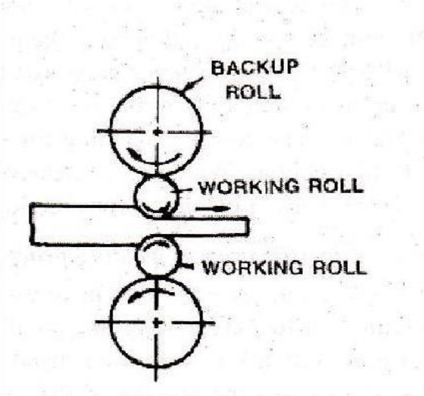
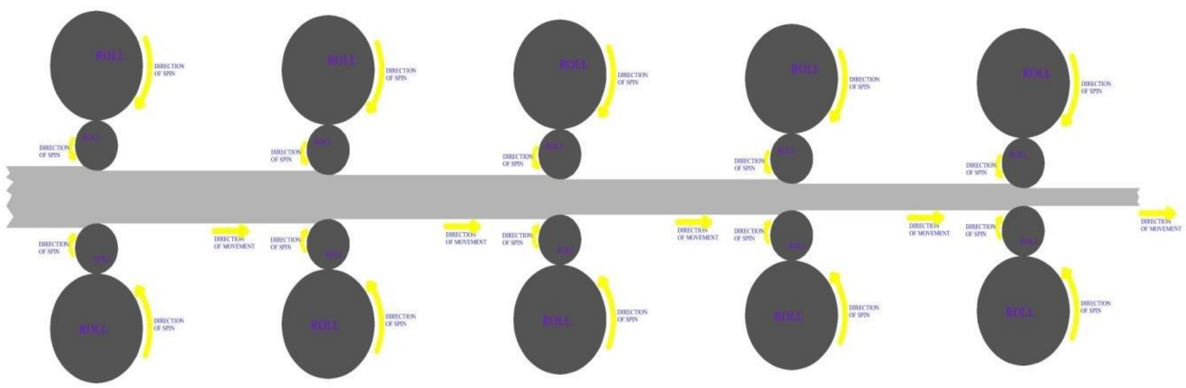


Fig 5.53 Four High Rolling Mill

d) Tandem Rolling Mills: -

- It is a set of two or three stands of rolls set in parallel alignment so that a continuous pass may be made through each one successively without change of direction of the metal or pause in the rolling process.

TANDEM ROLLING OPERATION



e) **Cluster Rolling Mills: -**

- It is a special type of four high rolling mill in which each of the two working rolls is backed up by two or more of the larger back-up rolls.
- For rolling hard thin materials, it may be necessary to employ work rolls of very small diameter but of considerable length. In such cases adequate support of the working rolls can be obtained by using a cluster-mill.

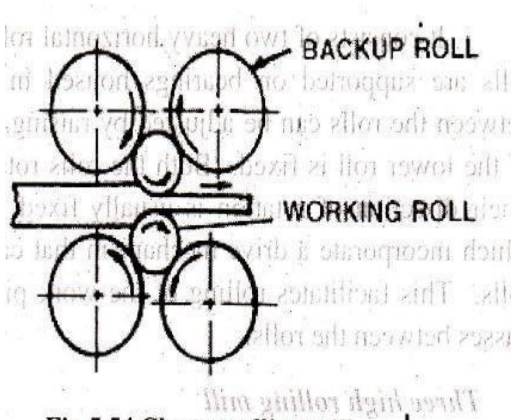
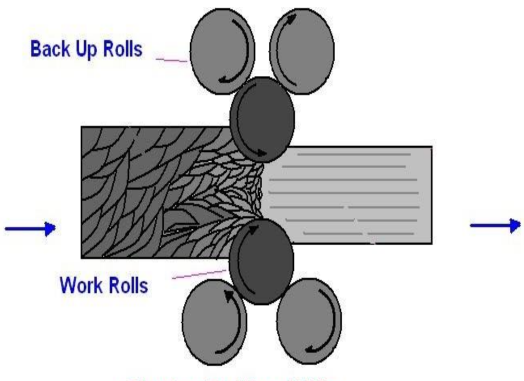


Fig 5.54 Cluster rolling mill



Cluster Rolling Mills

Rolling Of Rounds, Flats and Sections: -

Various common sections rolled are: -

i. Square.
ii. Round.
iii. Flat.

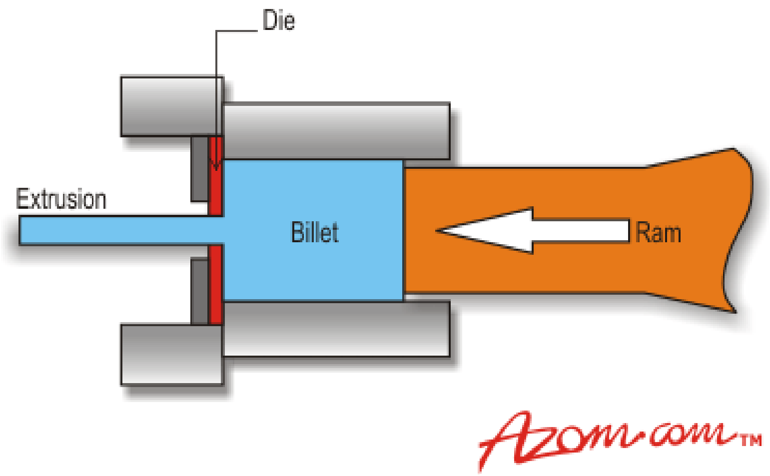
iv. Hexagon.
v. Angle.
vi. Tee.
vii. I-Beam.
viii. Channel.
ix. Rail.

Defects In rolled Products: -

i. Rolling frequently involves non-uniform deformation of the metal and this is most pronounced in the rolling of complex shapes such as rails, beams, channels, etc.
ii. Fins may be formed on the rolled bars if the metal forces itself into the clearance between the rolls. Fins may lead to various defects such as laps, cracks, etc.
iii. Laps may be caused by over filling in the rolling mill passes, which will produce fins. In passes which flow, these fins are pressed back in to the surface without welding, causing laps.
iv. When the metal is hot rolled, it's surface is not smooth and it has scale formed over the same.
v. Cracks may form during cold rolling if the metal becomes too much work-hardened during the process.

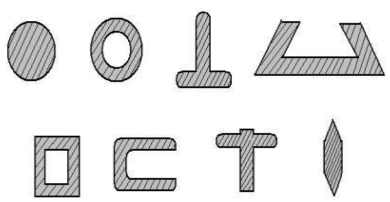
Fundamentals of extrusion: -

- Extrusion is a metal working process that produces continuous lengths of uniform, non-uniform, cross-sectional area from a metal billet, solid or hollow, by causing the latter to flow under high pressure through a restricted opening called die which is so shaped as to impart the required form to the product.
- Extrusion is mainly a hot working process, starting generally with cast billets and producing wrought sections and tubes in one stage.
- An extrusion press has three major components:
  i. The container,
  ii. Die,
  iii. Ram.
- A heated cylindrical billet is placed in the container and forced out through a steel die by a ram or plunger.
- The metal takes in cross-section the shape of the die.
- When pressed from the back, the tooth paste comes out of the front small portion of the tooth paste tube; this is an extrusion process.



Scope (Applications): -

- Extrusion is an uncomplicated hot metal working manufacturing process that can produce some of the most complex shapes of all the hot metal working manufacturing processes.
- Extrusion process is used to manufacture
  i. Rods,
  ii. Tubes,
  iii. A verity of circular, square, rectangular, hexagonal and other shapes both in the solid or hollow form.
  iv. Channel I, Z, T and other sections can be made.
- Extruded sections find almost infinite uses; some of each are in
  i. Transportation (ships, automobile, railroad and aircraft) industry.
  ii. Construction Industry. (Making Building).
  iii. Oil Industry (As drill pipe and pipelines).
  iv. Military Uses (Armor plate, guns and other weapons).
  v. Chemical and nuclear power industries (Extruded tubing).
- Extrusion is widely applied in non-ferrous field; however, it has only a limited application in steel component manufacture.



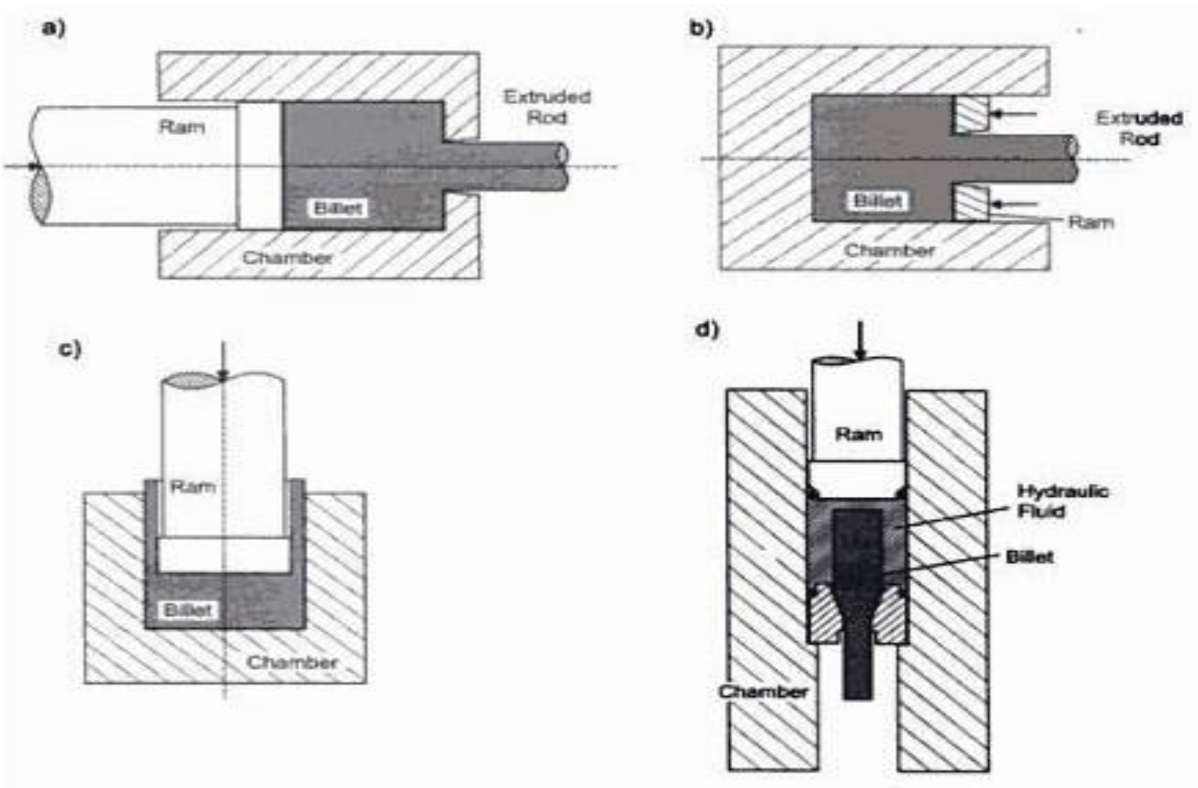
Typical Extruded Parts

Methods Of Extrusion: -

1. **Direct Extrusion: -**
   - Direct extrusion in which the flow of metal through the die is in the same direction as the moment of ram. Ram is solid.
   - A hot billet is placed within the container that has a die at one end.
   - A ram forces that hot billet through the die opening, producing the extruded products.
   - So that the oxides, etc., that exist on the exterior wall of the billet do not get mixed into the final extrusion as the billet is pushed through the die, direct sleeve extrusion method is used.
   - A dummy block which is little smaller than the billet chamber walls is employed for the purpose. As the punch moves forward, the exterior surface of the billet remains stationary, whereas the interior metals are forced through the die for making the extruded products.
2. **Indirect Extrusion: -**
   - The ram used is hollow and the die is mounted over the bore of the ram. The metals flow in the opposite direction to the movement of ram.
   - In indirect extrusion, the billet remains stationary while the die is pushed into the billet by the hollow ram, through which the extrusion takes place.
   - Indirect extrusion does not require as much force as direct extrusion because no force is required to move the hot billet inside the chamber walls.
   - The length of the billet in indirect extrusion is limited only by the column strength of the ram, because there is no relative motion between the billet surface and the container wall.
   - Many practical limitations restrict the usefulness of indirect extrusion, particularly the fact that the ram must be hollow and the extrusion product must be passed back through the ram.
   - Direct extrusion is more common.
   - The dummy block may be used in direct extrusion also. The dummy block used in direct extrusion separates the punch from the hot metal; in indirect extrusion the die plays the parts of the dummy block.
3. **Backward Extrusion: -**
   - In direct and indirect extrusion methods the ram is of the same diameter as the bore of the container, whereas in backward extrusion the ram is smaller in diameter than the container and the metal flow up the annulus formed by the ram and the container.

- Direct extrusion, indirect extrusion and backward extrusion possesses normally use a heated billet of metal for extrusion and hence the extrusion process is known as hot extrusion.

4. **Impact Extrusion: -**
   - Impact extrusion is used for manufacturing collapsible tubes for shaving cream, toothpaste and thin-walled cans. The process is limited to soft and ductile materials such as aluminum and its alloys.
   - The setup consists of die and punch. A slug of metal of suitable thickness is kept on the die. The outside die of tubes is same as that of diameter of hole in die.
   - Punches strikes a single blow causing the metal to flow through the annular shape between the punch and die.
   - The metal is extruded in the direction opposite to punch movement because of impact force. The process is conducted at room temperature.
   - In recent years the process has been developed and now also applied to production of components for air craft, cars and domestic appliances of Aluminum, Copper alloy and steels.



PRESS TOOL

PRESS WORK: -

- Press work is a cold working process generally used in mass production in the form of thin strip of sheet metal.
- In other words, it is a chip less manufacturing process by which various components are made from sheet metal. It is also called as cold stamping process.

DIE: -

- A die is that part of press tool which has an opening or cavity to receive the punch. The die is usually the lower member of the press tool.

PUNCH: -

- A punch is that part of the press tool which enters in to the cavity formed in the die section. The punch is usually the upper member of the press tool.

TYPES OF PRESS WORK: -

1. Manually operated press work.
2. Power operated press work.

Classification based on source or power: -

(a) Hand press or ball press / fly press.

(b) Power press / power hammer.

Types of Dies and Operations: -

Classification based on operations performed: -

(I) **Shearing**: -

(a) Piercing

(b) Punching

(c) Perforating

(d) Blanking

(e) Cutting off

(f) Parting

(g) Notching

(h) Slitting

(I) Lancing.

(ii) <u>Bending</u>

(a) Angle bending

(b) Curling

(c) Forming

(d) Plunging

(iii) <u>Drawing</u>

(a) Cupping

(iv) <u>Squeezing</u>

(a) Coining

(b) Embossing

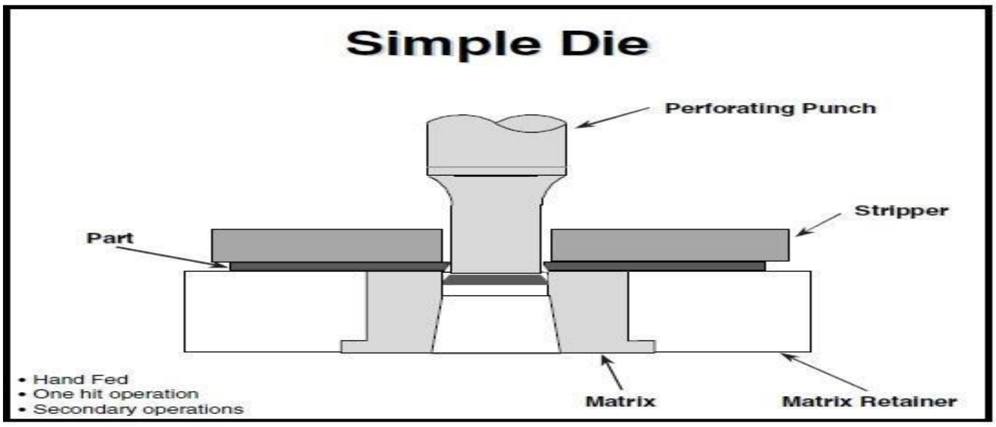
(c) Flattening or plenishing.

CLASSIFICATION OF PRESS WORKING DIES BASED ON CONSTRUCTION: -

1. Simple dies/Single operation dies.
2. Compound dies.
3. Combination dies.
4. Progressive dies.
5. Gang and follow dies.
6. Transfer dies
7. Forming dies.

SIMPLE DIES: -

- Simple dies or single operation dies perform single operation for each stroke of the press.



- The operation may be any one of the operations listed under cutting or forming dies

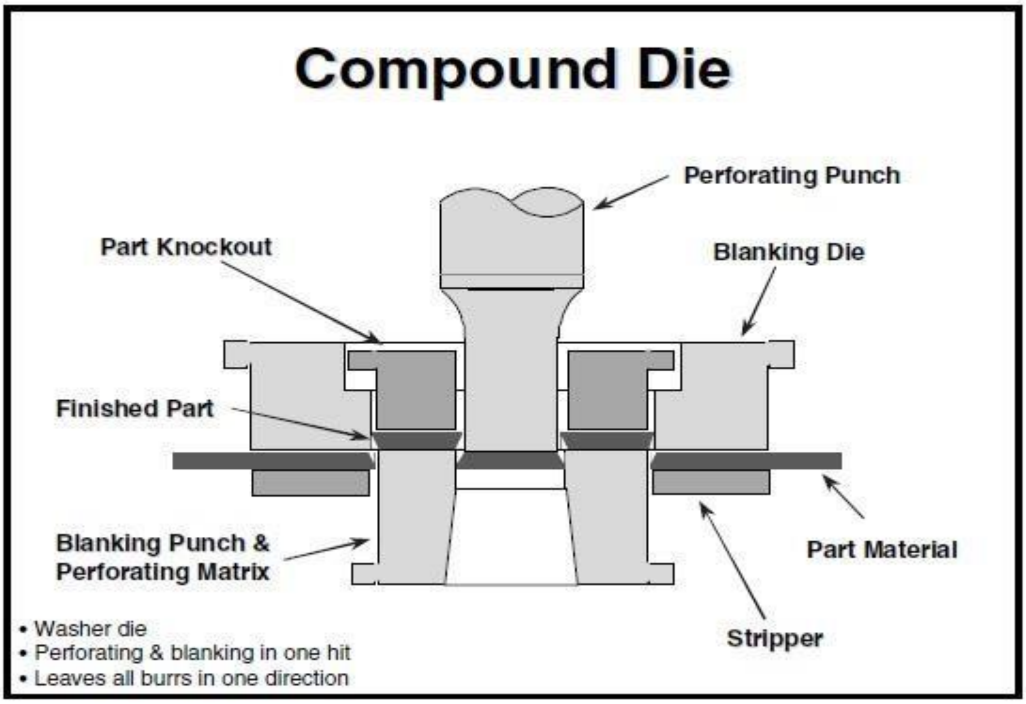
- Single operation dies may be blanking dies, piercing die, shaping dies, bending dies etc.

WORKING: -

- In simple die the shank portion is held in the ram the metal sheet is held in between stripper plate and dies block resting against the stop. So that some amount of sheet stock is feed every time for cutting.
- The stripper plate helps removal of stock from the punch as it moves up after doing the cutting operation.

COMPOUND DIE: -

- These dies two or more operation may be performing in one station such dies are considered as cutting tools. Since only cutting operation are carried out.



WORKING: -

- The metal sheet is placed between the upper die and lower die both blanking and piercing is carried out during the same stroke of the process.
- blanking operation in the metal sheet is carried out when the upper die descends the blank is cut, at the same time the lower die acting as punch pierces a hole in the Centre of the blank.
- The washer is produced by simultaneously blanking and piercing operation.

ADVANTAGES: -

- Compound dies are very economical in mass production as compare to simple die.
- It is used for doing multi operation in a single stroke of the operation.
- very accurate parts are produced by these dies.
- Compound dies makes close tolerances accurate concentric parts as all work is done in a single operation.

DISADVANTAGES: -

- Manufacturing cost is high.
- These dies are complicated in design.
- These dies are required more space to install.

PROGRESSIVE DIES: -

- In a progressive die, two or more operations are performed simultaneously at a single stroke of the press by mounting separate sets of dies and punches at two or more different station. The metal is progressed from one station to the other till the complete part is obtained.

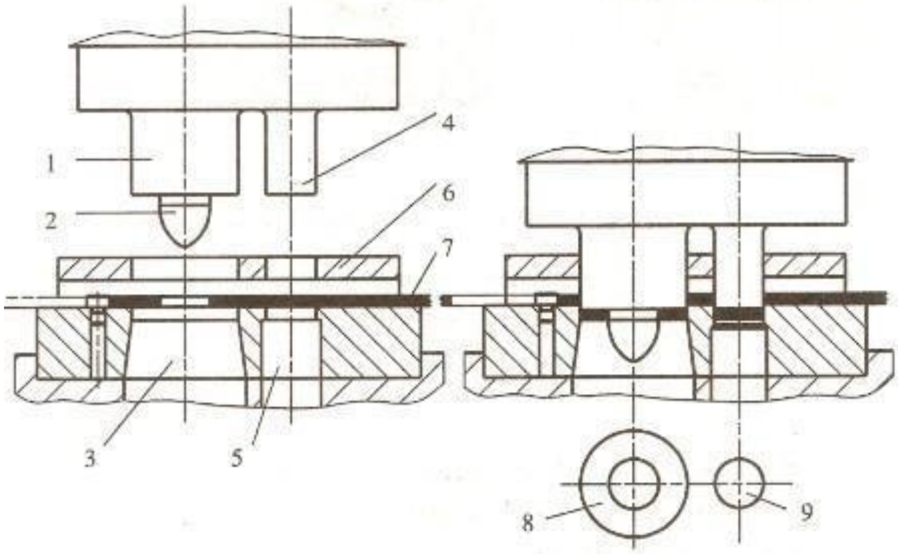


Fig. 1-8 Progressive die for blanking and punching

1-blanking punch 2-locating pin 3-blanking die 4-punching punch
5-punching die 6-stripper 7-blank 8-workpiece 9-waster

WORKING: -

- The sheet meal is feed in to the first die where a hole is pierced by the piercing die set in the first cutting stroke of the ram.

- The plate is then advanced in the next station and the correct spacing is obtained by the stop.
- In the second cutting stroke of the ram, the locating pin enters in to the pierced hole and correctly locates it. While the blanking punch descends and shears the plate to form a washer.
- By the time the blanking operation is performed, the hole for the next washer is also pierced at the first station.
- Thus, although two stroke are required to complete a washer, piece of washer is discharged on every stroke of the ram due to the continuity on operation.

ADVANTAGES: -

- It is used for mass production by the continuous feed of the strip from a coil.

DISADVNTAGES: -

•These are the multiple station dies so it requires more working space than compound die.

<u>PUNCHES: -</u>

- A punch is a male portion of complete die. It is usually upper member and is fastened to top bolster. Punches are used for piercing, blanking, embossing, coining, lancing etc.
- Punches are classified into
    - Plain Punch
    - Pedestal punch
    - Bossed punch
    - Flanged punch
    - Perforated punch
    - Quill Punch

<u>Plain Punch: -</u> A cross section of plain punches is rectangular side walls follow the cutting contour, originating from the cutting-edge plain punches are astronomical as their easy to make and machine. They can be ground straight through they and mounted with the help of screws and dowels. Plain punches can be regarding short height. If punches proportion are not favorable, that they cannot be assemble by mounting on punch plate or supporting end guiding, the punch in the stripper plate.

<u>Pedestal punch: -</u> The flange is an integral part of the punch. The pedestrian punch used when the punch is too large to be manufacture or too small to accommodate mounting hole and dowels due to long base area these punches are stable in addition. The large base area moves an ideal foundation for the punch as the cutting force get s spread over a large area.

Bossed punch: - The diameter of the boss should be kept as large as possible and boss height should be nearly 0.5 times the boss diameter.

Flanged punch: - These punches are used for low production dies & limited accuracy, so that extended area in flanged punches is provided into for attachment screw.

Perforated punch: - Punches whose cutting space diameter is lower than 25mm are termed as perforated the punches need not be round but the inscribe circle of the punch should have a diameter lower than 25mm.As a rule all the perforator are mounted on a punch plate. The simplest & most common perforator is the step head type Mounted in a punch type by means of step head.

Quill Punch: - For piercing where is small hole less than 6mm it is desirable to provide extra support to the punch shank by mean of a closely fitting quill as shown in the fig. Quill punches are most expensive. If made individually because of the cross-fitting reqd. between the punch and quill sizes. There for there are many produces measures standard size.

Different Press Work Operation in Sheet Metal: -

1. **Blanking: -**
   - Blanking is the operation of cutting a shape from a metal strip. The piece detached from the strip is known as blank and is used for further operations. The remaining metal strip is scrap.
   - Blanking is nearly always the first operation and may be the only one necessary, or it may be followed successively by many others.
   - Blanking is often combined with other operations in one tool, all the work being performed at one stroke of the press.
   - A blanking die must have clearance, otherwise the blank would not fall freely, it might remain struck in the die block.
2. **Piercing: -**

   Piercing is a punching operation. However, piercing is a distinct hole making process characterized by the lack of scrap from the hole. In piercing, a pointed, bullet-shaped punch is forced through the sheet metal to produce a hole with a rough flange around the hole.
3. **Trimming: -**
   - During any press working operation, in which the part must be held in place by the press, the outer edge of the part, which is the area usually gripped, becomes marked and scored. Trimming is the cutting of this excess metal edge.
   - Trimming dies are similar to the blanking dies and the part is forced through the die by a suitable punch to carry out trimming operation.
   - Trimming may be the last operation in the progressive die to separates the parts from the strips.

- Trimming may be performed horizontally or vertically, depending upon the configuration of the part.

4. **Punching: -**

   It is also known as piercing. It is a cutting operation by which various shaped holes are cut on sheet metal. Punching is similar to blanking except that in punching the hole is the desired product. The metal cut out is taken as waste metal.

5. **Notching: -**

   This is a cutting operation in which metal pieces are cut from edges of sheet metal.

6. **Perforating: -**

   This is a process by which a no of holes is cut close together in sheet metal.

7. **Lancing: -**

   This is a cutting operation in which a hole is cut partly and then one side is bent down. In this process no metal is removed and there is no waste of metal.

8. **Shaving: -**

   The edges of a sheet metal are rough uneven and unsquared. Accurate dimensions are obtained by removing a thin strip along the edges. This operation is known as shaving.

9. **Slitting: -**

   It is a cutting operation in which a no. of fine holes is made.

10. **Bending: -**

    It is a forming operation in which a sheet metal is pressed between two dies and is bent. The sheet metal is fixed in a die table and force is applied to the free end.

11. **Drawing: -**

It is a process of forming a flat work piece into a hollow shape by means of a punch.

ADVANTAGES & DISADVANTAGES OF DIES & PUNCHES: -

ADVANTAGES: -

- Requires minimal space in the press.

- Leaves all burrs in one direction.

- Superior accuracy between holes & trim edges.

- More economical to build than a progressive die.

- Die casting dies retain their accuracy for a very long time.

- High surface finish is obtained& often no further finishing is required.

DISADVANTAGES: -

- The limited space which ends to leave die components this & weak. This contracts the loads shock on punches & matrixes resulting in tooling failures.

- All metals & alloys cannot be cat.

- The cost of M/C &, dies & other equipment used is high.

- Not economical for small quality production.

- Heavy casting cannot be cast.

- Special precautions cannot be cost.

- Special precautions are necessary for evacuation of air from die cavity otherwise cause porosity.

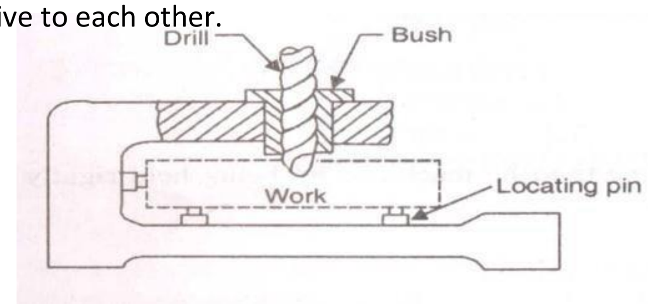
JIGS AND FIXTURE

- Jigs and fixtures are work holding and tool guiding devices which are used for repetitive work.
- The jigs and fixture are the economical means to produce repetitive type of work by incorporating special work holding and tool guiding devices.

JIG: -

- A Jig may be defined as a device which holds and locates a work piece and guides and controls one or more cutting tools.

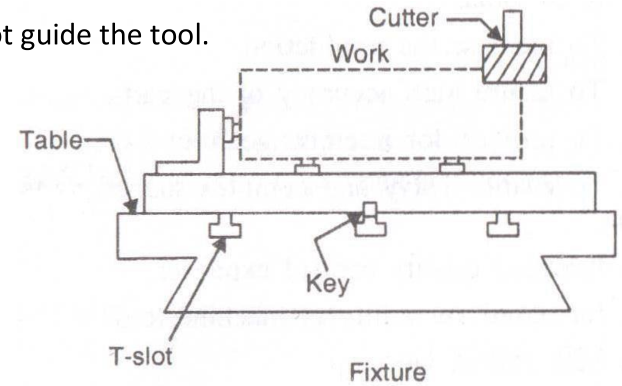
- The holding of the work & guiding of the holes are such that they are located in two positions relative to each other.



FIXTURE: -

- A fixture may be defined as a device which holds & locates a workpiece during an inspection or for a manufacturing operation.

- The fixture does not guide the tool.



ADVANTAGES OF USING JIG AND FIXTURE

- It eliminates the operation like setting, marking, measuring etc.
- It increases the accuracy because wok piece is located automatically and tool is guided without any manual adjustment.
- It increases the production efficiency.
- It reduces the labour time.
- Skilled labour is not required.
- No need to expand for quality control after production.
- It reduces the overall cost of production.

DIFFERENCE BETWEEN JIG AND FIXTURE: -

JIG: -

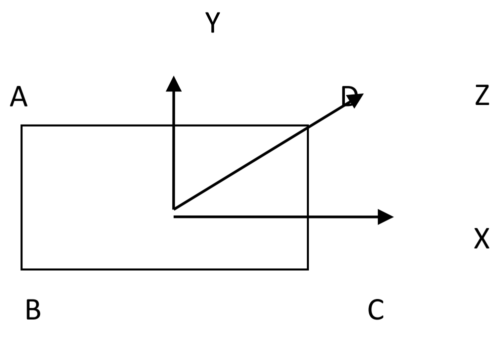
- It holds the work piece as well as guides the cutting tool.
- Jig is lighter.
- In case of jig the rigid attachment is unnecessary on machine tool.
- Jig is generally used for tapping and drilling.

FIXTURE: -

- It only holds the work piece.
- Fixture is heavier.
- Fixture is bolted rigidly with machine tool.
- Fixture is used for operation like planning milling, turning.

PRINCIPLE OF LOCATION.

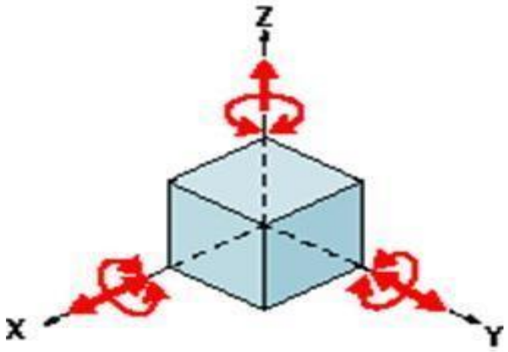
- It established the relationship between work piece jig and fixture.
- It required for the better accuracy on the work piece.
- The design of jig or fixture should be such that it restricts all the possible moment of the work piece, in x, y and z direction.



- ➢ Let a rectangular plate "ABCD" CAN MOVE IN X-axis Y-axis, and Z-axis (linear movement) also the plate can rotate about X-axis, Y-axis, Z-axis. So, the total degrees of freedom 3+3=6. So, the intention of jig and fixture is to prevent all the 6 motions in different direction.

3-2-1 PRINCIPLE OF LOCATION /6 POINT LOCATION: -

- In 3-2-1 principal all the possible movement of rectangular block is restricted by using 6 locations or 6 pin.
- 3 pins are located at the bottom side of the jaw. This 3 locations or pin are restricting the linear movement in – axis and rotational motion in z-axis and y-axis.
- 2 pins are located at the back side of the work piece. These 2 pins restrict the linear movement in y-axis and rotational movement in X–axis.
- One point is located at side of the work piece and it restricts the linear movement in x-axis.



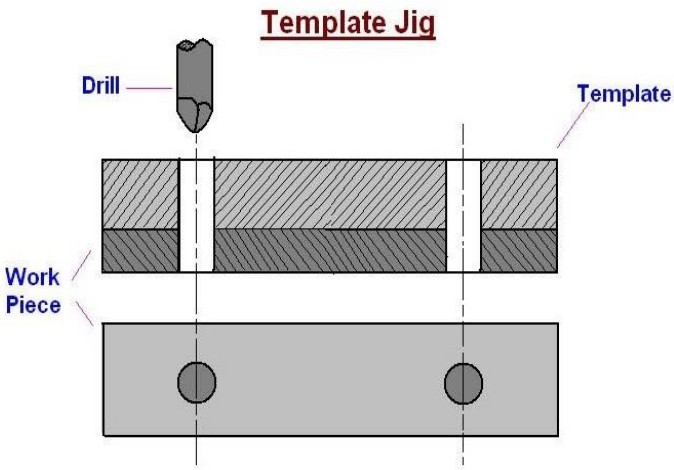
TYPES OF JIGS: -

- There are several types of jigs used for holding and locating the work piece at the same time guiding the cutting tool. They are

(i) Template jig.
(ii) Plate jig.
(iii) Box jig.
(iv) Pot jig.
(v) Chanel jig.
(vi) Sand witch jig.
(vii) Inducing jig
(viii) MultiTaction jig.
(ix) Ring jig.
(x) Diameter jig.
(xi) Leaf jig.
(xii) Angle plate jig.

TEMPLATE JIG: -

- It is the simplest form of all the jigs.
- It is the simple of metal, wood or any other suitable material which carries correct location.
- A plate having holes at the desired position serves as template which is fixed on the component to be drilled.
- The drill is guide through these holes up the template and the required holes are drilled on the work piece at the relative position with each other as on the template.
- Example, if a no. of small cast from pipe flanges of same size and shape are to be drilled to have four bolt holes each, the ordinary method will be, to mark the Centre of all holes. Separately on each flange and then drilling is done. Hence, the template of same size and shape as the flanges and caring the required no of holes at correct location can be prepared and the required Centre of holes marked directly from this template from all the flange, then drilling has to be some on same way as above.



- Template jig is the least expensive and simplest type of jig to use.
- This type of jig is normally used for accuracy rather than speed.
- Template jig fits over on or into the work piece and is not usually clamped.
- Same, shape and size of hole can be drilled.

PLATE JIG: -

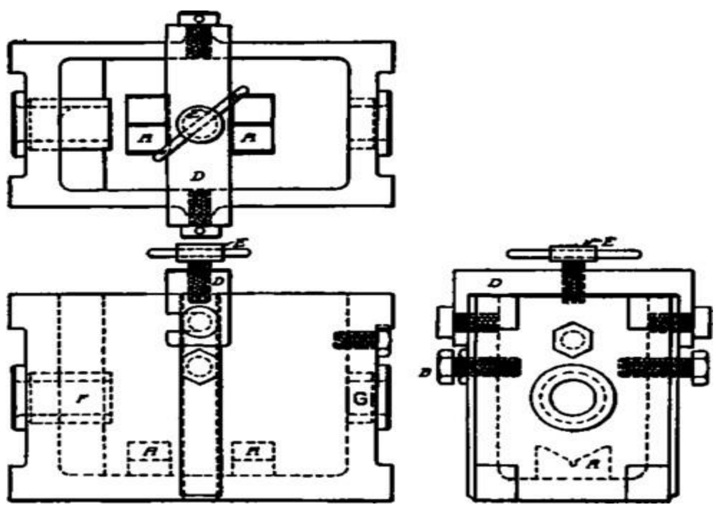
- A plate jig is an improvement of template jig. By incorporating drill bushes in the template,
- If the drilling has to be done on large scale, a large no. of similar flanges is to be drilled in such a scale template jig is not sufficient and not economical. A very reasonable and economical improvement over the template method will be to use a plate having drill bushes. And suitable means to hole and locate the work piece. So,

the work can be clamped to the plate and holds drill directly to the bushes tin correct position.

- The plate jigs are employed to drill holes on large part maintaining accurate spacing with each other.

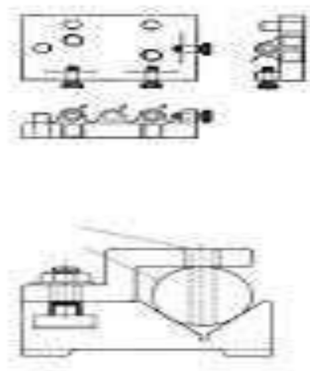
BOX JIG.

- It is named so because of its box shape construction closed from most of the sides.
- Such jigs are normally design and used for those components which carry complicated and irregular shape.
- Such components are usually difficult to held or supported during the operation by hand or in ordinary jigs of other types.
- They need very rigid support from many sides, which can be provided only by box type of jig.
- The body of this jigs is made as like as possible.
- The jigs are generally employed to drill a number of holes on components from different angles.



DIAMETER JIG: -

- The diameter jig is used to drill radially holes on a cylindrical or spherical work piece.
- The work is fixed in the V-Block and then clamp by the clamping plate which also locates the work.
- The tool is guided through the drill bush which is radially with the work.

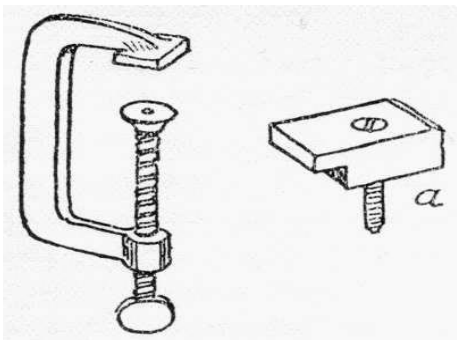


DIFFERENT TYPES OF CLAMPS: -

The following are the different types of clamps which are commonly used with Jig & fixture.

1. Screw clamp
2. Flat clamp
3. Wedge clamp
4. Pivoted clamp
5. Latch clamp
6. Equalizing clamp

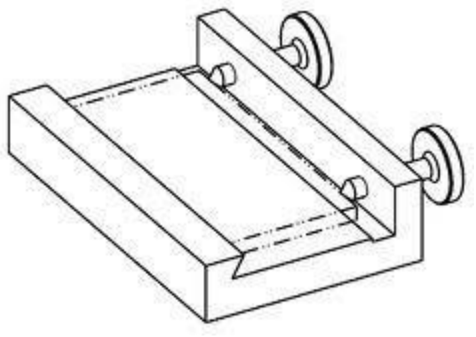
SCREW CLAMP: -



- The screw clamp is used to grip the work on its edge.
- This type of clamping arrangement enables the top surface of the work to be machine without any difficulty.
- Screw clamp offers almost unlimited application potential, lower cost and in many cases less complex design to be machined.

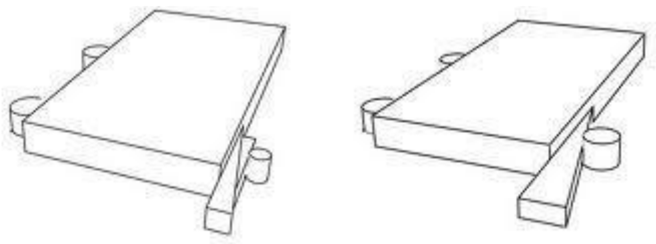
- Screw clamp used the torque develop by a screw thread to hold a part in place. This is done by direct pressure or by acting on another clamp.
- The only disadvantages of using screw clamp are their relatively slow operative speed.

FLAT CLAMP: -



- The flat clamp is supporting the work by the clamp face which is pressed against the work by tighten the nut.
- This clamp is only used for flat surface.

WEDGE CLAMP: -



- Wedge clamp applies the basic principle of the inclined plane to hold the work in a manner similar to cam.
- As shown in fig the wedge clamp is employed to grip the work by the wedge block which is made to slide by rotating screw.
- The wedge block grips the work against the fixed bottom and on the other end of the jig & fixture body.

There are two general forms of wedge clamp

- Flat wedge
- Conical wedge

POWDER METALLURGY

The powder metallurgy may be described as an art of manufacturing commercial products from the powdered metals and alloys. The process consists of compressing the irregularly shaped powdered metal particle in a die of the desired shape of the part to be produced. These compressed parts are then heated to bind the particles together and improve their strength and other properties. This process also called **sintering.** The temp during the process is kept below the melting point of the power.

ADVANTAGES OF POWDER METALLURGY: -

- There is no wastage of material through the entire manufacturing process, thus material is saved.
- The part produced have accurate dimensions and surface finish, thus the need for machining operations is eliminated.
- The large quantity production is relatively economical to machine parts.
- The skilled workers are not required to operate presses or other equipment; thus, the labor costs are low.
- It is possible to ensure uniformity of composition and structure as the exact desired proportion and purity of various metal powders can be used.
- The parts with controlled porosity can be made.
- The parts of highly refractory metals and high melting point such as tungsten carbide can be produced.
- It is possible to make parts from a mixture of metals and non-metals such as motor brushes.
- It is possible to make parts of mixture of metals which do not alloy with each other.

Methods of producing components by powder metallurgy technique

Production of metal powders: -

- A wide range of metal powders comprising of almost all metals and alloys are used in powder metallurgy. Sometimes, the manufacturing process include mixture of both metals and nonmetals like copper and graphite as self-lubricating bearings, dynamo brushes and ceramic-metal mixture for high temperature services.
- The powdered metals are produced by mechanical, physical and chemical means depending upon the particular application involved. The following are the methods commonly used for producing metal powders.

METHODS USED FOR PRODUCING METAL POWDERS: -

i. Crushing
ii. Machining
iii. Milling or grinding
iv. Reduction
v. Condensation of Vapor metal
vi. Atomizing

i. CRUSHING: -

This method is use for brittle material. The crushing equipment used for crushing brittle material may be rapidly moving hammer, jaw crushers etc.

ii. MACHINING: -

This method is employed to produce filling, turning, scratching, chips etc. which are subsequently pulverized by crushing and milling.

iii. MILLING: -

This is the most important and widely used method of producing powder of the required grade of fineness. Though the milling or grinding process is best suited to brittle materials. Milling operation is carried out by using equipment such as ball mill, impact mill, vortex mill, disc mill etc.

iv. REDUCTION: -

In reduction the compound of metals i.e., oxide is reduced with carbon monoxide or hydrogen at temperature bellow the melting point of the metal in an atmosphere control furnace. The reduced product is then crushed and ground.

v. CONDENSATION OF VAPOUR METAL: -

- The technique can be applied in the case of metal such as Zinc, cadmium and magnesium
- First of all, Zinc oxide is mixed with powdered charcoal and heated until zinc vapor is formed by the reaction of zinc oxide with carbon monoxide. The zinc vapor is condensed to the dust like particle by cooling.

vi. ATOMIZING: -

- In this method the molten metal is forced through a nozzle in to a stream of compressed air or water. The metal on cooling solidifies in to tin particle of various size and irregular shape.
- The size of these particles depends upon the size of the nozzle rate of flow of metal, temperature and pressure of water or air stream.

BLENDING: -

- Before the powders are pressed in to shape, they are usually blended/mixing further.

- To add lubricants to reduce friction during the pressing operation. Powder particles get coated with lubricants; this reduces wear and lowers the pressure required for pressing.
- to mixed powder of different materials in order to obtained properties like heat resistance, hardness, toughness
- In wet blending water or a solvent is used to obtain better mixing.
- Wet mixing is used for
    - reduce dust
    - Prevents surface oxidation.
    - Lesser explosion hazards.
- Blending is essential when a powder of different metals within same particles size, or when powder of same metal different particles size is used.
- The main purpose of blending/mixing is to produced uniformity of particles size and shape through the large amount of powder
- The blending or mixing of powders is the first step in the manufacture of parts from powdered metals.
- When one metal powder of the correct particle size is used, then no blending is required.
- But blending is essential when powders of the different metals with the same particle size or when powders of the same metal with different particle size are used.
- The main purpose of blending or mixing is produced uniformly of particle size and shape throughout the large amount of powder. This help in better control of subsequent pressing and sintering operation.

BRIQUETTING OR COMPACTING: -

- After the mixing the metal powders thoroughly, the briquetting or compacting is the next process used in the manufacture of parts through powder metallurgy.
- It is the process of converting loose powder particles in to green compact of the desired shape and size. The process is carried out at room temperature in hardened steel dies and punches.
- It is the process of heating the green compact to a temperature bellow the sintering temperature.
- This is necessary to remove the lubricants and binders added during blending and to increase the strength of green compact. This process is not applied to all metals.
- Compacting impacts adequate strength for handling.
- Powders are compacted by using high pressure. The degree of pressure required depends upon the density of final product.
- The pressure used for compacting process may be either mechanical or hydraulically or combination or both.

PRESINTERING: -

- It is the process of heating the green compact to a temperature bellow the sintering temperature. This is necessary to remove the lubricant and binders added during blending and to increase the strength of green compact.

SINTERING: -

- Sintering may be defined as the heating of loose or compacted aggregate metal powders below the melting point of the base metal with or without the application of external pressure in order to transform to a denser material by inter particle bonding.
- The temperature of the furnace in sintering is always maintained below the melting temp. Of base metal. Because it is very difficult to melt the base metal such as tungsten oxide, aluminum oxide whose melting temperature is around $3000^{\circ}c\ to\ 3500^{\circ}c$.
  - It is the process of heating the briquetted component at an elevated temperature in a furnace under reduced atmospheric conditions.
  - The atmospheric condition is necessary to prevent any oxidation. The sintering temperature is kept bellow the melting point of the major constituent in the components.
  - The sintering process increases density, porosity, mechanical strength and ductility of the component.

Applications: -

- Manufacturing of brake linings, clutch plate, connecting rod crank shaft, cam shaft and piston rings.

- Porous material such as bearing & filters can be manufactured.

- Tungsten filaments of electric bulb, radio valves, x-ray tube, oscillator valve.

- Military defence application.

- Atomic energy application.

- Manufacturing of grinding wheels.

- Clocks & timing devices, type writers, calculators, and permanent magnet can be manufactured.

- Manufacturing of toothed components like gear.

- Material which are very difficult for machining- wire drawing dies, press tools, stone hammers & rock drilling bits can be manufactured.
- Manufacturing of nozzles for rocket & missiles.

- Jet engine parts.

Advantages: -

- Accuracy is better

- Surface is good.

- Machining Processes are eliminated.

- Longer life of the product.

- Uniformity of structure.

- Void, blow holes are absent

- No material is wasted as scrap.

- Highly gratified labour is not required.

- Porous parts can be manufactured.

- Mixed powders of copper & lead can be successfully shaped by powder metallurgy.

- Product cost is cheaper.

- Hard tool bits can be formed.

Disadvantages: -

- Complicated shapes cannot be achieved.

- Don't have good physical properties.

WELDING

Introduction: -

- The welding is a process of joining two similar or dissimilar metals by fusion, with or without the application of pressure and with or without the use of filler metal. The fusion of metal takes place by means of heat.
- The process of joining similar metals by melting the edges together, without the addition of filler metal, is called autogenous welding.
- The process of joining similar metals with the help of filler rod of the same metal is called homogeneous welding.
- The process of joining dissimilar metals using filler rod is called heterogeneous welding. The filler rod material is such that its melting point is less than the parent metals.

Classification Of Welding Process: -

The welding is broadly divided into the following two groups:

- **Forge or pressure welding: -** In forge or pressure welding (also known as plastic welding), the work pieces are heated to plastic state and then the work pieces are joined together by applying pressure on them. In this case no filler material is used.
- **Fusion or non-pressure welding: -** In fusion welding, the edge of work pieces to be joined and the filler material are heated to a temperature above the melting point of the metal and then allowed to solidify.

In general, various welding and allied processes are classified as follows:

1. Gas Welding
   1. Air Acetylene Welding.
   2. Oxy hydrogen welding.
   3. Oxyacetylene Welding.
   4. Pressure gas Welding.
2. Arc Welding

-Carbon Arc Welding -Shielded Metal Arc Welding
-Flux Cored Arc Welding -Submerged Arc Welding
-TIG (or GTAW) Welding -MIG (or GMAW) Welding
-Plasma Arc Welding
-Electroslag Welding and Electro gas Welding
-Stud Arc Welding.

3. Resistance Welding

-Spot Welding -Seam Welding
-Projection Welding -Resistance Butt Welding
-Flash Butt Welding -Percussion Welding
-High Frequency Resistance Welding.

4. Solid State Welding

-Cold Welding -Diffusion Welding
-Explosive Welding -Forge Welding
-Friction Welding -Hot Pressure Welding
-Roll Welding -Ultrasonic Welding

5. Thermo-Chemical Welding Processes.

-Thermit Welding -Atomic Hydrogen Welding.

6. Radiant Energy Welding Processes

-Electron Beam Welding -Laser Beam Welding.

Types of welded joints: - The relative positions of the two pieces being joined determine the type of joint. The following are the five basic types of joints commonly used in fusion welding.

1. **Lap joint: -** The lap joint is obtained by overlapping the plates and then welding the edges of the plates. These joints are employed on plates having thickness less than 3 mm. The lap joint may be
   i) Single transverse
   ii) Double transverse
   iii) Parallel lap
2. **Butt joint: -** the butt joint is obtained by welding the ends or edges of the two plates which are approximately in the same plane with each other. In butt welding the plate edges do not require beveling if the thickness of plate is less 5 mm. on the other hand, if the plate thickness is 5 mm to 12.5 mm, the edges should be beveled to V or U – groove and plates having thickness above 12.5 mm should have a v or U – groove on both sides. The butt joints may be
   i) Square butt joint
   ii) Single V – butt joint
   iii) Double V – butt joint
   iv) Single U – butt joint
   v) Double U – butt joint
3. **Corner joint: -** The corner joint is obtained by joining the edges of two plates whose surfaces are at an angle of approximately 90° to each other. It is used for both light and heavy gauge sheet metal. In some cases, corner joint can be welded, without any filler metal, by melting off the edges of the parent metal.
4. **Edge joint: -** The edge joint, is obtained by joining two parallel plates. It is economical for plates having thickness less than 6 mm.
5. **T – Joint: -** The T- joint is obtained by joining two plates whose surfaces are approximately at right angles to each other. It is widely used to weld stiffeners in air craft and other thin-walled structures. These joints are suitable up to 3 mm thickness.

COMMONLYWELDED BASEMETALS: -

- Metal can be classified as:

  1. Ferrous 2. Non-ferrous.

- Ferrous materials contain iron and the one element people use more than all others is iron. Ferrous materials are the most important metals/alloys in the metallurgical and mechanical industries because of their very extensive use.

Ferrous materials finding day-to-clay welding applications are:

1. Wrought iron.
2. Cast iron.
3. Carbon Steels (Low, Medium and High Carbon Steels).
4. Cast steels.
5. Alloy Steels.
6. Stainless Steels, etc.

- Non-ferrous materials are those that are not iron-based.

Like ferrous materials, non-ferrous materials also find extensive industrial applications.

Non-ferrous materials finding day-to-day welding applications are:

7. Aluminum and its alloys. 8. Copper and its alloys.
9. Magnesium and its alloys. 10. Nickel and its alloys.
11. Zinc and its alloys, etc.

ADVANTAGES OF WELDING: -

(I) A good weld is as strong as the base metal.
(ii) General welding equipment is iron very costly.
(iii) Portable welding equipment are available.
(iv) Welding permits considerable freedom in design.
(v) A large number of metals/alloys both similar and dissimilar can be joined by welding.
(vi) Welding can join work pieces through spots, as continuous pressure tight seams, end-to-end and in a number of other configurations.
(vii) Welding can be mechanized.

DISADVANTAGES OF WELDING: -

(I) Welding gives out harmful radiations (light), fumes and spatter.
(ii) Welding results in residual stresses and distortion of the work pieces.
(iii) Jigs and fixtures are generally required to hold and position the parts to be welded.
(iv) Edge preparation of the work pieces is generally required before welding them.
(v) A skilled welder is a must to produce a good welding job.
(vi) Welding heat produces metallurgical changes. The structure of the welded joint is not same as that of the parent metal.
(vii) A welded joint, for many reasons, needs stress-relief heat-treatment.

PRACTICAL APPLICATIONS OF WELDING: -

-Welding has been employed in Industry as a tool for:

(a) Regular fabrication of automobile cars, air-crafts, refrigerators, etc.

(b) Repair and maintenance work, e.g., joining broken parts, rebuilding worn out components, etc.

- A few important applications of welding are listed below:

1. Air craft Construction
   (a) Welded engine mounts.
   (b) Turbine frame for jet engine.
   (c) Rocket motor fuel and oxidizer tanks.
   (d) Ducts, fittings, cowling components, etc.
2. Automobile Construction
   (a) Arc welded car wheels. (b) Steel rear axle housing.
   (c) Frame side rails.
   (d) Automobile frame, brackets, etc.
3. Bridges
   (a) Pier construction. (b) Section lengths.
   (c) Shop and field assembly of lengths, etc.
4. Buildings
   (a) Column base plates. (b) Trusses. (c) Erection of structure, etc.
5. Pressure Vessels and Tanks
   (a) Clad and lined steel plates. (b) Shell construction.
   (c) Joining of nozzles to the shell, etc.
6. Storage Tanks
   (a) Oil, gas and water storage tanks.
7. Rail Road Equipment
   Locomotive
   (a) Under frame. (b) Air receiver.
   (c) Engine. (d) Front and rear hoods, etc.
8. Piping and Pipelines
   (a) Rolled plate piping. (b) Open pipe joints.
   (c) Oil gas and gasoline pipe lines, etc.
9. Ships
   (a) Shell frames.
   (b) Deck beams and bulkhead stiffeners.
   (c) Girders to shells
   (d) Bulkhead webs to plating, etc.
10. Trucks and trailers.

11. Machine tool frames, cutting tools and dies.
12. Household and office furniture.
13. Earth moving machinery and cranes.

In addition, arc welding finds following applications in repair and maintenance work:

14. Repair of broken and damaged components and machinery such as tools, punches, dies, gears, shears, press and machine tools frames.
15. Hard-facing and rebuilding of worn out or undersized (costly) Parts rejected during inspection.
16. Fabrication of jigs, fixtures, clamps and other work holding devices.

Fluxes: -

When metals are heated, the oxygen from the air combines with them and form oxides. These oxides produce poor quality and low strength welds. In some cases, it makes the welding impossible. Thus, in order to prevent oxidation and other unwanted chemical reactions during welding fluxes is used. The fluxes are chemical compounds and form a fusible slag with the oxides of most metals at the welding temperature. The slag floats to the top of the molten metal and do not interfere with the deposition and fusion of filler metal. A good flux protects the molten metal from atmospheric oxygen and prevents the absorption and reaction of other gases in the flame. In addition, it helps to clean and protect the surfaces of the base metal.

The fluxes are available in several forms, such as a dry powder, a paste or thick solution or as a preplaced coating on the welding rod. The dry fluxes are applied by heating the end of the welding rod and dipping it into the powdered material. The flux adheres to the heated surface and is consumed with the rod during welding operation. The fluxes in the paste form are usually applied on the base metal with a brush, while the welding rod is either painted or dipped.

A single flux is not suitable for welding all metals. The ordinary grades of mild steels are successfully welded without the use of a flux. (The commonly used fluxes for welding different metals are as follows:

1. For ferrous metals, the fluxes used are borax, sodium carbonate, sodium bicarbonate and sodium silicate.
2. For copper and its alloys, the fluxes used are mixtures of sodium and potassium borates, chlorides, carbonates, sulphates and boric acid.
3. For aluminum, the fluxes used are alkaline fluorides, chlorides and bicolpate.
4. For magnesium alloys, the fluxes used are similar in composition to those used for aluminum and its alloys.

Since all the fluxes are chemically active and very corrosive, therefore it is very essential to remove all traces of flux from the finished weld. The flux residue may be removed by hot water, steam or by chipping hammer.

No Flux is used in the Gas Welding of Steel: -

Fluxes are used in the gas welding of cast-iron, stainless-steel metals other than Lad, zinc and some precious metals.

Flux for Welding Cast Iron: -

The use of a suitable flux is essential when gas welding cast iron. The flux increases the fluidity of the fusible iron-silicate slag, as well as aids in the removal of the slag.

Fluxes for gray iron rods are usually composed of borates or boric acid, soda ash etc.

Flux for Welding Stainless Steel: -

A flux is needed to ensure better control of the molten metal and to make possible a sound, clean, good-appearing weld.

Flux should be applied at the underside of the seam also to prevent oxidation.

Flux for Welding Aluminum and its Alloys: -

A flux is necessary for welding aluminum because of the formation of oxide film on the metal. This film of aluminum oxide will prevent the formation of a sound weld. A flux when used breaks down the oxides and changes them into a fusible slag. The fusible slag being lighter than the base metal floats to the surface of the weld puddle.

GASWELDING:

Definition

- Gas welding is a fusion-welding process. It joins metals, using the heat of combustion of an oxygen/air and fuel gas (i.e., acetylene, hydrogen, propane or butane) mixture. The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal.

Principle of Operation: -

- When acetylene is mixed with oxygen in correct proportions in the welding torch and ignited, the flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal.
- The oxy-acetylene flame reaches a temperature of about 320VC and thus can melt all commercial metals which, during welding, actually flow together to form a complete bond. A filler metal rod is generally added to the molten metal pool to build up the seam slightly for greater strength.
- Oxy-acetylene welding does not require the components to be forced together under pressure until the weld forms and solidifies.

To Ignite a Flame: -

- Open the acetylene control valve of the welding torch and after the system has been flushed clean of air the gas is ignited. At this stage, enough of oxygen is drawn in from the atmosphere to burn acetylene partially.
- The acetylene control valve is then adjusted until the flame ceases to smoke.
- The oxygen control valve of the welding torch is then opened in order to adjust the proportions in which acetylene and oxygen are required to mix and burn.
- This results in three distinct types of flames as discussed under.

Types of Welding Flames: -

1. Neutral Flame (Acetylene oxygen in equal proportions)
2. Oxidizing Flame (Excess of oxygen)
3. Reducing Flame (Excess of acetylene).

- In oxy-acetylene welding, flame is the most important tool. All the welding equipment simply serves to maintain and control the flame.

The correct type of flame is essential for the production of satisfactory welds.

The flame must be of the proper size, shape and condition in order to operate with maximum efficiency.

Neutral Flame: -

- A neutral flame is produced when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip. (More accurately the oxygen-to-acetylene ratio is 1.1 to 1).
- The temperature of the neutral flame is of the order of about 5900"F (3260^{0}c).
- The flame has a nicely defined inner cone* which is light blue in color. It is surrounded by an outer flame envelope, produced by the combination of oxygen in the air and superheated carbon monoxide and hydrogen gases from the inner cone. This envelope is usually a much darker blue than the inner cone.
- A neutral flame is named so because it affects no chemical change on the molten metal and, therefore, will not oxidize or carburize the metal.
- The neutral flame is commonly used for the welding of:

(I) Mild steel
(ii) Cast Iron
(iii) Stainless steel
(iv) Copper
(v) Aluminum

Oxidizing Flame: -

- If, after the neutral flame has been established, the supply of oxygen is further increased, the result will be an oxidizing flame. An oxidizing flame can be recognized by the small cone which is shorter, much bluer in color and more pointed than that of the neutral flame.

The outer flame envelope is much shorter and tends to fan out at the end; on the other hand, the neutral and carburizing envelopes tend to come to a sharp Point'

- An oxidizing flame burns with a decided loud roar.
- An oxidizing flame tends to be hotter than the neutral flame. This is because of excess oxygen and which causes the temperature to rise as high as 6300^0F.
- The high temperature of an oxidizing flame (O_2: C2H = 1.5: 1) would be an advantage if it were not for the fact that the excess oxygen, especially at high temperatures, tends to combine with many metals to form hard, brittle, low strength Oxides. Moreover, an excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance.
- For these reasons, an oxidizing flame is of limited use in welding. It is not used in the welding of steel.

A slightly oxidizing flame is helpful when welding most

(I)Copper base metals (ii) Zinc-base metals, and

(iii) A few types of ferrous metals, such as manganese steel and cast iron.

The oxidizing atmosphere, in these cases, creates a base-metal oxide that protects the base metal. For example, in welding brass, the zinc has a tendency to separate and fume away. The formation of a covering copper oxide prevents the zinc from dissipating.

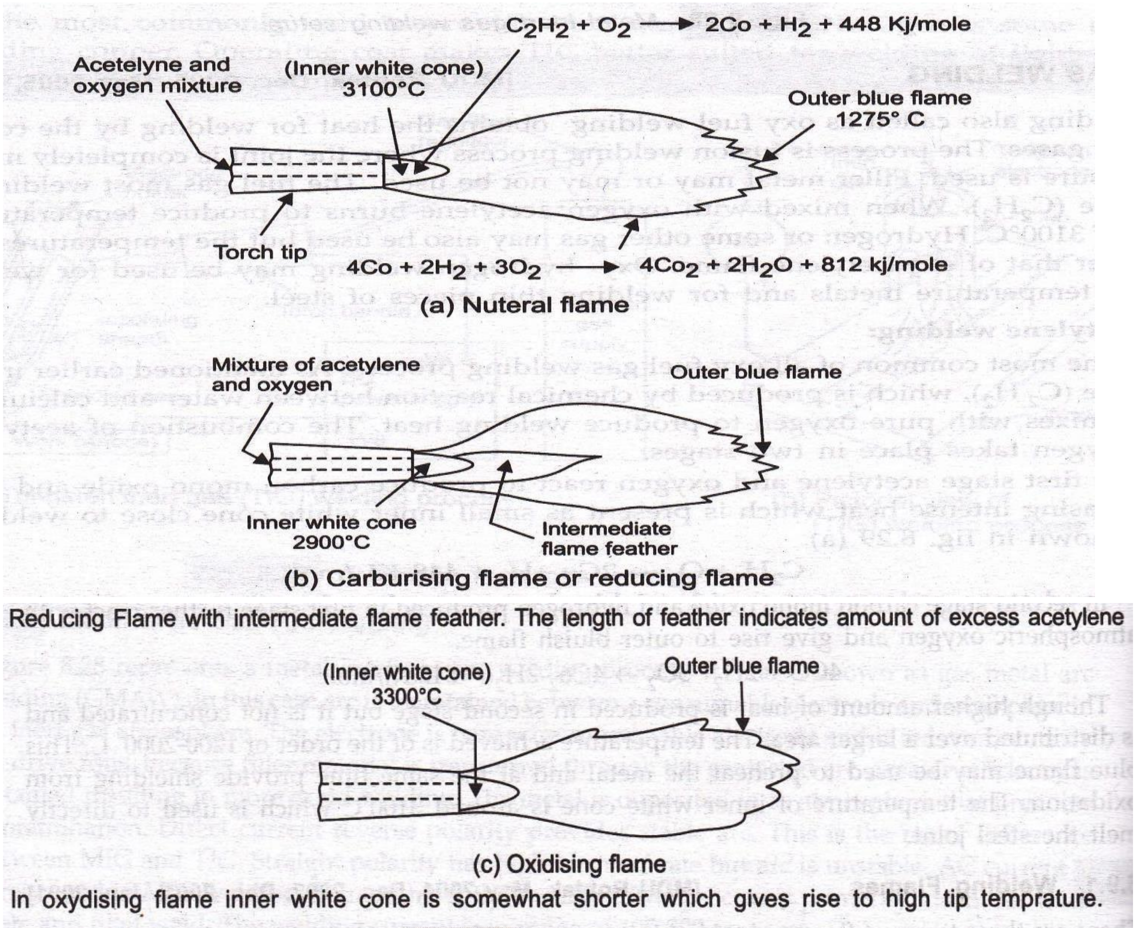


Fig. 8.29 *Welding Flames.*

<u>Reducing Flame: -</u>

- If the volume of oxygen supplied to the neutral flame is reduced, the resulting flame will be a carburizing or reducing flame, i.e., rich in acetylene.

- A reducing flame can be recognized by acetylene feather which exists between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is usually much brighter in color.

- A reducing flame does not completely consume the available carbon; therefore, its burning temperature is lower and the leftover carbon is forced into the molten metal. With iron and steel, it produces very hard, brittle substance known as iron carbide. This chemical change makes the metal unfit for many applications in which the weld may need to be bent or stretched. Metals that tend to absorb carbon should not be welded with reducing flame.

- A reducing flame has an approximate temperature of 5500^0F (3038"C).

- A reducing flame may be distinguished from carburizing flame by the fact that a carburizing flame contains more acetylene than a reducing flame.

A carburizing flame is used in the welding of lead and for car burning (surface hardening) purposes.

A reducing flame, on the other hand, does not carburize the metal; rather it ensures the absence of the oxidizing condition. It is used for welding with low alloy steel rods and for welding those metals, (e.g., nonferrous) that do not tend to absorb carbon. This flame is very well used for welding high carbon steel.

To conclude, for most welding operations, the Neutral Flame is correct, but the other types of flames are sometimes needed for special welds, e.g., non-ferrous alloys and high carbon steels may require a reducing flame, whilst zinc-bearing alloys may need an oxidizing flame for welding purposes.

GAS WELDTNG EQUIPMENTS: -

The basic equipment used to carry out gas welding are:

1. Gas cylinders.
   i) Oxygen gas cylinder
   ii) Acetylene gas cylinder
2. Pressure regulators.
   i) Oxygen pressure regulator
   ii) Acetylene pressure regulator.
3. Hose and Hose fittings.
   I) Oxygen gas hose (Blue)
   ii) Acetylene gas hose (Red).
4. Welding torch
5. Welding torch tip or nozzle.
6. Filler rods and fluxes.
7. Protective clothing for the welder (e.g., asbestos apron, gloves, goggles, etc.).

1. **Gas cylinders: -**

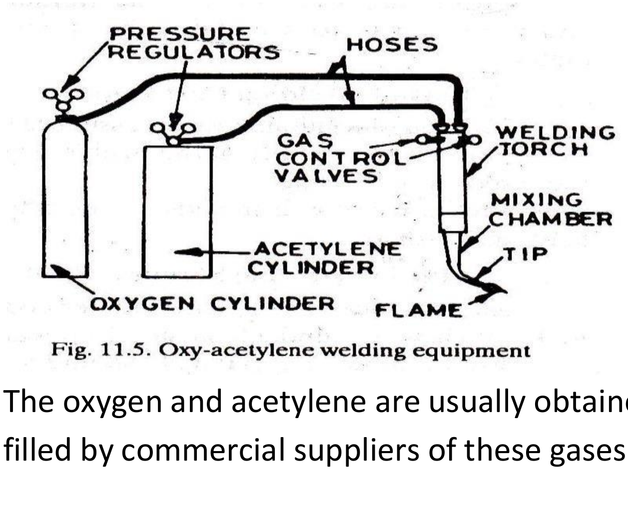
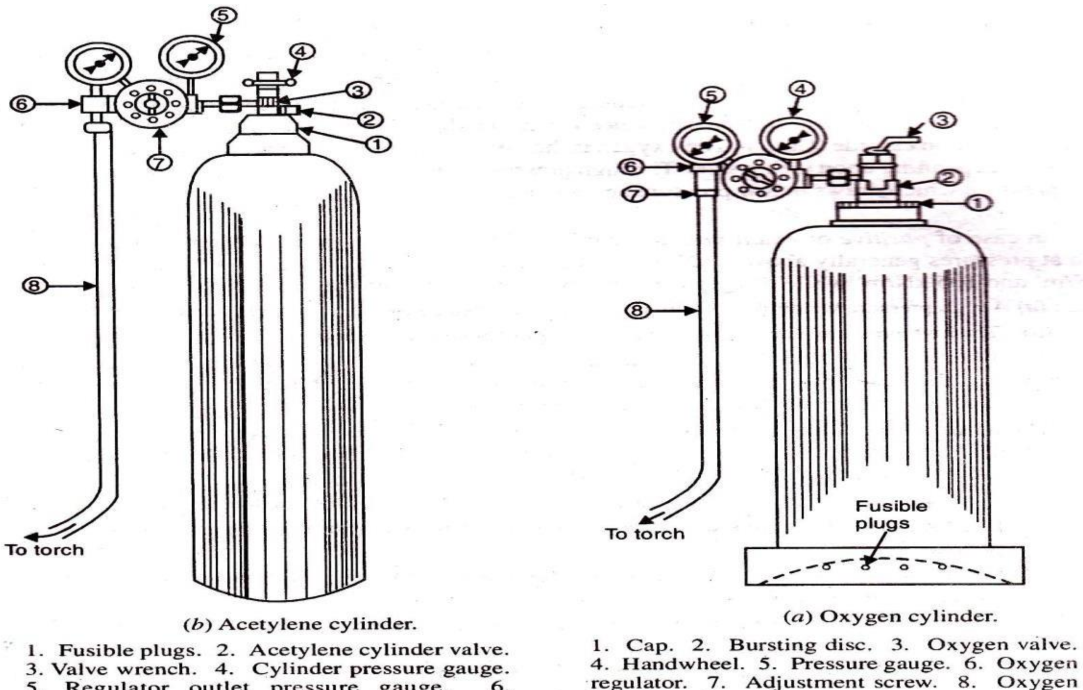


Fig. 11.5. Oxy-acetylene welding equipment

The oxygen and acetylene are usually obtained from strong steel cylinders, which are filled by commercial suppliers of these gases. The oxygen cylinders are usually filled at a pressure of 12.5 to 14 MN/m^2 and have capacity of 6.23 cubic meter. The mass of oxygen cylinder is approximately 66 kg when it is full. The standard color for the oxygen cylinder is black. The acetylene is stored in cylinders under an initial pressure of 15 atmospheres (1.545kN/m^2) and have the capacity of 7.6 cubic meter. Its mass is about 86 kg when it is full. The acetylene cylinders are equipped with fusible plugs at the bottom in order to save the cylinder from explosion in case of fire. The standard color for the acetylene cylinder is maroon.

The pure acetylene is not stable at pressures above atmospheric pressure (i.e., 103N/m2) and may decompose explosively. Therefore, in order to store acetylene at l5 atmospheres, it is dissolved in *acetone which is capable of absorbing a large volume of acetylene and of releasing it as the pressure falls. One volume of acetone at l5t and at atmospheric pressure dissolves about 25 volumes of acetylene. The dissolving capacity grows in proportion to the pressure so that at the same temperature but at 15 atmospheres acetylene pressure, one volume of acetone absorbs 25 x 15=375 volumes of acetylene. The cylinder is first filled with a dry porous material (e.g., charcoal or asbestos) which keeps the acetylene well separated. Then the tank is partially filled with acetone and acetylene is dissolved in it under a pressure of 15 atmospheres.



(*b*) Acetylene cylinder.
1. Fusible plugs. 2. Acetylene cylinder valve. 3. Valve wrench. 4. Cylinder pressure gauge. 5. Regulator outlet pressure gauge. 6. Acetylene regulator. 7. Adjusting screw. 8. Acetylene hose to torch.

(*a*) Oxygen cylinder.
1. Cap. 2. Bursting disc. 3. Oxygen valve. 4. Handwheel. 5. Pressure gauge. 6. Oxygen regulator. 7. Adjustment screw. 8. Oxygen hose to torch.

Fig. 15.28. Parts of gas cylinder.

2. **Pressure regulators: -**

The pressure regulators perform the following functions:

(I) It reduces the source pressure (from generator, cylinder, manifold or pipe line) to a workable pressure.

(ii) it maintains the constant delivery pressure and gas volumetric rate regardless of pressure variations at the source.

(iii) It permits adjustment to deliver gas at a certain desired pressure within its rated pressure range.

The mechanical details of a regulator may differ among the different manufacturers, but the fundamental operating principles are the same for all regulator. Generally, a pressure regulator has a union nipple to attach it to the cylinder and an outlet connection for the hose leading to the torch. There are two gauges on the body of the regulator, one showing pressure in the cylinder while the other shows pressure being supplied to the torch. The working pressure is adjusted by the operator according to the requirements of the job. The desired pressure at the welding torch for oxygen is between 70 and 280kN/m^2 and for acetylene it is between 7 and 103kN/m^2.

3. **Hose and hose fittings: -** The hose for welding torches should be strong, durable, non-porous, light and flexible. Two lengths of hose (one for oxygen and one for acetylene) are required to connect the regulator and the torch. The standard color for oxygen hose is black and for acetylene hose it is red. The special hose fittings or connections are provided for attachments to the torch and pressure regulators.

4. **Welding torch: -**

The welding torch (also known as blow pipe) is a tool for mixing the oxygen and acetylene in the desired volumes and burning the mixture at the end of a tip, which produces a high temperature flame. The welding torches have a handle at one end with two inlet connections for gases. Each inlet has a valve that controls the volume of oxygen or of acetylene passing through them. The desired proportions of oxygen and acetylene are thoroughly mixed, in the mixer, before issuing from torch to the tip or nozzle. The flame is produced by igniting the mixture at the torch tip.
The welding torches are commercially available in the following two types: -

(I) Injectors or low-pressure type; and

(ii) Positive or equal-pressure (also known as high pressure) type.

The principal difference between these types of torches is in the gas mixing chambers or gas mixer. A gas mixing chamber must be able

(a) To mix gases thoroughly for proper combustion,

(b) To arrest flash backs that might occur through improper operation,

(c) To stop any flame, travelling back through the tip at the mixer, and

(d) In some designs, to permit a range of tip sizes to be operated by the one size of mixer.

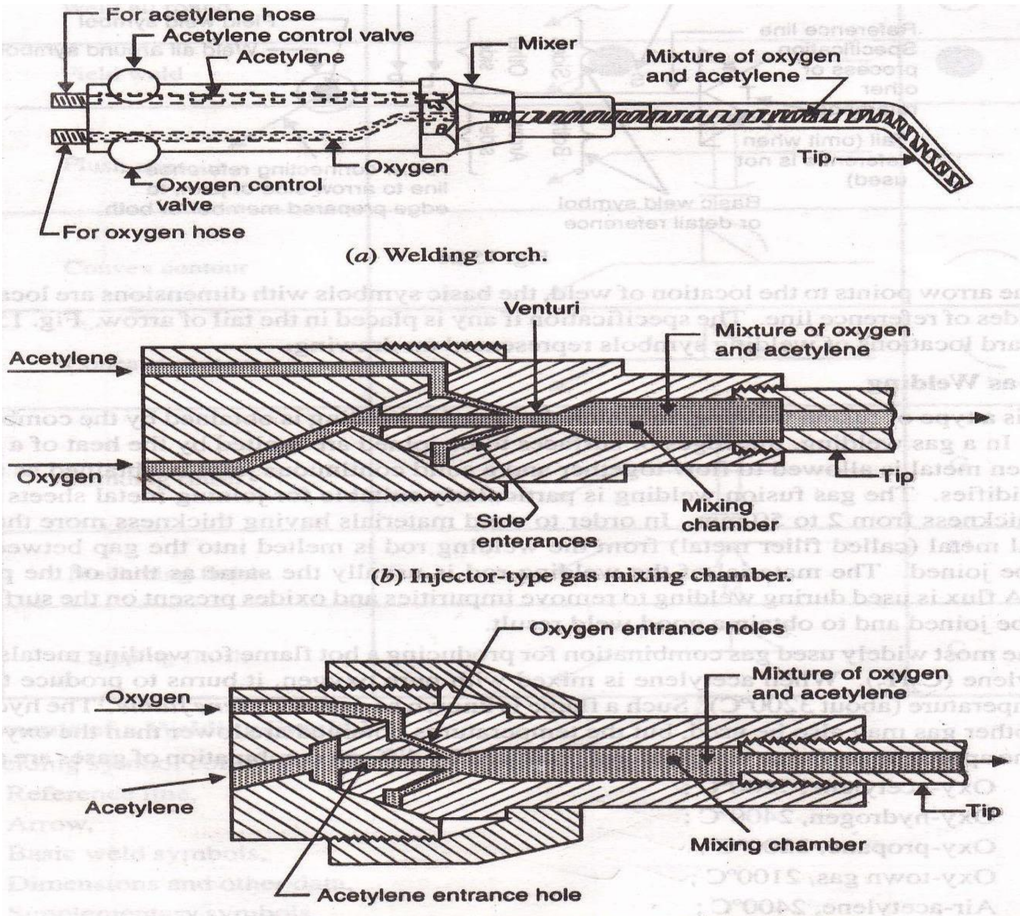
The injector or low-pressure type welding torch operates at an acetylene pressure of less than $7kN/m^2$. This low-pressure acetylene is produced at the welding site by the chemical reaction between water and calcium carbide (CaC_2). The oxygen is, however, supplied at a pressure ranging from 70 to $280kN/m^2$ depending upon the tip size. The high-pressure oxygen passing through the venturi creates a low pressure which draws in low pressure acetylene and mix with it before both gases pass into the tip.

In case of positive or equal pressure type welding torch, the gases must be delivered to the torch at pressures generally above $7kN/m^2$. In the case of acetylene, the pressure must be between$7kN/m^2$ and $105kN/m^2$ while oxygen is generally supplied at approximately same pressure.

Notes: -

(a) A high-pressure welding torch should never be connected to a low-pressure acetylene line.

(b) The high-pressure acetylene is usually stored in strong steel cylinders.



(a) Welding torch.

(b) Injector-type gas mixing chamber.

(c) Positive or equal pressure type gas mixing chamber.

Fig. 15.27.

5. Welding torch tip: - The welding torch tip (also called nozzle) is that portion of torch through which the gases pass just prior to their ignition and burning. The tips are made of high thermal conductivity material, such as copper or copper alloy. The tip size is measured by the diameter of the central hole through which the gaseous mixture passes. The tip size depends upon the thickness of the material to be welded. The interchangeable tips for the various thicknesses are usually provided with each welding torch.

Electric Arc Welding: -

INTRODUCTION: - The arc welding is a fusion welding process in which the welding heat is obtained from an electric arc between the work and the electrode. The electric arc is produced when two conductors of an electric circuit are touched together and then separated by a small distance. The temperature of heat produced by the electric arc is of the order of 6000°C to 7000°C. The most common method of arc welding is with the use of a metal electrode which supplies filler metal.

Electric arc welding is one of the most versatile joining processes and is externally used all over the world. One of the attractive features of arc welding is ease of use and high production rate that can be achieved economically.

Arc welding is a fusion welding process where fusion is obtained by heat produced by an electric arc. The arc may be obtained:

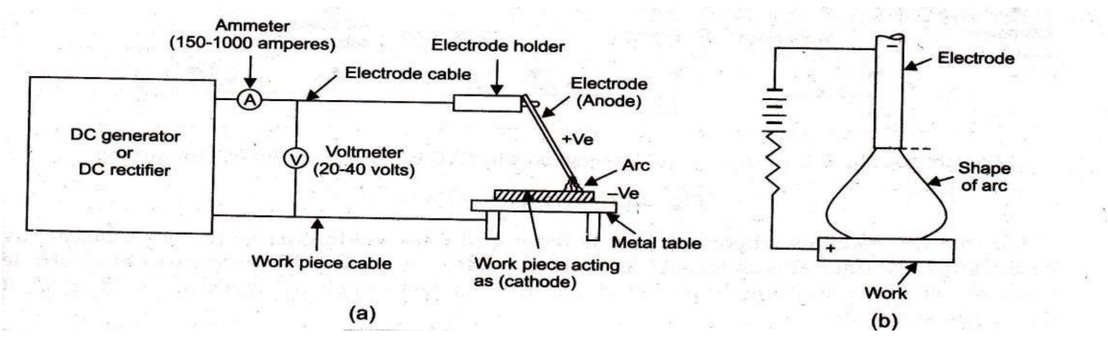
a) Between work piece and consumable electrode (acts as filler material also) as in shielded metal arc welding (SMAW), MIG welding etc.
b) Between work piece and non-consumable electrode as in tungsten inert gas arc welding. (TIG welding)
c) Between two non-consumable electrodes as in carbon arc welding.
d) Or between metal pieces which are to be welded together.

In arc welding Process when consumable electrodes are used it also acts as filter material continuously & deposited into the joint to make the weld. When non consumable electrodes are used separated filler metal rods are used.

Principle Of Arc Welding: -

First, the contact is made between two conductors of electricity anode and cathode to create an electric circuit. When the flow of current is established, they are separated by small distance and arc is formed. Actually, arc is a sustained electric discharge through the ionized gas column (called plasma) between two electrodes.

Electrons liberated from cathode move towards the anode and when they strike anode at high velocity large are amount of heat generated. Positively charged ions moving from anode are impinging in cathode thus liberating heat. About 75% of heat is generated at the anode by striking electrons. Thus, electric energy is converted into intense heat in the arc which attains the temperature around 5500^0cs.



Basic circuit for arc welding (DC arc welding with reverse polarity). Basic shape arc between electrode and work piece.

The potential difference between the electrodes and air gap between electrodes are two significant parameters which are to be controlled efficiently. If the air gap becomes too large for voltage the arc may be extinguished. Larger air gap requires higher potential differences. The fig. shows basic circuit for arc welding. The sources of current may be alternating current or direct current. The work piece is kept on the metallic table. One cable from power supply is connected to the electrode holder into which the electrode is gripped. Other lead is connected to the metallic table on which work piece is kept. When the electrode is brought into contact with work piece arc generates and welding takes place.

Arc Welding Equipment: -

The arc welding machines can be classified into two categories depending upon the source of electric power.

1. Alternating current machines.
2. Direct current machines.

Either alternating current or direct current can be used for electric arc welding.

Direct current arc welding is more expensive than AC arc welding; even then DC arc welding is preferred because of the control of heat input and easy arc maintenances.

Polarity In Arc Welding: -

As discussed earlier in case of DC arc welding about 60-70% of heat is generated at anode and rest of the heat is generated at cathode. So, if more heat is required on the work piece side, say for welding thick materials and materials having thigh thermal conductivity. The work piece may be made as anode (and electrode in the electrode holder of welding machine is working as cathode) liberating large heat near it. This arrangement is termed as straight polarity or D C E N (direct current electrode negative).

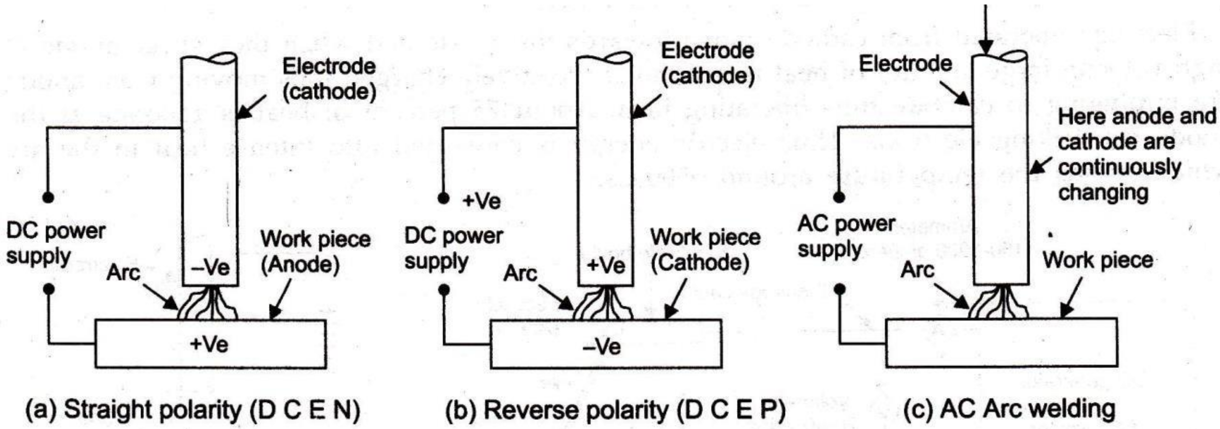


Fig. 8.23 *Polariy in arc welding.*

For thinner materials where less heat is required in the welding zone, the work piece may be made as cathode. This is termed as reverse polarity or D C E P (direct current electrode positive). D C arc welding is preferred for difficult tasks such as overhead welding as it maintains stable arc.

For AC arc welding there is no question of polarity because anode and cathode will interchange after every half cycle, so heat generated at each electrode is same.

The penetration obtained in straight polarity is large. In reverse polarity penetration is small

Arc Welding Electrodes: -

The electrodes used for providing heat are of two types.

1. Consumable electrodes.
2. Non consumable electrodes.

Consumable Electrodes: -

Welding using a consumable electrode is most common method now days. Here electrode consumed continuously and acts as filler material. The melting temperature of consumable electrode is below the temperature of arc. Since the electrode continuously melts the function of providing a filler metal and heat are both built into a single electrode. The consumable electrode must be continuously moved towards the work piece to maintain a stable arc and satisfactory welding condition.

In all the process using consumable electrodes it is better to connect the electrode to the positive terminal (reverse polarity) because more heat is generated on the electrode side and transfer of metal from consumable electrode of work piece is more uniform and better directed. It also provides necessary cleaning action metal with oxide layer such as aluminum.

Consumable electrodes are made of various materials depending upon the purpose and chemical composition of metals to be welded. They may be made of steel, cast iron, aluminum, copper, brass or bronze. When consumable electrode is used welding process is called metal arc welding.

The consumable electrode may be either bare or coated type. The coated electrodes most commonly known as stick electrodes are used in manual arc welding Process. The stick electrodes are normally available in diameters 3.2, 4, 5, 6, 8, and 9 mm and the length are 350 or 400 mm.

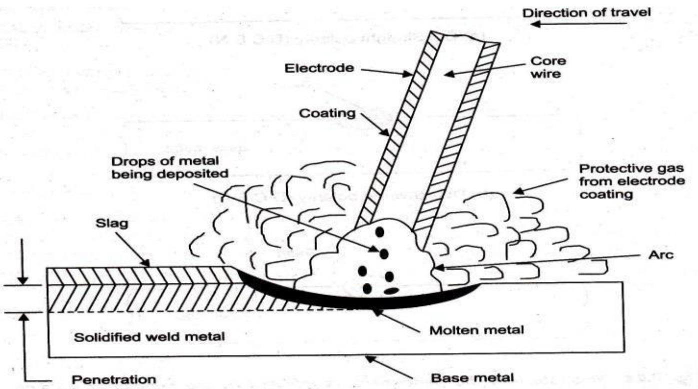


Fig. 8.25 *Important features of arc welding processes usng coated electrodes*

Characteristics Of Coated Electrodes: -

Coating on the electrodes and many desirable characteristics and serve following purpose:

i. Coating on the electrode provides a gas shielding around the arc to eliminate the formation of undesirable oxides and nitride, which would otherwise form by reacting with atmospheric oxygen and nitrogen.
ii. Coating forms a slag which being lighter than molten metal floats on the top of puddle and protects against the surrounding air during weld bead solidification.

It also helps metal to cool slowly, preventing the formation of brittle weld.

iii. Elements for stabilization of arc are added to these coatings.
iv. Alloying elements can also be added through these coatings to improve the strength and physical properties of weld metal.

Moisture is one of the major problems with coated electrodes. Therefore, it is preferable that should be kept in an oven to keep them thoroughly dry.

Non-consumable Electrode: -

When non consumable electrodes are used separates filler metals rods are used. We may say that in case of welding Processes using non consumable electrodes heat source and filler metal deposition can be separately controlled. For all processes using non consumable electrodes it is better to connect the electrode to the negative terminal (straight polarity) to keep the heat losses minimum. However, in case of welding aluminum and magnesium it is preferable to use AC power supply.

Non consumable electrodes are usually made of Tungsten, Graphite or carbon: When non consumable electrodes are used processes are named after the electrode material like tungsten arc welding (tungsten is used as electrode) or carbon arc welding (carbon is used as electrode).

Electric resistance welding: -

Electric resistance welding is a fusion welding process where both heat and pressure are applied on the joint but no filler material or fluxes are added. Resistance welding is based on well-known principal that heat is generated by the resistance offered to flow of current. Resistance welding has wide applications in welding of sheet metal of all engineering material (except Cu, Ag), automobile and aircraft industries, pipe and tubing production.

A resistance welding is a pressure welding. When a high current is supplied through the work pieces high resistance produces at the point of contact. The high current and high resistance generate intense heat required for the welding purpose. A pressure is then applied to complete the weld. No filler metal is needed.

Types Of Electrical Resistance Welding: -

The electric resistance welding may be classified as follows:

1. Spot welding,
2. Roll spot and seam welding,

3. Projection welding,
4. Butt welding, and
5. Flash welding.

We shall now discuss these types of electric resistance welding, in detail. in the following articles.

<u>Spot Welding: -</u> The spot welding is used for welding lap joints, joining components made from plate material having 0.025 mm to l.25 mm in thickness. The plate thickness is limited by the pressure and current capacity of the available spot-welding machine. The plates to be joined together are placed between the two electrode tips of copper or copper alloy. A low Voltage and high amperage current is passed between electrodes, causing the metal temperature to be raised to welding temperature. The heat generated by the electric current is rapidly transferred from the outer faces of the plates to the electrodes which are water cooled. The pressure is applied which squeezes the metal together and thus completes the weld' A spot welding machine is shown in Fig. The spot welding is used for welding most of the ferrous and non-ferrous alloys. It is widely used in manufacturing automobiles, refrigerators and other metal stamping assemblies.

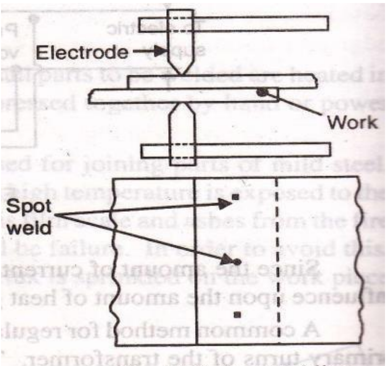


Fig. 15.9. Spot welding.

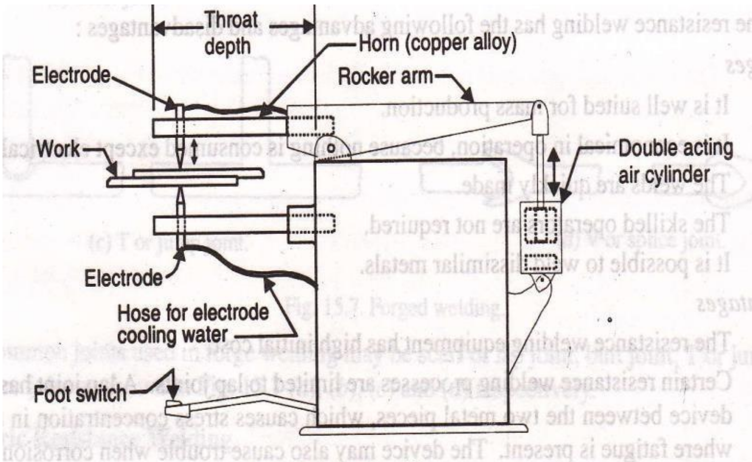


Fig. 15.10. Spot welding.

Spot welding is a resistance welding process in which over-lapping sheets are joined by local fusion at one or more spots by the heat generated by resistance to the flow of electric current through work pieces that are held together under force by two electrodes, one above the other below the two overlapping sheets.

Procedure-

The steps involved in making a spot weld are listed below and shown in figure but before spot welding, one must make sure that

i) The job is clean, i.e., free from grease, dirt, scale, oxide etc.

ii) Electrode tip surface is clean, since it has to conduct the current into the work with as little loss as possible. Very fine emery cloth may be used for routine cleaning.

iii) Water is running through the electrodes in order to

  a) cool the weld
  b) Avoid them from getting overheated and thus damaged.

iv) Proper welding current has been set on the current selector switch.

v) Proper time has been set on the well timer.

Step-I

Electrodes are brought together against the over-lapping work pieces and pressure is applied so that the surfaces of the two work-pieces under the electrodes comes in physical contact after breaking any unwanted film existing on the work-pieces.

Step-II

Welding current is switched on for a definite period of time. The current may be of the order of 3000 to 10000 A for a fraction of second to a few seconds depending upon the nature of material and its thickness. As the current passes through one electrode and work-pieces to the other electrodes, a small area where the work-pieces are in contact is heated. The temperature of this weld zone is approximately 815°C to 930°C.

Step-III

At this stage, the welding current is cut off. Extra electrode force is then applied or the original force is prolonged. This electrode force or pressure forges the weld and holds it together while the metal cools down and gains strength.

Step-IV

The electrode pressure is released to remove the spot welded work-pieces.

Roll Spot And Seam Welding:- When the spot welds on two over-lapping pieces of metal are spaced, the process is known as roll spot welding. If the spot welds are sufficiently made close so that they overlap and make a leak proof seam (i.e., joint), the process is called seam welding. The typical applications of seam welding include sheet metal radiator and drums where both longitudinal and circumferential lap joints are used.

Seam welding is a continuous type spot welding over the two overlapping metal plates or sheets. The work pieces are allowed to pass between two copper wheels or a roll which acts as electrodes. The wheels also apply the pressure on the work pieces. When currents supplied to the electrode high heat is produced on the work pieces, at the same time the work pieces are passed continuously between the rolls and a continuous weld is formed.

The work pieces to be welded are passed between the rotating discs or wheel shaped electrodes (of copper alloy) which are in the form of rollers. These electrodes are not separated after each individual weld as in spot welding, but maintain a continuous pressure on the work. The current passing from roller to roller through the work piece heats up the parts to be joined and the pressure on the roller electrodes forms the weld. The cooling is accomplished by flooding the electrodes and metal pieces with water. This process is best adopted for metal thickness ranging from 0.025 mm to 3 mm. it is used to join tanks, barrels, pressure vessel etc.

Projection Welding: - It is a kind of resistance welding on one side of the work pieces. Small projections are raised on one side using a die and punch. The two work pieces are placed between two copper electrodes. The two electrodes are clamped between fixed and movable arms. When current is passed, heat is produced due to electrical resistance; mechanical pressure is applied by pressing the movable arms. The two plates are joined together at the point of contact.

It is similar to spot welding except that one of the metal pieces to be welded has projections on its surface at the points where the welds are to be made. These projections should extend about 1 mm above the surface to be welded. The projections are readily made with punch presses by embossing. The contact between the two metal pieces to be joined is made at the projections. When the welding current passes through these projections, they are melted and flattened, allowing the two surfaces to come together. The melted projections become the welds.

This process is used for cross-wise welding and for parts where the ridges are produced by machining. It is most suitable for large quantity production. The main advantages of projection welding over spot welding are as follows:

1. It is a quick process and number of welds can be made simultaneously. The ideal number of projections is three and the maximum number of projections which can be used satisfactorily is about six.
2. The welds may be more closely spaced than is possible with spot welding.
3. There is no thickness limitation.
4. The life of the electrodes used is much longer as compared with the life of spot-welding electrodes.

Notes: 1: - When two pieces of different metals arc to be welded by projection welding, then the projections should be made on the metal piece with the higher conductivity.

2: When the two metal pieces are of different, thicknesses, the projections should be MS & on the thicker metal piece.

Butt Welding: - A type of resistance welding which produces a butt weld between the ends of two metal rods is known as resistance butt welding.

The butt welding is of the following two types:

(a) Upset butt welding, and (b) Flash butt welding.

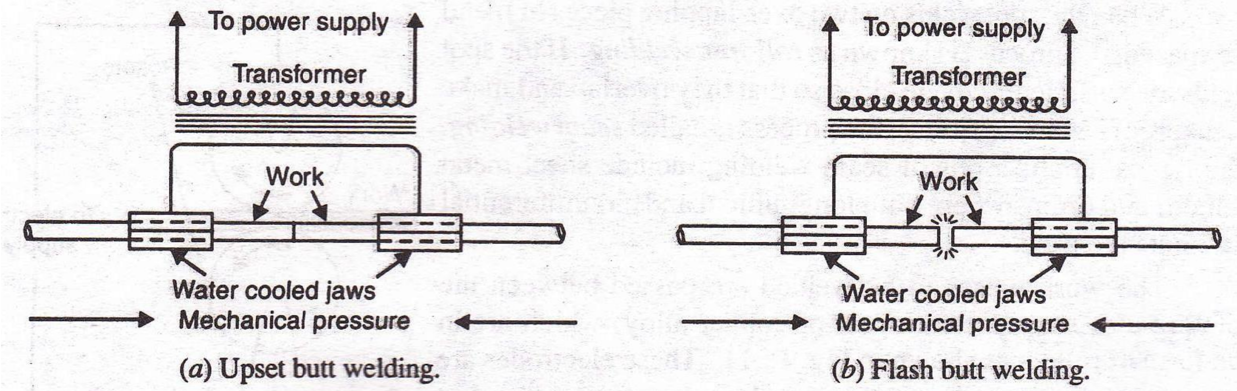


Fig. 15.13. Butt welding.

In upset butt welding, the two parts of metal having the same cross-section are held by two heavy water-cooled copper jaws and forced together. The heat is generated in the contact surface by the electrical resistance when a suitable electric current flows across the joint. When the metal at the joint is heated sufficiently, the pressure is applied by the two jaws in order to force the two pieces together. The upset butt welding is especially applied for joining ends to ends of rods, pipes, small structural shapes and many other parts of uniform section.

In flash butt welding, the parts to be welding are clamped in copper jaws of welding machine. The heat required for the welding operation is derived from the arc that occurs in the space between the parts to be joined, in this process, the ends to be welded are pushed together and immediately after contact is made, they are separated by a short distance. In separating, an arc is formed which heats the ends of the pieces to the fusion temperature. After the ends are fused, the current is shut off and the pieces are forced together. In this process, a slight burr is produced when the two sides are forced together, forming what is called a flash (i.e., a ragged line of extruded material which can be machined or ground away). This process is used extensively in the manufacture of steel containers and in the welding of mild steel shanks to high-speed steel drills and reamers.

Flash welding: - Flash welding is a resistance welding process wherein coalescence is produced, simultaneously over the entire area of abutting surfaces by the heat obtained from resistance to electric current flow between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.

Principle of operation –

The sequence of operations required for flash welding is given below.

i) Flash-butt welds are made on a machine having one stationary and one opposing movable platen, on which are mounted the flash-welding dies or clamps. These clamps securely hold the two work-pieces to be welded while simultaneously serving to conduct the welding current through these work-pieces.

ii) The work-piece held in the movable platen is brought towards the one gripped in the stationary platen until the two come in light contact, and as the welding current (with voltage sufficiently high) is turned on, flashing is established. While incandescent metal particles are being expelled by flashing the movable platen keeps on moving constantly towards the stationary one at a carefully controlled and accelerated rate. As the flashing continues, the ends of the two work-pieces burn off as they reach a higher and higher temperature until finally, they attain the welding temperature.

iii) At this stage, the pressure of the moving clamp is quickly and greatly increased to (upset) forge the parts together and expel the molten metal and slag out of the joint thereby making a good solid weld. The metal expelled forms a ragged fin or flash around the joint which is removed later on by cutting or grinding.

iv) The welding current is cut off and the work-pieces are unclamped as the fusion weld cools.

<u>Welding Defects: -</u>

During welding process if proper care is not taken the following defects may arise. They may be because of the faulty technique used by operator or sometimes they are inherent in the Process:

1. Incomplete fusion
2. Slag inclusion or oxides
3. Poor penetration
4. Porosity
5. Cracking
   (a) Hot-cracking
   (b) Cold cracking

(1) Incomplete fusion: -

Incomplete fusion results from poor joint preparation improper, cleaning, incorrect welding parameter like welding current. If welding current is lower than the required all the faces or joint would not be sufficiently heated to promote Proper fusion.

(2) Oxides and slag inclusion: -

Oxidation is the number one enemy to welding and they should be removed because they tend to get entrapped in the solidifying metal. Fluxes are after used to remove oxides. Fluxes react with oxides and other impurities and form and slag which being lighter floats on the top of weld pool. However, some timer because of stirring action slag goes into the weld pool and there is not enough time for it to' float. It may get solidified inside the fusion zone and ends up as slag inclusion.

(3) Poor penetration: -

Poor penetration results from too little heat input. Because welding on cool base metal requires low travel speed and as the base metal absorbs heat and temperature rises, speed may be increased. It may be also caused because of the incorrect edge preparation and may lead to cracking.

(4) Porosity: -

It results from oily, wet or dirty base metal and insufficient gas shielding. It is also caused by presence of gases such as hydrogen, oxygen and nitrogen which get entrapped during solidification. Hydrogen is the main cause of porosity in weld. Hydrogen is absorbed by weld pool if an incorrect welding technique is applied.

(5) Cracking: -

Cracking is one of the most serious defects and may occur due to incorrect welding technique or using a filler material having different rate of contraction compared to that of parent metal. It may occur at two stages during the cooling of weld metal.

(a) Hot cracking: -

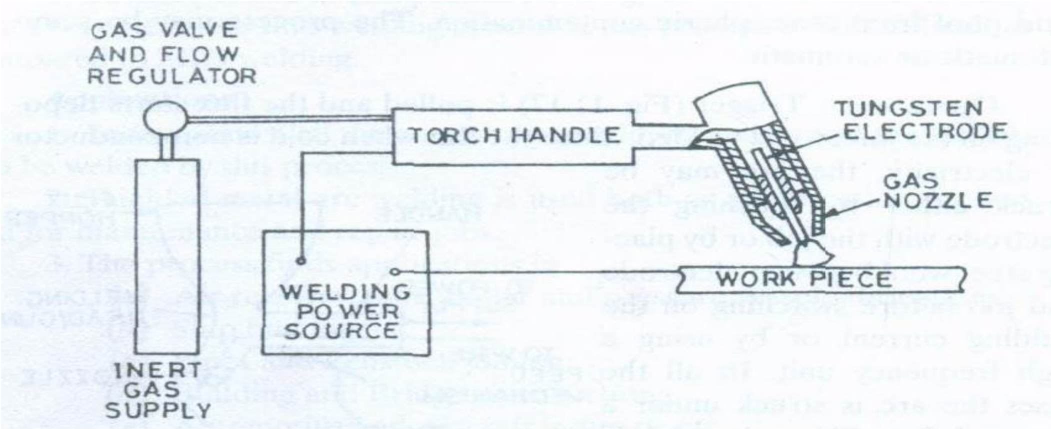
Hot cracking is influenced by the Sulphur and carbon contents of mild steel weld metals. The hot cracking can be avoided by using sufficient manganese. It can also be prevented by preheating the base metal and increasing the cross-sectional area of root weld bead.

(b) Cold cracking: -

Cold cracking occurs at room temperature after the weld is completely cooled and can be seen in heat affected zone. Cold cracking can be reduced by pre and post heating of the weldments and reducing the cooling rates.

TUNGSTEN INERT GAS (TIG) OR GAS TUNGSTEN ARC WELDING (GTAW): -

Definition: - It is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job. A shielding gas (argon, helium, nitrogen, etc.) is used to avoid atmospheric contamination of the molten weld pool. A filler metal may be added, if required.



TIG welding equipment

Principle of Operation: -

Welding current, water and inert gas supply are turned on. The arc is struck either by touching the electrode with a scrap tungsten piece or using a high frequency unit. In the first method arc is initially struck on a scrap tungsten piece and then broken by increasing the arc length. This procedure repeated twice or thrice warms up the tungsten electrode. The arc is then struck between the electrode and pre-cleaned job* to be welded. This method avoids breaking electrode tip, job contamination and tungsten loss. In the second method, a high frequency current is superimposed on the welding current. The welding torch (holding the electrode) is brought nearer to the job. When electrode tip reaches within a distance of 3 to 2 mm from the job, a spark jumps across the air gap between the electrode and the job. The air path gets ionized and arc is established.

After striking the arc, it is allowed to impinge on the job and a molten weld pool is created. The welding is started by moving the torch along the joint as in oxy-acetylene welding. At the far end of the job, arc is broken by increasing the arc length. The shielding gas is allowed to impinge on the solidifying weld pool for a few seconds even after the arc is extinguished. This will avoid atmospheric contamination of the weld metal. The welding torch and filler metal are generally kept inclined at angles *of* 70-80° and 10-20° respectively with the flat work-piece. A leftward welding technique may be used. Filler metal, if required, should be added by dipping the filler rod in the weld pool. When doing so, the tungsten electrode should be taken a little away from weld pool. During welding operation, alternatively filler rod and tungsten electrode will withdraw and come closer to the weld pool. This procedure will avoid contamination front the tungsten electrode. Introducing and withdrawing of filler rod into the molten weld pool may disturb the inert gas shielding, entrain air, oxidize filler rod end and thus contaminate the weld pool. In order to avoid these problems, it is preferred to keep the heated end of the filler rod always within the inert gas shield even when withdrawing the same from weld pool during welding.

Equipment: -

(a) Welding Torch, tungsten electrode and filler metal.
(b) Welding power source, high frequency unit, DC suppressor unit and cables.
(c) Inert gas cylinder, pressure regulator and flow meter.
(d) Cooling water supply.
(e) Water and gas solenoid valves.

Welding torch which may be air or water-cooled, energizes the tungsten electrode held in a collect and feeds shielding gas to the weld puddle. When welding above 150 amps, generally a water-cooled torch is preferred.

The electrode material may be tungsten, or tungsten alloy, *i.e.,* thoriated tungsten or zirconated tungsten. Alloy-tungsten electrodes possess higher current carrying capacity, high resistance to contamination and produce a steadier arc, as compared to pure tungsten electrodes. When welding copper in nitrogen atmosphere, alloy-tungsten electrodes are preferred because nitrogen attacks liquid (pure) tungsten; but, for the welding of aluminum under argon shielding, pure tungsten electrode is more suitable. Fig. 11.20 shows the electrode geometry for AC and DC welding.

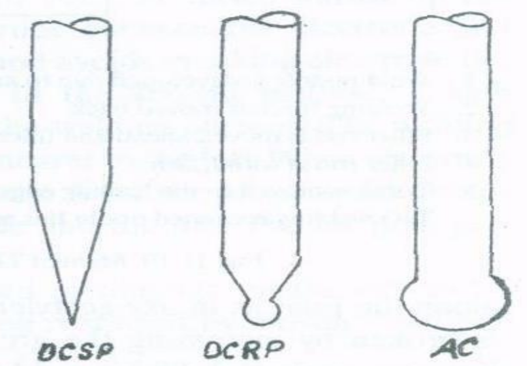


Fig. 11.20. Geometry of tungsten electrodes

A filler rod is generally used when welding thicker pieces with edges prepared. Preferably the filler rod should possess the similar chemical composition and be of the diameter same as the thickness of the work piece to be welded. Filler metals up to 4.5 mm diameter in the form of straight lengths or coils are available for TIG welding of different metals and alloys.

Both DC and AC welding machines with good current control can be used for TIG welding. DC is preferred for welding of stainless steel, nickel, copper and copper alloys whereas DCRP or AC is used for welding magnesium, aluminum and their alloys. Reverse polarity of current removes oxide film on aluminum and magnesium.

When using AC, a *high frequency unit* is employed to keep the arc ignited and stabilized. A *DC suppressor unit* is incorporated in the electrical circuit to balance the current wave. A DC suppressor unit reduces the effect of DC component of current which comes into operation due to the fact that arc voltage is more when electrode is positive, than when it is negative. In the absence of a DC suppressor unit, arc may blow and behave erratically and the transformer may become saturated, over-heated and derated.

Inert gases ordinarily used in TIG welding are

(i) Argon
(ii) Helium
(iii) Argon-helium mixtures
(iv) Argon-oxygen mixtures,
(v) Argon-hydrogen mixtures.

Pressure regulator and flowmeter are used respectively to step down the inert gas pressure from cylinder pressure (approx. 140 kg/cm^2) to working pressure (1-1.5 kg/cm^2) and to feed the same at a definite flow rate (4.12 1pm) to the welding torch. For welding mild steel, aluminum and its alloys, copper, nickel and their alloys and stainless steel, generally argon, helium or a mixture of argon and helium can be used. Argon is preferred for welding bronzes and argon or helium can be employed for the welding of titanium and magnesium.

Gas and water solenoid valves if incorporated in the system, control the respective flows, *i.e.,* they start the gas and water flow before the arc ignites and stop the same after the welding is over, tungsten electrode has cooled and weld metal has solidified.

Base Metals welded

(I) Carbon and alloy steels, (ii) Stainless steels,
(iii) Heat resisting alloys, (*iv)* Refractory metals,
(v) Aluminum alloys, (*vi)* Copper alloys,
(vii) Magnesium alloys (VIII) Nickel alloys, etc.

TIG welding is well adapted to weld thicknesses up to 6 mm.

<u>Joint Design: -</u>

— *Bull, Lap, Comer, Edge,* and *T* Joint — are all used in TIG welding. •
— A square groove but joint is used for smaller thicknesses.
— A single V-groove butt joint is required for base metal thicknesses between 4.8 and 9.6 mm.

The included angle of V- groove is 60° and root face 3.2 to 6.4 mm.

— A double V-groove butt joint is generally used on base metals thicker than 12.5mm.
— A corner joint is used for fabricating boxlike structures.
— An edge joint does not usually require the addition of filler metal.

METAL INERT GAS (MIG) OR GAS METAL ARC WELDING (GMAW): -

Definition: -

It is an arc welding process wherein coalescence is produced by heating the job with an electric arc established between a continuously fed metal electrode and the job. No flux is used but the arc and molten metal are shielded by an inert gas, which may be argon, helium, carbon dioxide or a gas mixture.

Principle of Operation (Semi-automatic process): -

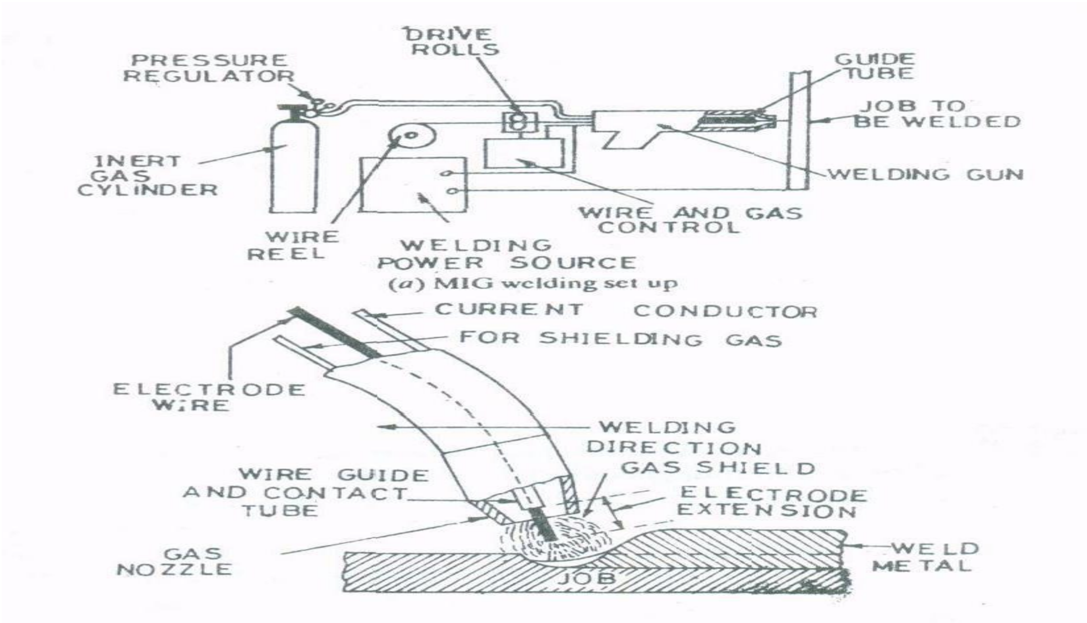
Before igniting the arc, gas and water flow is checked. Proper current and wire feed speed is set and the electrical connections are ensured. The arc is struck by any one of the two methods. *In the first method* current and shielding gas flow is switched on and the electrode is scratched against the job as usual practice for striking the arc. *In the second method,* electrode is made to touch the job, is retracted and then moved forward to carry out welding; but before striking the arc, shielding gas, water and current is switched on. About 15 mm length of the electrode is projected from the torch before striking the arc. During welding, torch remains about 10-12 mm away from the job and arc length is kept between 1.5 to 4 mm. Arc length is maintained constant by using the principles of *self-adjusted arc,* and *self-controlled arc* in semi-automatic (manually operated) and automatic welding sets respectively.

Equipment: -

(a) Welding power source and cables.
(b) Welding torch and wire electrode coiled on a spool.
(c) Wire feed mechanism and controls consisting of a pair of driving rolls, electric motor, etc.
(d) Shielding gas cylinder, pressure regulator and flow meter.
(e) Controls for switching on and off the current, electrode wire and inert gas.

Power sources possessing flat or drooping characteristics and rated at 400 Amps can be employed for MIG welding. Flat characteristic welding sources ensure a more constant arc length. The major types of power sources are DC generator or AC transformer with rectifier. DC electrode negative produces weld with shallow penetration and thus can be used on thinner sections. DC electrode positive is preferred (when welding aluminum and magnesium) for its better arc cleaning action. DCRP also provides deeper penetration. AC is generally not recommended because of unequal burn off rates during negative and positive half cycles.

The welding torch energies the electrode, feeds the electrode and the shielding gas. The torch may be air-cooled or water-cooled. Torches working above 200 Amps are generally water-cooled. The torch may have a straight or bent nozzle fitted on the end (Fig.). Bent nozzles can be used for welding complicated shapes and intricate joints.



MIG welding torches

Wire feed mechanism may deliver electrode to the torch at a constant speed or at different speeds. The wire spool, in manually operated units, is mounted elsewhere to facilitate welding over a bigger area whereas in automatic machines, the wire spool is fixed on the same carriage over which the torch is mounted. The different diameters of the electrode wire are 0.8, 1.2, 1.6 mm, etc. A standard wire spool may have from 1 to 15 kgs of wire. Steel electrodes are generally copper coated. As far as possible, the chemical composition of the work piece and that of the electrode should be similar; of course, there may be the addition of deoxidizers. Electrodes are available for welding aluminum, magnesium, nickel, their alloys, carbon, low alloy and stainless steels, etc.

The function of a **shielding gas** is to protect the molten metal and the electrode end against atmospheric contamination. A number of shielding gases and gas mixtures, like argon (for welding Al, Mg, Cu, Ni, It), helium (for welding Al, Mg, Cu), carbon dioxide (for welding mild steel), nitrogen (for welding copper), argon 4-(1-5%) Oxygen (for welding Al, low alloy and carbon steels, stainless steels), argon + CO_2 (for welding mild steel, low alloy and stainless steel), argon + helium + CO_2 (for welding austenitic stainless steels), argon + helium (for welding Al, Cu, Ni and their alloys), have been used in MIG welding. Helium and CO_2 help increasing penetration whereas argon reduces spatter loss.

Solenoid valves and relays may be incorporated in the system to put on and. off gas, water and wire feed mechanism.

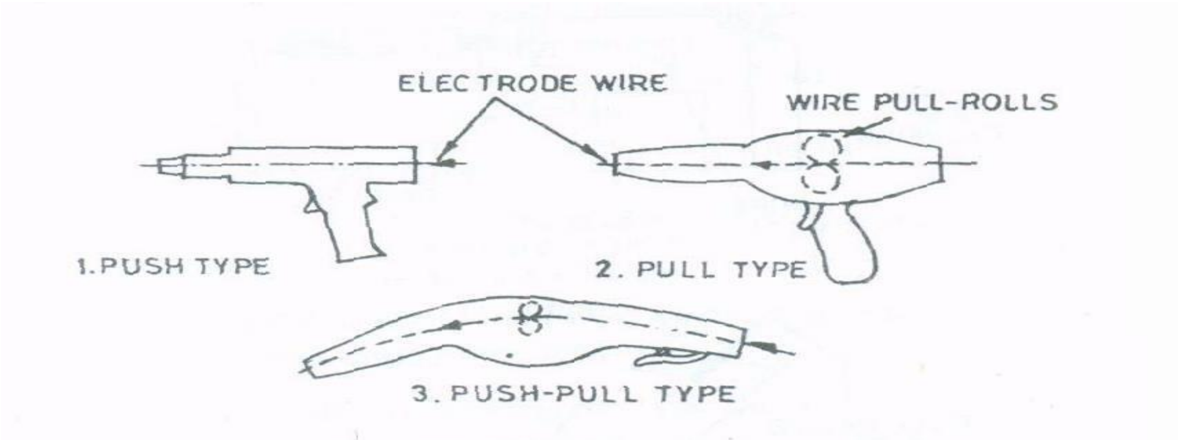


Fig. 11.22 MIG welding torches

Metals Welded.

Base metals commonly welded by MIG welding are:

(i) Carbon and low alloy steels,
(ii) Stainless steels,
(iii) Heat resisting alloys,
(iv) Aluminum and its alloys,
(v) Copper and its alloys (other than high zinc alloys), and
(vi) Magnesium alloys.

Joint Design.

MIG welding is applicable to the following types of joints:

(i) Butt,
(ii) Lap,
(iii) T,
(iv) Corner,
(v) Edge.

CASTING

Casting is the process of producing metal or alloys component parts of desired shape by pouring the molten metal or alloys in a prepared mould of that shape and then allowing the metal or alloys to cool and solidify.

Classification of Casting

Metal Casting Process

Expandable mold casting | **Non expandable mold casting**

Expandable mold casting

i) sand casting
ii) shell mold casting
iii) investment casting
iv) carbon dioxide mold casting

Non expandable mold casting

i) permanent mold casting
ii) die casting
iii) centrifugal casting

Procedural steps of sand casting: -

- Make the pattern out of wood, metal or plastic.
- In case of sand casting select, test and prepare the necessary sand mixture for mould and core making.
- With the help of pattern prepare the mould and necessary cores.
- Melt the metal or alloy to be cast.
- Pour the molten metal or alloy into the mould and remove casting from the mould after the metal solidify.
- Clean and finishing the casting.
- Test and inspect the casting.
- Remove the defects, if any.
- Relief the casting stress by heat treatment.
- Again, inspect the casting.
- The casting is ready for shipping.

Foundry Tools and Equipment's: -

The foundry tools and equipment are divided in to the following five groups: -

i. Hand Tools,
ii. Molding boxes (Flasks),
iii. Molding Machines,
iv. Melting Equipment's, and
v. Pouring Equipment's.
vi.

Type Of molding Sands with Their Composition & Property & Specify Different Binding Materials: -

1. Green sand molding: -It is the most widely used molding process. The green sand used for molding consists of silica sand, clay, water and other additives. Typical green sand mixture contains 10 to 15% clay binder, 4 to 6% water and remaining silica sand. The green mixture is prepaid and the mold (cope and drag) is made by packing the same around the pattern. Cope and drag are assembled and molten metal is poured while is made by packing the same around the pattern. Green and molding is preferred for making small and medium sized castings.

2. Dry sand molding: -Dry molding sand differs from the green molding sand in the sense that it contains binders (like clay, Bentonites, molasses etc.) which harden when the mold is heated and dried. A typical dry sand mixture (for making non-ferrous castings) consists of floor sand 40%, new silica sand 30% coal dust 20% and betonies 10%. A dry sand mold is prepaid in the same manner as a green sand mold however it is baked at 300-to-700-degree F for 8 to 48 hours depending upon binders used and the amount of sand surface to be dried.

3. Skin-dried molding: -A skin-dried mold is intermediate between green sand mold and dry sand mold. Whereas a dry sand mold has its entire surfaces dried, a skin dried mold has its (6 to 25mm) skin dried. Moisture from the skin is removed either by storing the mold for some times or with the help of gas torches. Skin dried molding possesses partially the advantages of both green and dry sand molding. Large molds and molds for pit molding are skin- dried.

The molding sand is the principal element used in the foundry shop for molding. Principal ingredients of molding sands are silica and grain, clay, moisture and miscall anions materials.

4. Loam molding: - The mould made with loam sand is called loam mould. The loam sand also contains fire clay. The loam mould is similar to pit mould and are used for large work where the pattern required will be too expensive to make. The mould is first built up with bricks or large iron parts. These parts are then plastered with a thick loam sand mixture consisting of silica (22 volumes). Clay (5 volumes), coke (10

%) and moisture (18 – 20 volumes). The shape of the mould is obtained by either with sweep or skeleton pattern.

5. Metal molding: - The mould made of metal is called metal mould. The metal mould is used in casting of low melting temperature alloys. Since the casting produced by metal mould has a smooth finish, therefore much of the machine work is eliminated.

Molding sands: -

Molding sand should possess certain desirable properties and they are:

- **Flowability**
  Flow ability is the ability of the molding sand to get compacted to a uniform density. Flow ability assists molding sand to flow and pack all-around the pattern and take up the required shape.
- **GreenStrength**
  it is the strength of the sand in the green or moist state. A mold having adequate green collapse, even after the pattern has been removed from the molding box. Green strength helps in making and handling the molds.
- **Drystrength**
  It is the strength of the molding sand in the dry condition. A mold may either intentionally be dried, skin dried or a green sand mold may lose its moisture and get dried while waiting for getting poured or when it comes in contact with the molten metal being poured. Dry and strength is related to grain size, binder and water content.
- **HotStrength**
  It is strength of the sand (of mold cavity) above 212-degree F or 100 degree C in the absence of adequate hot strength, the mold may enlarge, break, erode or get cracked.
- **Porosity**
  While being poured, the molten metal comes in contact with green sand mold cavity and cores made up of core sand. The moisture, binders (organic compounds) and additives present in a, produce steam and other gases, though much of these gases escape through vents and open feeder heads yet a good amount same tend to pass through the pore spaces of the molding sand. Thus, to provide a path for free escape of the gases, the molding sand should be permeable or porous. Sands which are coarse or have rounded grains exhibit more permeability. defects like surface blows, gas holes, mold blast etc. may be experienced.

- **Refractoriness**

  It is the ability of molding sand to withstand high temperatures (experienced during pouring) without fusion. Cracking, buckling or scabbing, experiencing any major physical change.

- **Adhesiveness**

  It is the property of molding sand owing to which, it sticks with the walls of molding boxes, sticks with gaggers, and thus make it possible to mold cope and drag.

- **Collapsibility**

  Collapsibility is that property of the molding sand or mold, automatically get collapsed after casting solidifies and break down in knock out and clearing operations.

- **Fineness**

  Finer sand molds resist metal penetration and produce smooth casting surfaces. Fineness and permeability are in conflict with each other and hence they must be balanced for optimum result. Fineness permeability both the properties of molding sand can by maintained by using mold coating on highly permeable mold cavity walls.

- **BenchLife**

  It is the ability of the molding sand retain its properties during storage or while satang (i.e., in case of any delay)

- **Coefficientofexpansion**

  Molding sand should possess low coefficient of expansion.

- **Durability**

  The molding sand should possess the capacity to withstand repeated cycle of heating and cooling during casting operations.

- **Molding sand should be chemically immune to molten metals.**
- **Molding sand should be reusable.**
- **It should be easy to prepare and control the molding sand.**

The molding sand may be classified into:

- **Natural sand: -** The natural sand is one which content sufficient clay. The natural sands have advantages of simplicity in their preparation, handling and use.
- **Synthetic sand: -** The synthetic sand one which is artificially compound by missing sand grains and selected type of clay. These sands have lower cost in larger volume.

- **Special sand: -** The special sand content mixture in organic compounds. This sand cost more and produces better cast surface and better high temperature stability.

The moulding sands are classified as:

(i) Green sand: The sand in its natural state or moist state is called green sand. It also called temperature sand. It is mixture of silica sand with 20 to 30 percent clay, having total amount of water from 6 to 10%. The mould prepared with this sand are called green sand mould. It is used for small size casting of ferrous and non-ferrous metals.

(ii) Dry sand: The green sand moulds when dried before pouring the molten metal are called dry sand moulds. The sand is dry sand. The dry sand moulds have greater strength. These are used for large and heavy casting.

(iii) Loam sand: A mixture of 50% sand grain and 50% clay is called loam sand. It is used for large grey iron casting.

(iv) Facing sand: Sand use for facing of mould is called facing sand. It is a mixture of silica and clay, without addition of used sand. The thickness of layer of facing sand in a mould range from 20 to 30 mm and is used directly next to the surface of the pattern. It possesses high strength and refractoriness.

(v) Backing sand: Sand used to back up the facing sand not used next to the pattern is called backing sand. This sand which has been repeatedly used, may be employed for this purpose. It is also known as black sand.

(vi) System sand: Sand employed in mechanical sand preparation and handling system is called system sand.

(vi) Parting sand: Sand employed on the faces of the pattern before molding is called parting sand. The function of the parting sand is that when the pattern is withdrawn, the face of the mould impression is damaged by adhesion of grain of sand. It consists of dried silica sand, sea sand, burnt sand etc.

(viii) Core sand: Sand used for the preparation of cores is called core sand. It sometimes called oil sand. It is the silica sand mixed with linseed oil or any other oil as binder.

(ix) Molasses sand: Sand which carries molasses as a binder is called molasses sand. It is used for making moulds of small castings of intricate shapes.

Sources: -

River Beds, Sea, Lakes, Deserts etc.

Ingredients: -

- Refractory sand grains.
- Binders.
- Water.
- Additives.

<u>Binding Materials: -</u>

i. As compared to molding sands binders are less refractory.
ii. Binders produced cohesion between the molding sand grains in the green or dry state.
iii. Binders give strength to the molding sand so that it can retain its shape as mold cavity.
iv. Increasing binder contain to a limit increases green compression strength; after which green compression strength remains practically unchanged with further increase in binder contain.
v. Clay binders are most commonly used for bonding molding sands. Clay binders can be classified as:
   a. Fire Clay.
   b. Bentonite
   c. Sodium Montmorillonite
   d. Calcium Montmorillonite.
   e. Illite.
   f. Limonite.
   g. Kaolinite.
   h. Clay is inorganic binders.
vi. The best clay is one which imparts that the optimum combination of bonding properties, moisture, life and cost of producing the required casting.
vii. A clay binder which produces a thin and adhesive film around the molding sand grains and thus makes the bond stronger is the best.

<u>Pattern And Various Pattern Allowances: -</u>

Pattern may be defined as a model or replica of desired casting which when moulding in sand forms an impression or cavity called mould. A pattern is a model or replica of the object to be cast.

<u>Functions:</u> -

- A pattern prepares a mould cavity for the purpose of making a casting.
- A pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.
- Runners, Gates, Risers (used for introducing and feeding molten metal to the mould cavity) may form a part of the pattern.
- Pattern establishes the parting line and parting surface in the mould.
- Patterns properly made and having a finished and smooth surface reduces casting defects.

For selecting a particular kind of pattern for making a casting, one may consider the following points:

- Quantity of castings to be produced.
- The size and complexity of the shape of the casting to be produced.
- Types of molding methods to be used.
- Problems associated with the molding operation such as withdrawing the pattern from the mold, etc.
- Other difficulties resulting from the poor casting design or pattern or pattern design.

Material For Making Pattern: -

The common materials used for making pattern are Wood, metal, plastic, wax, plaster, etc.

Types of Patterns: -

- **One piece or solid pattern: -** A single piece or solid pattern is a compact form made from wood. It has no joints, partings or loose pieces in its construction. It has usually one board surface or flat surface that serves as parting surfaces in the mould. This type of pattern is use for a limited number of castings, because most of the molding operations like parting surface formation, cutting of gating system, providing runners and risers, withdrawal of pattern etc. is done by hand.
- **Split pattern: -** Most of the patterns are not made in a single piece because of the difficulties encountered in mounding, in order to eliminate these difficulties some patterns are made into two or more pieces. This pattern made from wood, consisting of two pieces is also called two-piece patterns. One half of the pattern rests in the lower part of the moulding box known as drag and other half in the upper part of the moulding box known as cope. The line of separation of the parts is called parting line.
- **Loose piece pattern: -**A pattern has been made with projections or overhanging part; these projections make the removal of the pattern. Therefore, such projections are made in loose pieces and are fastened loosely to the main pattern by means of wooden or wire dowel pin. These patterns are made from wood or metals.
- **Match plate pattern: -**The match plates are used in machine moulding for quantity production of casting. A single pattern or a number of single piece pattern mounted on a match plate, when a cope & drag portion of the split pattern are mounted on opposite side of the wooden plate, the pattern is called match plate pattern. The gates,

runners & risers are permanently fastened to the drag side of plate in their correct position in order to form a complete match plate pattern.

- **Cope and Drag pattern: -**When very large casting are to be made, the complete mould becomes too heavy to be handled by a single operator, in order to omit this problem the cope & drag pattern is used. Cope & drag pattern is a simple two pattern split in a convenient joint line. One part is moulded in a cope and the other part in a drag of the moulding box.
- **Sweep pattern: -**The moulds of large size and symmetrical in shape particularly of circular section can be easily prepared by using a sweep instead of a full pattern. It is not considered as a true pattern when compared with others. A sweep is a template of wood or other material which has the shape corresponding to the shape and size of casting. It is arranged to rotate about a central axis by mounting it on a spindle. The sand is rammed in place with a cavity of approximately similar shape d size to that of the required mould. Now by revolving the sweep, the desired shape of the mould is generated. The sweep and the spindle are then removed and the hole in the Centre is filled up.
- **Gated pattern: -**Gated pattern is used for mass production of small casting. When a number of small patterns are placed in a single mould, then each pattern may be provided with a gate with it. It consists of pieces of wood or metal fixed to the pattern to form the runner and rising channel in the mould. In this way, full supply of the molten metal flows into every part of the mould.
- **Skeleton pattern: -**When a few and large sized casting are required, it is not advisable to use a large solid pattern of that size, as it will require a lot of wood and time to make a full pattern. In such cases, a skeleton pattern in the hollow form, consisting of a wooden frame and strip is used. The frame work is filled and rammed with loam sand and a strickle board is used to scrap the excess sand out of the spaces between the ribs so that the surface is even with the outside of the pattern. The skeleton pattern is made in two halves, one for the cope and the other for the drag. After taking the impression, the cope and the drag are assembled together with the core in position to form the complete mould. The skeleton patterns are used for casting of hollow cast iron pipe, bends, valve bodies, boxes, etc.
- **Segmental Pattern: -**The segmental patterns are also known as part patterns. These patterns are sections of a pattern so arranged as to

form a complete mould by being moved to from each section of the mould. These patterns are usually applied to circular work such as rings, wheel rims, gears etc.

When a mould is to be made using a segmental pattern, a vertical spindle is firmly fixed in the centre of a drag flask. The mould bottom is rammed and swept level. Now the segmental pattern is fastened to the spindle. The moulding sand is rammed between the outside of the pattern and the flask and on the inside except at the ends of the pattern. After ramming one segment, the next segment is rammed, and so on until entire perimeter of the mould is completed.

- **Follow board pattern: -**A follow board pattern is used for solid patterns having an irregular parting line. It may be used with either single or multiple gated patterns. The patterns requiring follow boards and the boards routed out so that the patterns rests in it up to the parting line and this board then acts as a moulding board for the first moulding operation. The follow board supports the mouldind cavity with moulding sand at the bottom side of moulding box.
- **Shell pattern: -**The shell pattern is used largely for drainage fittings and pipe works. This type of pattern is usually made of metal mounted on a plate and parted along the centre line; the two sections being accurately doweled together. The short bends are usually moulded and cast in pairs. The shell pattern is a hollow construction like shell. The outside shape is used as a pattern to make the mould while the inside is used as a core box for making cores.

Various Pattern Allowances: -

A pattern is always larger in size as compared to the final casting because it carries certain allowances due to metallurgical and mechanical reasons for example, shrinkage allowance is the result of metallurgical phenomenon whereas machining, draft, Shake and other allowances are on the patterns because of mechanical reasons .

The various pattern allowances are: -

i. Shrinkage or contraction allowances.
ii. Machining or finish allowances.
iii. Draft or tapper allowances.
iv. Distortion or camber allowances.
v. Shake or rapping allowances.

- **Shrinkage or contraction allowances: -**

Almost all cast metals shrink or contract volumetrically after solidification and therefore the pattern to obtain a particular sized casting is made oversize by an amount equal to that of shrinkage or contraction.

Different metal shrinks at different rates because shrinkage is the property of the cast metal or alloy.

The metal shrinkage depends upon:

i. The cast metal or alloy.
ii. Pouring temperature of the metal or alloy.
iii. Casting Dimensions.
iv. Casting design and aspects.
v. Molding condition.
vi. Cast iron poured at higher temperatures will shrink more than that poured at lower temperature.
vii. Harder grades of cast iron shrink more than the softer grades of cast iron.

- **Machining or finish allowances: -**

A casting is given allowances for machining, because:

i. Casting gets oxidized in the mold and during the heat treatment; scales; etc., thus form need to be removed.
ii. It is intended to remove surface roughness and other imperfections from the casting.
iii. It is requiring achieving exact casting dimensions.
iv. Surface finish is required in casting.
v. The above factor necessitates the provision of extra metal on the casting or the machining.

How much extra metal should be provided, depends upon the factors listed below:

i. Nature of metal i.e., ferrous and nonferrous ones do not.
ii. Size and shape of the casting. Longer casting tends to warp and need more metal to be added to ensure that after machining the casting will be alright.
iii. The types of machining operation to be employed for cleaning the casting. Grinding removes much lesser metal as compare to turning.
iv. Molding process employed. Die casting produces parts which need little machining whereas parts sand-cast, require more machining allowances.

v. Number of cut to be taken. Machining allowances is directly proportional to the number of cuts required for finishing the casting.
vi. The degree of surface finish desired on the cast part.

- **Draft or tapper allowances: -**

It is given to all surface's perpendicular to the parting line.

Draft allowance is given so that the pattern can be easily removed from the molding material tightly packed around it without damaging the mold cavity

The amount of taper depends upon

i. Shape and size (length) of the pattern in the direction in contact with the mold cavity.
ii. Molding method.
iii. Mold materials.
iv. Draft allowance is imparted on internal as well as external surface; of course, it is more on internal surfaces.

Taper on external surface = 10 to 25 mm/meter.

Taper on internal surface = 40 to 65 mm/meter.

- **Distortion or camber allowances: -**

A casting will distort or warp if:

i. It is of irregular shape,
ii. All its parts do not shrink uniformly i.e., some parts shrink while others are restricted from doing so,
iii. It is U or V-shaped,
iv. It has long, rangy arms as those of the propeller strut for the ship,
v. It is a long flat casting,
vi. The arms possess unequal thickness,
vii. One portion of the casting cools at a faster rate as compared to the other, etc.

After distortion the arms of a U-shaped casting will tend to draw together. Distortion can be practically eliminated by providing an allowance and constructing the pattern initially distorted i.e., outsize in the opposite direction so that the casting after cooling neutralizes the initial distortion given on the pattern and acquires the correct shape (i.e., a U-shaped casting will tend to have both its)

The amount of distortion allowance may vary from 2 to 20 mm depending upon the size, shape and material of casting.

- **Shake or rapping allowances: -**

i. A pattern is shaken or rapped by striking the same with a wooden piece from side to side. This is done so that the pattern is loosened a little in the mold cavity and can be easily removed.

ii. In turn, therefore, rapping enlarges the mold cavity which results in bigger sized casting.
iii. Hence, a negative allowance is normally provided on the pattern i.e., the pattern dimensions are kept similar in order to compensate the enlargement of the mold cavity due to rapping.
iv. Shake allowances is normally provided only to large castings because it is negligible in case of small casting and is thus ignored.
v. The magnitude of shake allowance can be reduced by increasing the tapper.
vi. The amount of rapping varies with the molder doing the same and, therefore, the foundry supervisor must be consulted while fixing this allowance.

Construction Of Core & Core Boxes: -

Core: -

- A core may be defined as a sand shape or form which makes the contour of a casting for which no provision has been made in the pattern for molding.
- Core is an obstruction which when positioned in the mold, naturally doesn't permit the molten poured metal to fill up the shape occupied by the core. In this way the core produces hollow casting.
- Cores are required to create the recesses, undercuts and interior cavities that are often a part of casting.
- Cores may be made up of sand, metals, plaster or ceramics.
- Cores re used to:
- Forms the air space between the cooling fins of an air-cooled engine cylinder.
- Make the water-cooling chamber in internal combustion engines.

Different Functions of Cores: -

- For hollow casting, cores provide the means of forming the main internal cavities.
- Cores may form a part of green sand mold.
- Cores may provide external undercut features.
- Cores may be employed for improving the mold surface.
- Cores may be inserted to achieve deep recesses in the casting.
- Cores may be used to strengthen the molds.

Types of cores: -

The various types of cores depending upon their position are: -

- **Horizontal core: -** These cores are placed horizontally in the prints at the parting line of the mould, such that one half remains in the cope and the other half in the drag. This type of core is often used in a split or two-piece patterns.
- **Vertical core: -** These cores are placed vertically in the mould. The core print is provided on the cope and drag side of pattern. Generally, the upper end of this core is tapered.
- **Balanced core: -** These are similar to horizontal core but these cores supported at one end only. Therefore, the core print should be made up sufficient length in order to prevent the core from falling in the mould. The balanced core is used to produce hollow cavities, blind holes along a horizontal axis in a casting.
- **Drop core: -** The drop core is also known as wing core are used when a hole or cavity to cored is not in-lined with the parting line, i.e., it is either above or below the parting line.
- **Cover core: -** The cover cores are used when the entire pattern is rammed in the drag and the core is required to be supported from the top of the mould. This type of core usually requires a hole through the upper part to permit the metal to reach the mould.

Core Boxes: -

- A core box is basically a pattern for making cores.
- Core boxes are employed for ramming cores in them.
- Core boxes impart the desired shape to the core sand.
- Core boxes range from simple wooden structure to precision metal assemblies which process a long life under exacting condition.

Types of core boxes: -

A few commonly used types of core boxes are:

- **Half Core Box: -**It can make cylindrical Cores. A half core box is most common type of core box used for preparing the two identical halves of a symmetrical core. Half portion of the core is made in the core box, at one time. The two halves are then pasted together to form a complete core.
- **Slab Or Dump Core Box: -** It employed for making rectangular, square or trapezoidal cores. A slab core box is similar to half core box but the core produced by this core box do not require pasting and they are

complete by themselves. If the core produced is in the shape of slab, then it is slab core box. If the core produced is in the form of half round then it is called dump core box.

- **Split Core Box: -**Unlike dump and half core box, a split core box is in two parts. The two portions of the split core box can be aligned and temporarily joined together with the help of dowels. When join the two halves of a split core box depict the full core cavity. Rammed core can be removed by splitting the core box again into two halves.
- **Left- And Right-Hand Core Box: -** The right- and left-hand core box is used when the core is not symmetrical about the Centre lines and the two halves of the core are made in the same core box and are not identical. They are used to make cores for producing pipe bends. Half of the pipe bend core is made in each core box. Two Halves of pipe bend thus rammed are baked and then cemented together to make the full core.
- **Strickle Core Box: -** A strickle core box is used when the core is required to have an irregular shape which can't be easily rammed by other method. The desired irregular shape is achieved by striking of the core from the top of the core box with a piece of wood called a strickle board. The strickle is called to correspond exactly to the contour of the required core.
- **Gang Core Box: -** Gang core box is used when large number of small sized core are to be prepared. In this type of core box, it contains a number of core cavities so that more than one core can be rammed at one time.
- **Loose Piece Core Box: -**It resembles half core box; but unlike half core box, loose piece core box can produce two halves of a core, which may be neither identical in size nor in shape. His is achieved by inserting loose wooden pieces in the core whenever necessary. The insertion of loose pieces in the core box will naturally alter the symmetry of the rammed half core. After they are baked the two un identical halves of the core can be pasted together.

Construction of core: -

The cores are mostly made of a core sand mixture consisting of sand grains and organic binders which provide green strength and collapsibility. The green strength is required so that core sand may be molded to shape for making. The simplest core sand mixture commonly used comprises sand, 1% core oil, 1% cereal and 2.5 to 6 percent water.

- **Mixing Of Core sand: -**

i. The first consideration in making the dry sand cores is to mix and prepare the sand properly in order to obtain best cores.
ii. If the binder is dry, it should be thoroughly mixed with the sand before any moisture is added.
iii. The mixture must be homogeneous so that the core will be of uniform strength throughout.

- **Ramming Of Core Sand: -**

i. The core is usually made in core boxes.
ii. The core box is filled with core sand, rammed and struck off.
iii. The rammer may be done manually or with machine.

- **Venting Of Core: -**

i. Since the cores are often surrounded by hot metal after the casting is poured, Therefore the cores are required to be sufficiently permeable to allow core gases to pass through the core and into the mold or atmosphere.
ii. The vent holes are provided for the escape of gases.
iii. These vent holes are usually made with wire.

- **Reinforcing Of Core: -**

i. Some cores required internal rain forcing to prevent breakage or shifting when the casting is poured.
ii. Wires being used to support the barrel of the cylinder core.
iii. The wire should be surrounded with the sand to keep them from fusing to the casting and making their removal difficult.

- **Baking Of Core: -**

i. The core is transferred to a cope plate or drier for baking.
ii. This is done by placing the plate over the core box.
iii. The core which is to be baked on a core plate, must have a flat surface resting on it.
iv. The core with flat surface must be supported on a core driver until they are baked.
v. The core baked at temperature up to about 260^0c to develop strength obtainable from the organic binders in the core sands.
vi. The under baked cores may collapse too soon and break or erode before the casting is solidified.

- **Cleaning Of Core: -**

i. The cleaning of cores consists of trimming, brushing, coating and mudding.
ii. The trimming is done to remove fins arising from loose joints or loose pieces in the core box or other sand projections by rubbing them or filling with an emery stone.
iii. The brushing of cores is performed with a brush to remove loose sand.
iv. The coating of cores is done with refractory or protective materials which improves their resistance to molten metal or produce a better casting.
v. The muddling is a localized coating to make the core completely smooth.
vi. This is avoided by drying in a core oven for 20 minutes to 1 hour.

- **Sizing Of Cores: -**

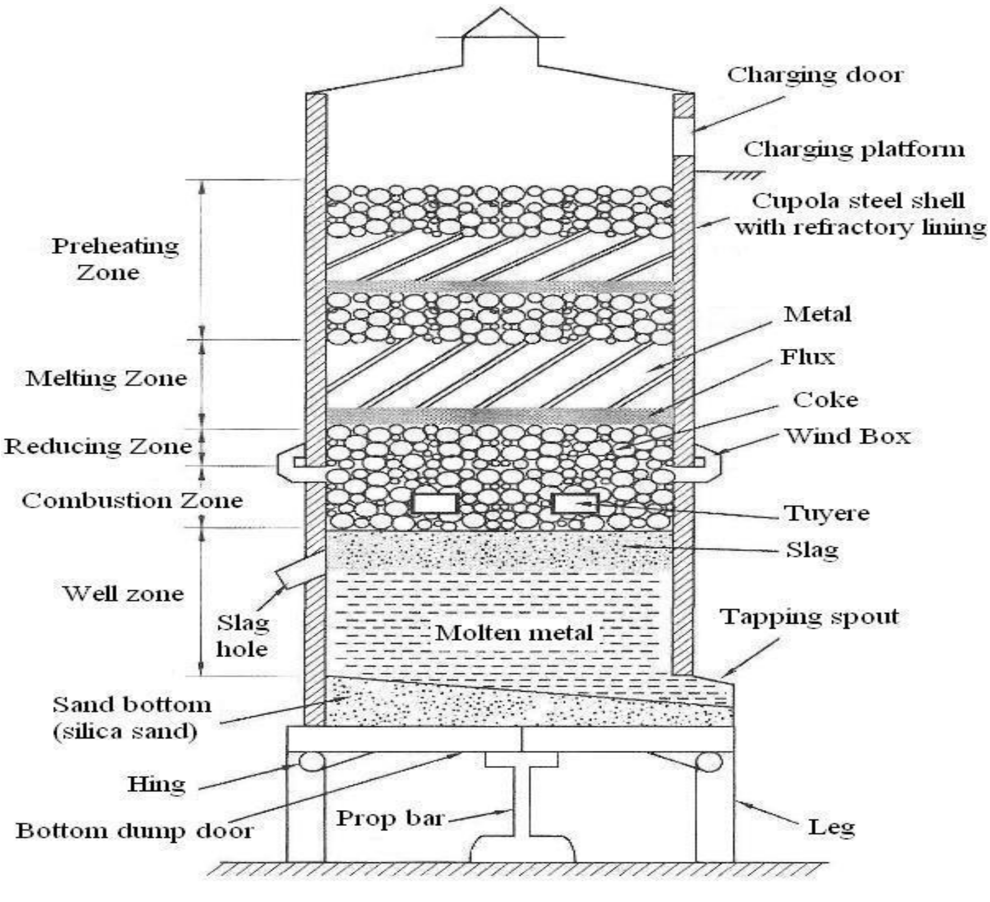
i. The sizing usually involves gauging the core to see if its size is correct and then removing the material.
ii. The gauges may be used to check critical dimensions.
iii. The cores may be inserted in a gauging fixture which will check a number of dimensions at once.
iv. Some cores are made slightly over size and ground to correct height.
v. Joining Of Cores: -
vi. Sometimes core is made of two or more pieces before they can used.
vii. They are held together by pasting, bolting.
viii. The pasting is commonly used on small work. A core paste, usually a mixture of talc, dextrin, flour, water or other ingredients, is apply to the surfaces to be joined.
ix. The bolting is useful in large core work. The recessed holes are left in the cores so that they may be bolted together. The bolt and nut heads are covered with a core plug or mud.

Construction And Working of Cupola Furnace: -

Cupola is a furnace which is most widely used to melt grey cast iron, nodular cast iron and some malleable cast iron. Cupola is simple in construction, economical to operate and melts iron continuously with a minimum of maintenance.

Constructional Details: -

Cupola is essentially a refractory lined vertical cylinder open at both its top and bottom. The inside diameter of cupola ranges from few inches to 7 feet. Small size has been built for demonstration and experimental purposes. Cupola consists of drop door at the bottom. After closing drop door, a proper sand bed can be prepared. This sand bed provides a necessary refractory bottom for the molten metal and the coke. Immediately above the sand bed is the metal tapping hole which is initially closed with clay till molten metal is ready for tapping. Above the metal tap hole is the slag hole through which slag generated during the melting process is tapped. Above the slag hole is wind box. Air from suitable blower comes through the blast pipe and enters in wind box.



Cupola Furnace

Cupola Operation: - There are six steps in cupola furnace operation.

i) Preparation of cupola
ii) Lightening of cupola
iii) Charging of cupola
iv) Melting
v) Tapping of slag and molten metal through slag and tapping hole
vi) Drop down the bottom part of cupola

While starting cupola a bottom is first prepared by closing the drop door and ramming the molding sands which slops gently towards tap hole. Then a coke bed of suitable height is prepared above the sand bottom. While igniting, first the coke bed is ignited through tap hole or any other hole near its bottom. After coke bed is properly ignited, layers of coke, iron charge and lime stone or fluxes are alternatively fed into cupola through charging door maintaining the necessary proportion and rate of charging. Then the air blast is turned on and combustion occurs rapidly within 5 to 10 minutes. Molten metal is collected near the tap hole. When enough molten metal is collected in the well of cupola the slag is drained of through slag hole before opening the tap hole. The molten metal is collected in ladles and transported to the mould in which it is to be poured.

The charge needed to produce cast iron consists of pit iron, cast iron scrap. Steel scrap is also used when alloy cast iron is needed. The fluxes are added in the charge to remove oxides and other impurities present. The flux most commonly used is limestone ($CaCO_3$). The flux is expected to react with oxides and from compounds which have low melting point and also lighter than molten metal. As a result, molten slag tends to float on the metal pool and thus can be very easily separated.

Zones in cupola furnace: -

i) Combustion zone
ii) Reduction zone
iii) Melting zone
iv) Preheating zone
v) Stack zone.

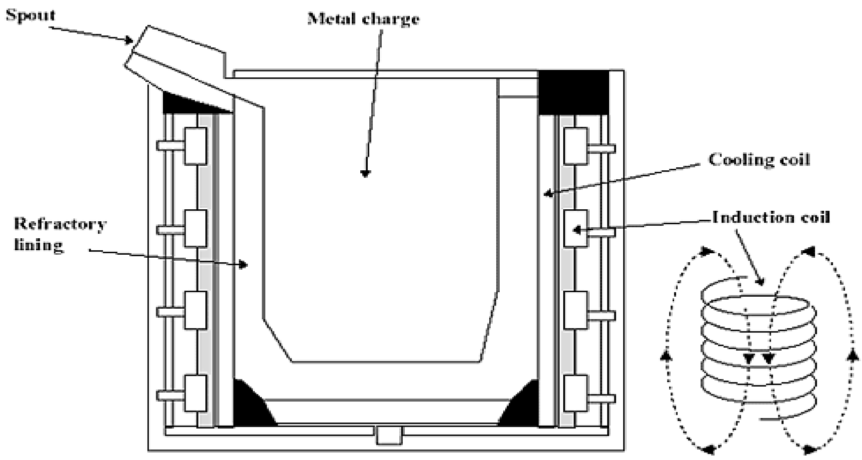
Construction And Working of Induction Furnace: -

The furnace contains a refractory line crucible surrounded by water cooled copper coils. The furnace walls on the principle of transformer. Water coils and copper coils are primary and the secondary is the metal charge. When A.C. is passed to the copper tubing a magnetic field is set up. This magnetic field induced eddy current in the crucible charge which melt the metals. If ferrous metal show magnetic property the loss due to hysteresis produces extra heat. Very high temperature can be obtained by this method of melting, the only limitation being the ability of the furnace lining to with stand the temperature developed.

The charge ratio in steel=40 to 60%.
In pig iron=4 to 7%.
Rest= Other.

Induction furnaces are of two types: -

i. Core less and high frequency induction furnace.
ii. Channel furnace or low frequency induction furnace.



High frequency induction furnace: -

In this case water cooled copper coils consisting the primary coil of transformer, completely surrounding the crucibles. A high frequency current is passed through the coil. A heavier secondary current is induced in the charge consisting the secondary coil. The resistance of metal charge will cause it to heat up to the desired temperature.

Low frequency induction furnace: -

In this types coil surrounded only a small person of crucible and the A.C. passed through the coil is of low frequency.

The induction furnaces are exploited to metal steel, iron, brash and aluminum base alloys.

Induction furnace is suitable especially for smaller quantities like 50 kg to 10 tons. The furnace doesn't required electrodes, it prevents combustion of metals and the process is control.

Working principle: -

The principle of an induction furnace resembles that of a transformer. It has a primary coil about which an alternating magnetic field is set up with magnetic lines of force of a definite density when an alternating current is passed through the coil. The magnetic field induces alternating eddy currents in the secondary circuit which comprises a crucible containing the metal charge. The eddy currents heat up and melt the metal.

An induction crucible furnace comprises a refractory crucible and a coli or inductor. The letter is made of copper tubing through which cooling water circulates and is arranged inside the refractory crucible. An insulating lining is provided between the coil and e crucible. The metal to be melted is charged into the crucible where it is melted down by the heavy secondary currents induced by the magnetic flux of the primary coil. The crucible can be tilted on horizontal trunnions to pour the molten metal. Induction furnaces operate on an alternating current with a frequency of 500-2500 Hertz.

Induction furnaces are most often employed in making high alloy steels and special purpose alloys. An advantage of these furnaces is that they don't require electrodes. This prevents carburization of the metal and simplifies control of the process.

Construction And Working of Crucible Furnace: -

In crucible furnace, the metal charge is placed and melted in a crucible.

A crucible is made up of silicon carbide, graphite or other refractory metals and it can withstand the high temperature. Crucible is available in different sizes ranging from No.1 to No.400. Each number indicates the amount of metal which can be handled conveniently by that crucible. A crucible furnace consists of a steel shell provided with refractory lining inside.

A crucible furnace has the following advantages:

a. Low initial cost.
b. Easy to operate.
c. Low cost of fuel, etc.

A crucible furnace may be of the following type: -

i. Pit Crucible furnace.
ii. Crucible furnace of bail-out type.
iii. Crucible furnace of tilting type.
iv. Gas and oil-fired crucible furnace.
v. Coke fired crucible furnace.

- **Pit crucible furnace: -**
  i. A pit furnace has crucibles placed in a pit below the ground level.
  ii. It may be coke, oil or gas fired furnace, but usually it is fired with coke.
  iii. Enough coke is packed round and above the crucible pot so as to melt and superheat the metal charge.
  iv. Since molten metal does not come in contact with fuel, there is no pick up of elements by the metal from the coke and a very little compositional change occurs in the metal charge.
  v. Coke fired pit furnace is employed for melting cast iron and non-ferrous metals and alloys.
  vi. The metal charge consists of pig iron, foundry returns and broken castings.
  vii. The coke bed is formed, ignited and allowed to burn. Once it reaches the state of maximum combustion, coke from the Centre of coke bed is

shifted towards sides to make space for the crucible containing the metal charge.

viii. The crucible is surrounded from all sides with the coke and its top is covered (with a lid).

ix. A blower is used to provide the necessary air for the combustion of coke while the charge is melting.

x. As the charge melts and attains the required pouring temperature, crucible is brought out of the furnace with the help of tongs etc. and is taken to the place of pouring.

- **Crucible Furnace of Bale-out Type: -**

  i. Unlike pit furnace, crucible of a bale out type furnace rests above the ground level.

  ii. Such furnaces are normally fired by oil or gas.

  iii. Bale-out type furnaces are made cylindrical so that the flame may sweep around and uniformly heat the crucible.

  iv. The forced draft is provided usually by a fan.

- **Crucible furnace of tilting type: -**

  i. As compared to stationary furnaces, tilting type furnaces are preferred where large amounts of metal are melted.

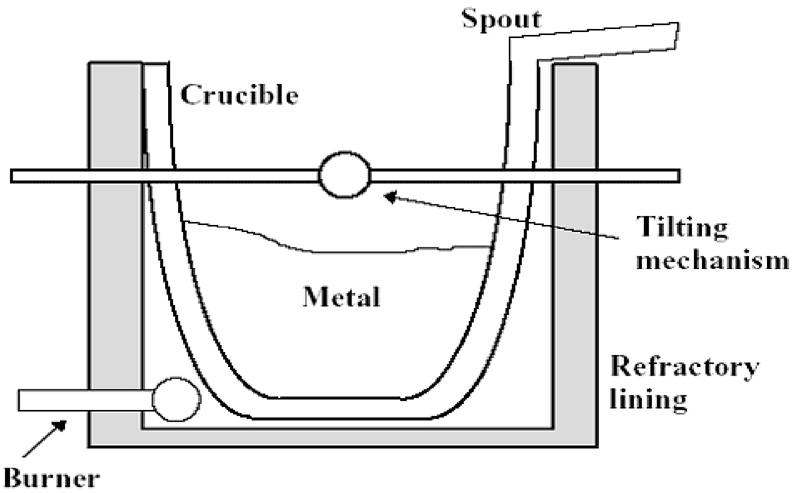
  ii. In stationary furnace, the crucible can be taken out from the furnace and move to the place of pouring whereas in tilting type of furnace the crucible is permanently cemented in place.

  iii. Against stationary furnace of capacities up to above 100kg, tilting furnace may have capacities up to 500kg of metal or more.

  iv. A tilting furnace consists of an outer shell having a refractory lining inside.

  v. A tilting furnace may be coke, oil or gas fired, employing forced draught for combustion purposes.

  vi. A tilting crucible furnace unlike pit furnace is above the floor level. It is mounted on two pedestals and is rotated either by a geared hand wheel or power.



- **<u>Stationary Gas or Oil-Fired Crucible Furnace: -</u>**
  i. It has an outer shell having a refractory lining inside.
  ii. As explained under tilting furnace, the flame swirls around the outside of the crucible containing the charge and melts the same.

- **<u>Stationary Coke Fired Furnace: -</u>**
  i. It differs from pit furnace in the sense that it is above the floor level.
  ii. In operation it resembles coke fired pit furnace.

<u>Defects in casting: -</u>

The defects in a casting may be due to pattern and molding box equipment, molding sand, cores, gating system or molten metal. Some of the defects and their reasons are discussed below:

- **<u>Mould shift</u>**: - It results in a mismatching of the top and bottom parts of a casting, usually at the parting line. it occurs due to following reasons:
  i. Misalignment of pattern parts,
  ii. due to worn or damaged patterns, and
  iii. Misalignment of molding box or flask equipment.

This defect can be prevented by ensuring proper alignment of the pattern, on pattern plates etc.

- **<u>Core shift: -</u>**It is an abnormal variation of the dimensions which are dependent on core position. It is caused by
  i. Misalignment of cores in assembling cored-mould,
  ii. Undersized or oversized core prints, and
  iii. By using incorrect size of chaplet.

This defect can be eliminated by providing the core at the proper place and must be gripped properly in the sand.

- **Swell: -** It is an enlargement of the mould cavity by molten metal pressure resulting in localized or general enlargement of the casting.

It is due to following reasons:

i. Insufficient ramming of sand,
ii. Insufficient weighting of the mold during casting, and
iii. Pouring of molten metal too rapidly or too hard.

The swells are avoided by the proper ramming of sand and uniform flow of molten metal in to the mold.

- **Fins and Flash: -** These are thin projections of metal not intended as a part of casting. These usually occur at the parting line of mold or core sections. These are caused by:

i. Excessive rapping of the pattern before it is withdrawn from the mould.
ii. Insufficient weight on the top part of the mold, and
iii. Loose clamping of the mold.

In order to avoid this defect, sufficient weight should be placed on the top part of the mold so that the two parts fit tightly together.

- **Sand Wash: -** It is usually occurring near the in gates as rough lumps on the surface of a casting. The sand that has been washed away appears on the upper surfaces of the casting as rough holes or depressions. This is due to the following reasons:

i. Soft ramming of sand.
ii. Weak sand,
iii. Poor pattern, and
iv. Insufficient draft.

This defect is avoided by the proper ramming of sands.

- **Shrinkage: -** It is a crack in the casting or dishing on the surface of casting which results from unequal contraction of the metal during solidification. This is due to following reasons:

i. Improper location and size of gates and runners.
ii. Inadequate risers,
iii. Lack of directional solidification,
iv. Incorrect metal composition, and
v. Incorrect pouring temperatures.

This defect can be eliminated by the use of feeders and chills at proper locations to promote directional solidification.

- **Hot Tear: -** It is an internal or external ragged discontinuity in the metal casting resulting from hindered contraction occurring just after the metal has solidified. This defect is due to the following reasons:

i. Abrupt changes in section, inadequate filleting of inside corners, and improper placement of chills.
ii. Poor collapsibility of mold and core materials which will place extra stress on certain details.
iii. Improper pouring temperature.

In order to eliminate this defect, abrupt changes in section should be avoided. The pouring temperature should be correct and there should be even rate of cooling.

- **Sand Blow or Blow Hole: -** It is excessively smooth depression on the outer surface of a casting. This defect is also called blow holes. This defect is due to the following reasons:

i. High moisture content in molding sand,
ii. Low Permeability of sand,
iii. Hard ramming of sand,
iv. Defective gating system, and
v. Improper Venting Of sands.

The defect can be removed by proper venting, completely drying up the mould, selecting the proper sand with required permeability and proper in-gate system for the flow of molten metal.

- **Core Blow: -** It is an excessively smooth depression on the inner surface of a cored cavity or a gas pocket immediately above a cored cavity. This defect is caused by using insufficient baked cores.

Thus, the cores should be sufficiently baked before using.

- **Honeycombing Or Slag Holes: -** These are smooth depression on the upper surfaces of the casting. The usually occur near the in gates. This defect is due to imperfect skimming of the metal or due to poor metal.

This defect can be avoided by preventing the slag from entering along with the molten metal.

- **Scabs: -** These are patches of sand on the upper surface of casting. This defect is due to the following reasons:

i. Uneven ramming of sand, and
ii. Slow or intermittent running of metal.

The proper ramming of sand and uniform flow of the molten metal in to the mould can eliminate this defect. Another method of remove this defect is to mix additives such as wood flour, sea coal or dextrin into the sand.

- **Cold Shuts and Misruns: -** These occur when the mould cavity is not completely fitted and an incomplete casting result. This defect is due to the following reasons:

i. Too small gates,
ii. Too many restrictions in the gating system,
iii. Pouring head is too low,
iv. Facility Venting of the mould, and
v. Metal lacking in fluidity.

In order to eliminate these defects, the casting should be designed keeping in mind the fundamental principles of gating and reserving. Then thin selection should be preheated and the molten metal should be poured at the correct temperature.

- **Poured Short: -** It occurs when the mold cavity is not completely filled because of insufficient metal. It is due to the following reasons:

i. Interruptions during pouring operation, and
ii. Insufficient metal in the ladles being used to pour the metal.

In order to avoid this defect, the ladle should have sufficient molten metal at the correct temperature.

- **Metal Penetration: -** It occurs when the alloy being cast tends to penetrate into sand grains and causes a fused aggregate of metal and sand on the surface of the casting. It is due to the following reasons:

i. Soft rammed sand,
ii. Molding sand and core sand being too coarse,
iii. Improper use of mould and core washes will cause penetration,
iv. Excessive metal temperature or increased fluidity of metal.

These defects can be eliminated by removing the above-mentioned reasons.

- **Run-outs And Bust-outs: -** These permit drainage of the metal from the cavity and result in incomplete casting. This defect is due to the following reasons:

i. A pattern that is too large for a given flask or pattern placed too close to the flask edge results in a weak spot and cause run-out.
ii. The match plate surface that are out of parallel or uneven results in a poorly formed parting line and cause a run out.
iii. Inadequate mould weights or clamps will permit the cope to fit which results a run-out.
iv. Improper sealing of mould joints causes run-out.
v. Excessive pouring pressures may cause run-out.

The corrective measures taken in respect of the above reasons will prevents the defects.

- **Rough Surface Finish: -** It is merely a lack of sufficient smoothness in the casting. It is due to the following reasons:

i. Soft ramming of sand,
ii. Coarser Sand,
iii. Hard pouring or too high metal fluidity
iv. Improper use of mould and core washes often promote rough casting surface.

This defect can be avoided by using a proper mould and ramming of sand.

- **Crush: -** It is an irregularly shaped cavity or projection on the castings caused by the displacement of the sand at the mould joints or core prints, which usually occurs when the mold is being closed. It occurs due to the following reasons:

i. Badly made mould joints,
ii. Excessive pressure on the sand surface,
iii. Too large core or too small core prints.

The defect can be eliminated by taking proper care in placing the cope over the drag. The sand in the cope should be rammed properly.

- **Warpage: -**It is un intentional and undesirable deformation that occurs during or after solidification. It is due to the following reasons:

i. Continuous large flat surface on castings, indicating a poor design,
ii. No directional solidification of casting.

The defect can be eliminated by modifying the casting design and proper directional solidification.

SPECIAL CASTINGS: -

- Sand casting is not suitable for economical in many applications where the special casting process would be more appropriate.

TYPES OF SPECIAL CASTING METHODS: -

- Die casting.
- Investment casting.
- Centrifugal casting

DIE CASTING: -

- Die casting involves the preparation of components by injecting molten metal an in to metallic die by means of pouring the molten metal under gravity or by external pressure.
- The process of forcing the molten metal into the metallic mould (die) cavity under pressure and allowing it to solidify.

- Pressure is generally obtained by hydraulically or pneumatically.
- The range of the pressure is (70 -5000) Kg/cm2
- The range of the pressure will be maintained during the solidification of casting.
- In this type of casting the liquid metal will be injected into the die.

DIE CASTING MACHINE: -

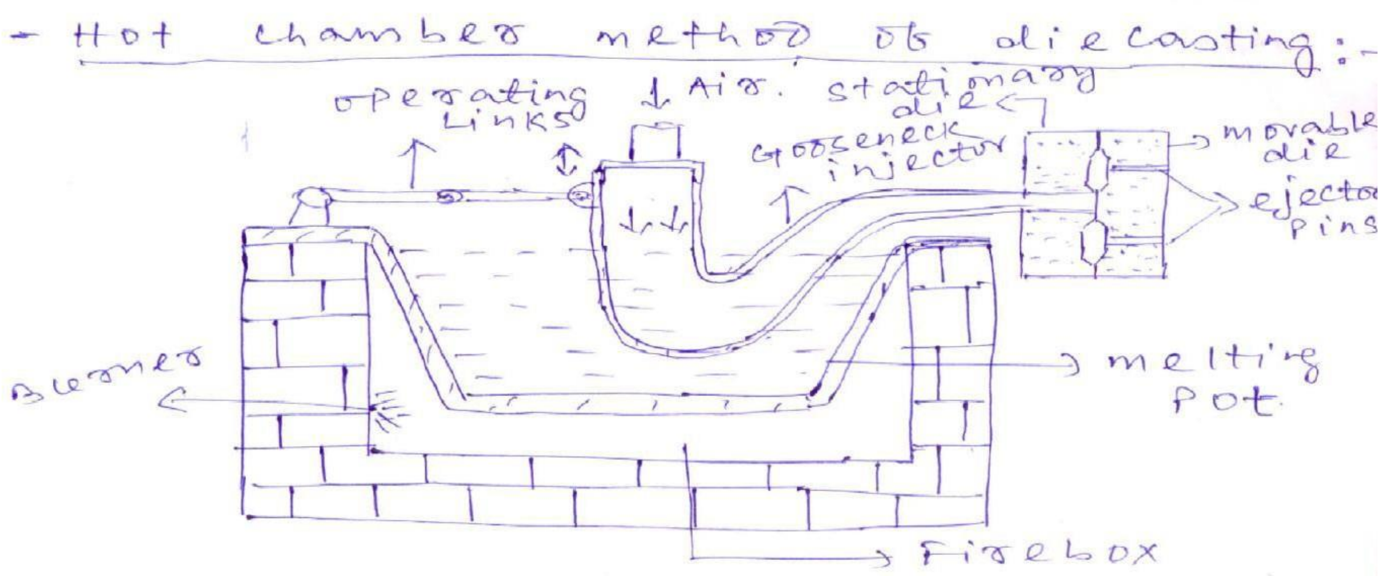
There are two types of die casting machine.

- Hot chamber die casting machine.
- Cold chamber die casting machine

FUNCTION OF DIE CASTING MACHINE: -

- holding two dice's halves firmly together
- closing the die
- Injecting the molten metal in to die.
- opening the die.
- Injecting the casting out of the die.

HOT CHAMBER DIE CASTING PROCESS: -



In hot chamber machine the melting unit constitutes an integral part of the process. The injection chamber is immersed in the molten metal at all times. At first the metal is melted in melting pot. After the metal reaches the molten state, the injection chamber is operated by air pressure which forces the metal into the die to complete the casting. The air pressure is maintained till the solidification of casting. When the solidification of the casting is completed, the movable die will be opened. The die is having two halves. One half is stationary die and another half is movable die. Stationary is fixed one and movable die can be opened and closed. After opening of the movable, the casting is removed by the help of ejector pins.

WORKING: -

- The hot chamber die casting machine of the submerged type.
- The molten metal is forced in the die cavity at pressure from 7 to 14. The pressure may be obtained by the application of compressed air, or by a hydraulically operated plunger.
- In the first method, the goose neck is lowered into the molten metal for filling it. It is then raised and connected to the die neck.
- A suitable mechanism is provided to raise and lower the goose neck.
- The compressed air at a pressure of about 2.5 to 5 MPa is now injected into the goose neck to force the molten metal into the die.
- In the second method, the plunger acts insides a cylinder formed at the end of the goose neck, which is immersed in a pot of molten metal.
- A port is provided rear the top of the cylinder to allow the entry of the molten metal.
- The downward stroke of the plunger pushes the molten metal through the goose neck into the die.

Advantages –

- - Simple in constriction
- - Operation is simple.
- - It requires less space

Disadvantages–

- Production rate is lower.
- Compressed air does not produce pressure on molten metal.
- Life and efficiencies are less.

APPLICATION: -

- The hot chamber die casting machine is used for casting zinc, tin, lead and other low melting alloys.

COLD CHAMBER DIE CASTING PROCESS: -

The molten metal is poured into the cold chamber and this molten metal is forced hydraulically into the die is known as cold chamber method of die casting.

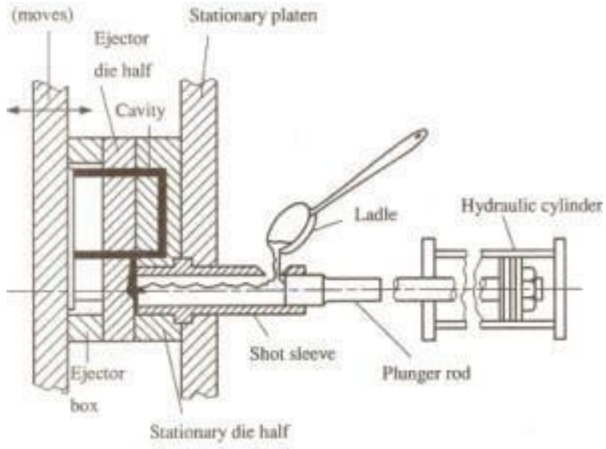


Fig. 3-13 A typical cold-chamber die-casting machine

Process: - The metal is melted in a melting pot. In this method the melting pot is separated from cold chamber machine. After the metal reaches into molten state, the molten metal is poured into ladle. From the ladle the molten metal is poured into the cold chamber after the die is closed and all cores are locked in position. The molten metal is entered into the die by the help of hydraulic ram. The pressure required to force the metal into the die is of the order of (200-2000) kg/cm2 and hence high squeezing action is exerted on the metal while it solidifies. Once the casting has solidified, the movable half of the die opens. Cores are withdrawn, ram moves to the backward and the ejector is advanced to force the casting out of the die half.

CONSTRUCTION AND WORKING: -

- In cold chamber die casting machine, the melting unit is usually separate and molten metal is transferred to injection mechanism by ladle.
- The pressure on the casting metal in cold chamber die casting machine may vary from 21 to 210MPa and in some `cases may reach 700MPa.
- The greater pressures are required for semi molten alloys to compensate for reduced fluidity resulting from low pouring temperatures.
- This process is used for casting aluminum, magnesium, copper base alloys and other high melting alloys.
- The cold chamber die casting machine consists of a pressure chamber of cylindrical shape fitted with a piston or ram that is usually operated by hydraulic pressure.
- A measured quantity of molten metal is brought in ladle from the melting pot to a chamber and forced into the closed die sections by applying hydraulic pressure upon the piston.

The complete cycle is completed in the following four steps.

- The metal is loaded in the chamber.
- The plunger forces the metal into the die cavity.
- After the metal solidifies, the die is opened.
- The casting together with the slag of the excess metal, is ejected from the die.

ADVANTAGES: -

- The rapid economical production of large quantities of identical parts can be achieved.
- The parts having smooth surfaces and close dimensional tolerances may be produced very little machining is required.
- The parts having thin and complex shapes can be casted accurately and easily.
- The die casting requires less floor area than is required by other casting process.
- The casting produced by die casting process are less defective, owing to increased casting soundness.
- The rapid cooling rate produces high strength and quality in many alloys.
- The inserts, if required, can be casted easily in desired places.
- The die retains its trueness and life for longer periods. For example, the life of a die for zinc base castings is up to one million casting, for copper base alloys up to 45000 castings, and for aluminum base alloys up to 50000 casting.

DISADVANTAGES: -

- The cost of equipment and die is high.
- here is a limited range of non-ferrous alloys which can be used for die castings.
- The die castings are limited in size
- . It requires special skill in maintenance.

APPLICATION: -

- This process is used for casting aluminum, magnesium, copper base alloys and other high melting alloys.

CENTRIFUGAL CASTING: -

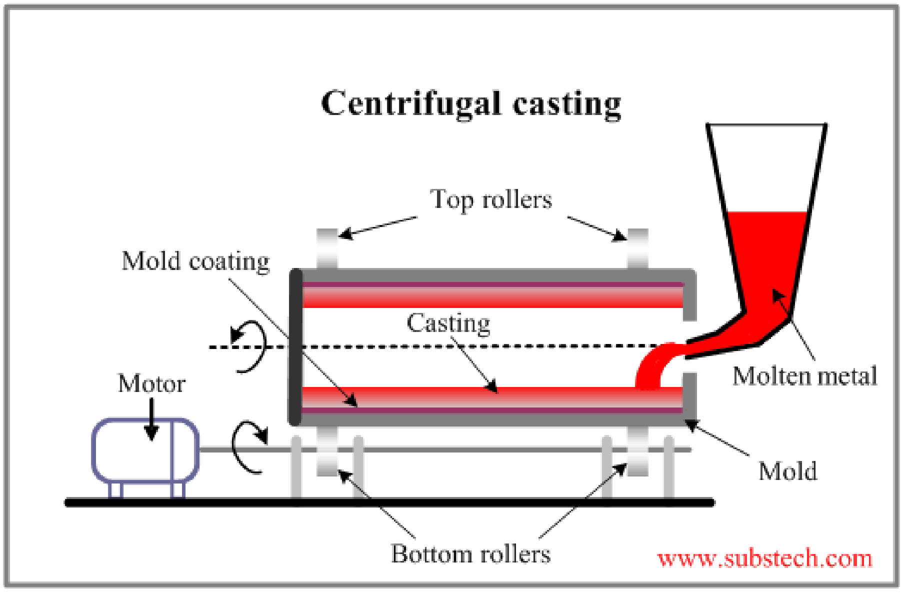
- A casting process in which molten metal is poured and allowed to solidify while the mold is revolving, is called centrifugal process.
- The castings produced under this centrifugal force are called centrifugal castings.
- This is a process where the mould is rotated rapidly about its central axis as the metal is poured in to it. Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies.

- The lighter slag, oxides and other being lighter, gets separated from the metal and segregate towards the Centre.

TYPES OF CENTRIFUGAL CASTINGS: -

- True centrifugal casting
- Semi centrifugal casting
- centrifuging.

TRUE CENTRIFUGAL CASTING: -



In utilizes the forces generated by the centrifugal action to distribute the molten metal in the rotating mould.

- Centrifugal force plays a major role in shaping and feeding of the casting.
- Mould is rotated about its own axis at a predetermined speed.
- Moulds may be rotated about its horizontal axis or vertical axis.
- Moulds for longer parts may be rotated about its horizontal axis.
- Moulds for smaller parts may be rotated about its vertical axis.
- The molten metal for the cast part is introduced to the mould from an external source by the help of a pouring spout. The liquid metal flows down into the rotating mould.
- The metal casting will harden as the mould continuous to rotate.
- By the help of the pipe puller the casting can be extracted from the mould.
- The forces play a major role for the solidification of casting.
- Due to the greater force in outer region of the rim that portion will be denser.

- All the impurities will remain in less dense region of metal casting, closer to the centre of the axis of rotation.
- Impurities are solid inclusions and trapped air.
- The impurities will be removed by the machining process.

CONSTRUCTION AND WORKING: -

- This process is especially employed for casting articles of symmetrical shape e.g., cast iron pipes, sleeves, steel gun barrels and other castings of cylindrical from.
- In this process, the mould is made of metal and lined with refractory material or sand. the molten metal is poured by ladle into the cavity of rapidly rotating mould.
- The centrifugal force directs the fluid metal to the inner surface of the mould with considerable pressure where solidification occurs forming hollow castings.
- The outside of mould is covered by water bath for quick cooling of metal.

ADVANTAGES: -

- The main advantages of a true centrifugal casting process are:
  - It is a quick and economical than other methods
  - . It eliminates the use of risers, feed heads, cores etc.
  - The ferrous and non-ferrous metal can be casted by this process.
  - The castings produced by this process have dense and fined grained structure with all impurities forced back to the Centre where they can be frequently machined out.
  - No use of sprues, risers or other gating systems.
  - Good surface finish
  - Quality castings with good dimensional accuracy can be produced.
  - Material of high density and with few impurities is produced in the outer regions of cylindrical parts.
  - Large metal casting 10ft in diameter, and 50ft long can be produced.
  - High melting point materials iron, steel can be cast.
  - Core is not required.

Disadvantages: -

- All alloys cannot be cast.

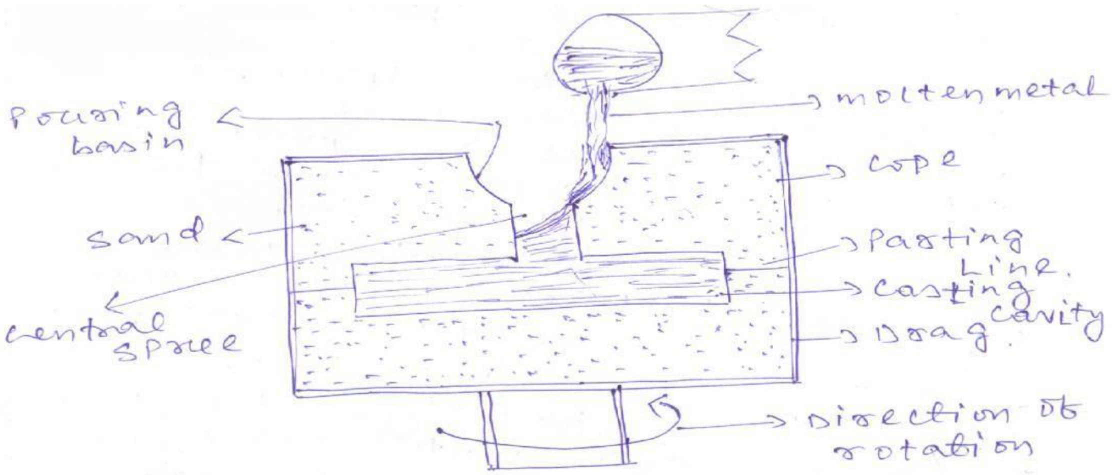
- Small items cannot be cast by this process.

Applications: -

Manufacturing of various tubes and pipes such as sewage pipes, gas pipes, water supply lines, rings, bushing, the liner for engine cylinder, brake drums, street lamp posts

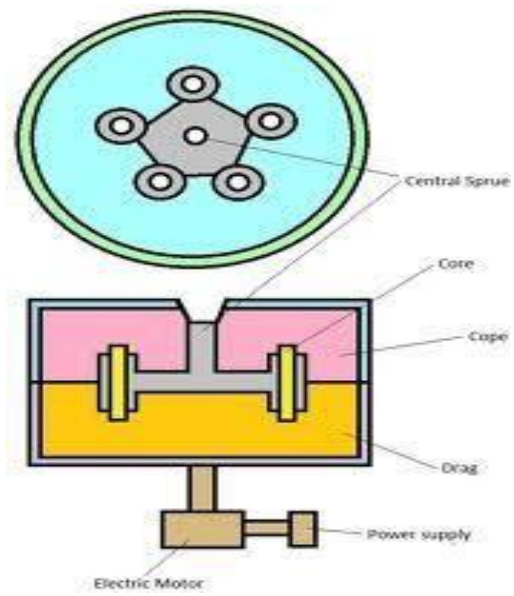
Semi centrifugal Casting: -

- The molten material for the metal casting is poured into a pouring basin and is distributed through a central sprue to the areas of the mould. The forces generated by the rotation of the mould ensure the distribution of molten material to all regions of the casting.
- As the metal casting solidifies in a rotating mould the forces constantly push the material out from the central sprue.



CENTRIFUGING: -

- In order to obtain higher metal pressure during solidification, when casting shapes are not axisymmetric, the centrifuging process is used.
- The casting of irregular shape can be produced by this method and a large number of small size casting can be produced at one time.
- Centrifuging casting is the third main branch of centrifugal casting process used for industrial manufacture of cast parts.



In centrifuging casting moulds are arranged around the central sprue.

- These moulds contain all the necessary geometry for the cast part. Runners travel from the central sprue to the mould entrances.

- The molten material is introduced into the central sprue. The entire system is rotated about its axis with the central sprue at the centre of rotation. When an object is rotated, forces are produced that act directly away from the centre of the axis of rotation.

- The molten material moves into the moulds from the centre through the runners. When the correct amount of molten metal to manufacture the casting is poured and distributed completely into the moulds, the apparatus will continue to rotate as solidification is occurring.

- During the solidification of the casting the moulds will be rotated. The forces acting on the material farther from the centre are greater than the forces, those are acting on the material closer to the centre.

- The material is dense at the outer region and the material is less dense at the area closer of the centre of rotation.

- The impurities such as inclusions and trapped air will be deposited at the less dense region.

- The impurities can be removed by the help of machining process.

WORKING: -

- In this process a number of small mould cavities are made symmetrically around a common central sprue and then metal is fed to them by radial gates.
- In this case, the mould cavities are not rotated about their own axis, but they are rotated about central sprue which act as the axis of rotation.
- Since the centrifugal force used to fill the mould cavities is not same for all the castings, therefore it is not purely centrifugal process.

Advantages: -

- Cast parts with thin-walled sections can be manufactured.

- High density, high mechanical strength and fine-grained structure can be produced.

- Desired shape can be manufactured.

- Great surface finish can be achieved.

Disadvantages: -

- All alloys cannot be cast.

- Small items can be produced

INVESTMENT CASTING:-

It is also known as lost wax process or precisin casting. The casting produced by this method are within very close tolerances and do not require subsequent machining.

Process –

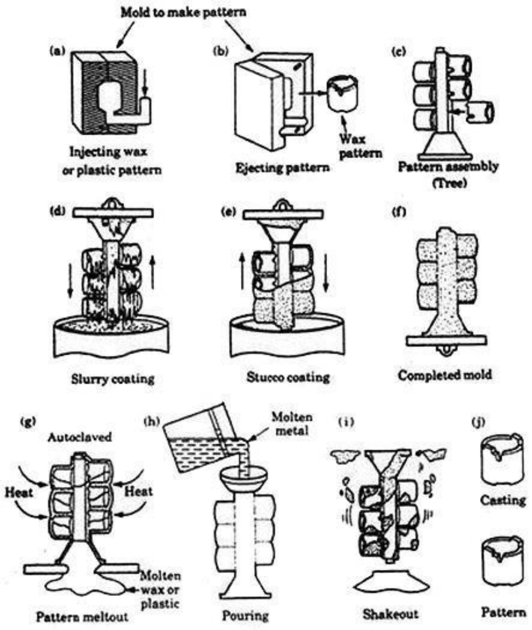
- The liquid wax is injected (150 – 170)0F into the metallic die at pressure (7 – 70) kg/cm2. After cooling the wax mould is removed out of the metallic die. The silicate slurry is prepared in a pot.

- The constituents of silicate slurry are 91.2% sand, 33.8% water, 6.5% calcium phosphate 2.3% magnesium oxide and meshed silica. After the preparation of silicate slurry is over then the wax mould is dipped in the solution of silicate slurry. The wax mould can be dipped for 6 to7 time. Now the wax mould is coated with silicate slurry.

- The silicate moulds are allowed to cool in air. Then the moulds are taken into auto clave machine. In auto clave machine the wax is removed out of the mould by the application of steam. The wax from the silicate mould is collected in wax collector.

The silicate mould is taken into pre-heater for pre-heating. Before pouring the molten metal into the mould the pre-heating is required. Pre-heating is to remove vapours and any wax linings present on inside wall of the mould.

- The metal is melted in a melting pot. After the metal reaches into molten stage, the molten metal is poured into the ladle. From the ladle the molten metal is poured into the silicate mould. Then the casting is allowed to cool and solidify in air.



WORKING: -

- This is the process where the mould is prepared around an expandable pattern. The various steps in the process are as follows.

STEP-1

- The first step in this process is the preparation of the pattern for every casting to be made. To do this, molten wax, which is used as the pattern material is injected under pressure of about 2.5 MPa in to a metallic die, which has the cavity of the casting to be made.

STEP-2

- The wax when allowed to solidify would produce the pattern. The pattern is injected from the die.

STEP-3

- Then the cluster of wax pattern are attached to the gating system by applying heat.

Step-4

- To make the mould, the prepared pattern is dipped in to a slurry made by suspending fine ceramic materials in a liquid such as ethyl silicate or sodium silicate.

STEP-5

- The excess liquid is allowed to drain off from the pattern. Dry refractory grain such as fused silica or Zircon are stuccoes on this liquid ceramic coating. Thus, a small shell is formed is around the wax pattern. The shell is cured and then the process of dipping and stuccoing is continued with ceramic slurries of gradually increasing grain size. Finally, when a shell thickness of 6 to 15 mm is reached, the mould is ready for further processing.

STEP-6

- The next step in the process is to remove pattern from the mould, which is done by heating the mould to melt the pattern. The melted wax is completely drained through the sprue by inverting the mould. Any wax remains in the mould are dissolved with the help of the hot vapor of a solvent, such as trichloro-ethylene.

STEP-7

- The molten metal is poured in to the mould under gravity, under slight pressure, by evacuating the mould first.

ADVANTAGES: -

- The close tolerance (± 0.05) are easily maintained in average work.
- It produces extremely smooth surfaces.
- It eliminates most machining operations including thread cutting and gear tooth forming.
- Very close tolerance and excellence surface finish can be obtained.
- Little or no machining is required.
- Almost any metal can be cast.
- No flash on parting lines.
- Stronger components.
- Strength is higher
- Light stressed wax impression dies have a very long life.

DISADVANTAGES: -

- The investment mould is as well as the materials from which they are made are single purpose, therefore they cannot be reused. This increases cost of production.
- The larger objects are impractical for investment casting due to equipment size limits
- Expensive due to preparation of wax patterns and shell moulds.
- It is a time-consuming process.

Applications: -

- - Textile industries
- Automobile industries
- - Food industries
- - Oil gas industries
- - Pump and valve industries.

Inspection of Casting

1. The process of detecting casting defect is known as inspection of casting.
2. There are three types of inspection used for casting parts.
   (a) **Process inspection**: -Inspection done while parts are being processed. This is helpful to detect defects at the start and allow them correction. In process inspections are carried out before a lot of castings have been completed to detect any flaws that may have occurred in the process so that corrective measures can be taken to remove the defect in the remaining units. Finished product inspections are carried out after the castings have all been completed to make sure that the product meets the requirements specified by the customer.
   b) **Visual inspection**: - It is simplest and most fastest inspection method visually or manually. It is usually good to check surface defects but fails to identify internal defects. It consists of inspecting the surface of the casting with naked eye or sometimes with a magnifying glass or microscope. It can only indicate surface defects such as blow holes, fusion, swells, external cracks, and mismatch. Almost all castings are subjected to certain degree of visual inspection

(c) **Dimensional Inspection**: -Before casting parts are to be machined, dimension inspection is done. Casting is placed on surface plate or surface table with angle measuring instrument to measure the accuracy or dimension of parts. Dimensional inspection is carried out to make sure that the castings produced have the required overall dimensions including allowances for machining. It may sometimes be necessary to break a part of the casting to take measurements of inside dimensions.

Testing Methods: -

(i) Pressure testing
(ii) Destructive testing
(iii) Non-Destructive testing

I)Pressure testing: -Casting that is used for containing or conveying liquids, gases such types are subjected to pressure testing. It is tested for any leaks through their walls. Leaks may be detected by sub-merged the complete casting under water for gas pressure or by visual inspection by liquid pressure. This test is carried out on castings required to be leak proof. All openings of the castings are closed and a gas or fluid under pressure is introduced in it. Castings having porosity leak under this pressure. The leakage may be detected by submerging the casting in a water tank or using a soap film if the pressure is applied by compressed air. If a liquid is used for applying pressure the leakage can be found by visual inspection.

ii) Destructive testing: -This test is done causing harm to the casting i.e., by destroying it. Various destructive test includes compression test, fatigue test, creep test, tensile test etc.

iii) Non-Destructive testing: -Parts to be tested are inspection for internal defects and surface defect without be non-destructive testing are

- Liquid penetration testing,
- Magnetic particle testing,
- X-ray radiography testing,
- Ultrasonic testing.

X-ray radiography: - Radiography uses X-rays or gamma rays penetrating through the castings and giving a shadow picture on a photographic film placed behind the work piece. These rays have very short wave length of the order of 0.001 Angstrom (10^{-10}m) units to 40 Angstrom units for x-rays and 0.005 to about 3 Angstrom units for gamma rays compared to about 5500 Angstrom units for the centre of the visible spectrum.

The ability of these waves to penetrate through metal depends also on the density of the metal and as such they can penetrate more easily in places where there is less metal that those where more metal is present leading to a shadow picture formation on the film. Any defects in the casting can easily be identified from this picture. Because of their shorter wave length gamma rays have a better penetration through the metal and are more commonly used.

Magnetic particle test: - This test is used for detecting cracks in metals like cast iron and steel which can be magnetized. For carrying out the test the casting is magnetized and then fine particles of iron or steel are spread on its surface. Presence of a crack or void in the casting results in interruption of the magnetic field and leakage of magnetic flux at the place of the crack.

The particles of iron or steel spread on the casting surface are held by this leaking flux giving a visual indication of the nature and extent of crack. Very small cracks or voids at or near the surface which may not even be detected by radiography are easily revealed by this method.

Liquid Penetrant Testing: - This method also is used for detecting very small surface cracks and has the advantage over the magnetic particle method that it can be used for any material. The parts to be tested are either dipped into or covered with a penetrant testing liquid which has very good wetting and penetrating ability. The liquid is drawn into the cracks or voids by capillary action.

After the penetrant has been applied to the surface to be tested extra penetrant is wiped off the surface is dried and a developer applied to it. This developer helps in drawing out the penetrant so that it becomes visible on the surface. The penetrant liquids often contain materials which fluoresce under ultraviolet light or a die to indicate their presence.

Ultrasonic Testing: - Ultrasonic testing is used to detect defects like cracks, voids or porosity within the interior of the casting. The method uses reflection and transmission of high frequency sound waves. Ultrasonic sound waves much higher than the audible range are produced and made to pass through the casting.

The time interval between the transmitted ray and reflected ray is recorded by a cathode ray oscilloscope. Any crack or void in the casting results in reflection or some of the sound from the crack which appears as a pip between the two pips representing the thickness of the casting. The depth of the crack from the surface of the casting can be easily calculated from the distance between these pips.

Economics of Casting: -

- The cost of the cast part (unit cost) depends on several factors: including materials, tooling, equipment, and labor. ™
- Preparations for casting a product include the production of molds and dies that require raw materials, time, and effort – all of which also influence product cost. ™
- There are also major costs involved in making patterns for casting. ™
- Costs also are involved in melting and pouring the molten metal into molds and in heat treating, cleaning, and inspecting the casting. ™
- Heat treatment in an important part of the production of many alloys' groups (especially ferrous castings) and may be necessary to produce improved mechanical properties. ™
- The equipment cost per casting will decrease as the number of parts cast increase. Sustained high production rates, therefore, can justify the high cost of dies and machinery. ™

- However, if the demand is relatively small, the cost-per-casting increases rapidly. It then becomes more economical to manufacture the parts by sand casting.

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GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

FLUID-MECHANICS

4TH SEMESTER

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Chapter-1

Properties of Fluid

Fluid

Definition:

A fluid is a substance which is capable of flowing or a substance which deforms continuously when subjected to external shearing force.

Characteristics:

- It has no definite shape of its own but will take the shape of the container in which it is stored.
- A small amount of shear force will cause a deformation.

Classification:

A fluid can be classified as follows:

- Liquid
- Gas

Liquid:

It is a fluid which possesses a definite volume and assumed as incompressible

GAS:

It possesses no definite volume and is compressible.

Fluids are broadly classified into two types.

- Ideal fluids
- Real fluids

Ideal fluid:

An ideal fluid is one which has no viscosity and surface tension and is incompressible actually no ideal fluid exists.

Real fluids:

A real fluid is one which has viscosity, surface tension and compressibility in addition to the density.

PROPERTIES OF FLUIDS:

1. **density or mass density : (S)**

   Density of a fluid is defined as the ratio of the mass of a fluid to its vacuum. It is denoted by δ The density of liquids are considered as constant while that of gases changes with pressure & temperature variations.

   Mathematically

$$\rho = \frac{mass}{volume}$$

Unit $= \frac{kg}{m^3}$

$$\rho_{water} = 1000 \frac{\text{kg}}{m^3}$$

$$\text{or } \frac{gm}{cm^3}$$

2. **Specific weight or weight density((W):**

   Specific weight of a fluid is defined as the ratio between the weights of a fluid to its valume. It is denoted by W.

   Mathematically $W = \frac{weight\ of\ fluid}{volume\ of\ fluid}$

$$= mg/v$$

$$W = \rho g$$

Unit - $\frac{N}{m^3}$

3. **Specific volume:**

   Specific volume of a fluid is defined as the volume of a fluid occupied by a unit mass or volume per unit mass of a fluid is called specific volume.

Mathematically

$$\text{Specific volume} = \frac{\text{Volume of fluid}}{\text{Mass of fluid}} = \frac{1}{\frac{\text{Mass of fluid}}{\text{Volume}}} = \frac{1}{\rho}$$

4. **<u>Specific gravity:</u>**

Specific gravity is defined as the ratio of the weight density ofa fluid to the density or when density standard fluid.

For liquids the standard fluid is water.

For gases the standard fluid is air.

It is denoted by the symbol S

$$\text{Mathematically,} \quad S(\text{for liquids}) = \frac{\text{Weight density (density) of liquid}}{\text{Weight density (density) of water}}$$

$$S(\text{for gases}) = \frac{\text{Weight density (density) of gas}}{\text{Weight density (density) of air}}$$

$$\begin{aligned}\text{Thus weight density of a liquid} &= S \times \text{Weight density of water}\\ &= S \times 1000 \times 9.81 \text{ N/m}^3\\ \text{The density of a liquid} &= S \times \text{Density of water}\\ &= S \times 1000 \text{ kg/m}^3.\end{aligned}$$

Unit: $\frac{m^3}{kg}$

Simple Problems:

Problem: - 1

Calculate the specific weight, density and specific gravity of one litre of a liquid which weighs 7N.

Solution. Given :

$$\text{Volume} = 1 \text{ litre} = \frac{1}{1000} \text{ m}^3 \quad \left(\because \; 1 \text{ litre} = \frac{1}{1000} \text{ m}^3 \text{ or } 1 \text{ litre} = 1000 \text{ cm}^3\right)$$

$$\text{Weight} = 7 \text{ N}$$

(*i*) Specific weight (w) $= \dfrac{\text{Weight}}{\text{Volume}} = \dfrac{7 \text{ N}}{\left(\dfrac{1}{1000}\right) \text{m}^3} = \mathbf{7000 \ N/m^3}$. **Ans.**

(*ii*) Density (ρ) $= \dfrac{w}{g} = \dfrac{7000}{9.81} \text{ kg/m}^3 = \mathbf{713.5 \ kg/m^3}$. **Ans.**

(*iii*) Specific gravity $= \dfrac{\text{Density of liquid}}{\text{Density of water}} = \dfrac{713.5}{1000}$ $\{\because$ Density of water $= 1000 \text{ kg/m}^3\}$

$= \mathbf{0.7135}$. **Ans.**

Problem: - 2

Calculate the density, specific weight and specific gravity of one litre of petrol of specific gravity = 0.7

Solution. Given : Volume $= 1 \text{ litre} = 1 \times 1000 \text{ cm}^3 = \dfrac{1000}{10^6} \text{ m}^3 = 0.001 \text{ m}^3$

Sp. gravity $S = 0.7$

(*i*) *Density* (ρ)

Using equation (1.1.A),

Density (ρ) $= S \times 1000 \text{ kg/m}^3 = 0.7 \times 1000 = \mathbf{700 \ kg/m^3}$. **Ans.**

(*ii*) *Specific weight* (w)

Using equation (1.1), $w = \rho \times g = 700 \times 9.81 \text{ N/m}^3 = \mathbf{6867 \ N/m^3}$. **Ans.**

(*iii*) *Weight* (W)

We know that specific weight $= \dfrac{\text{Weight}}{\text{Volume}}$

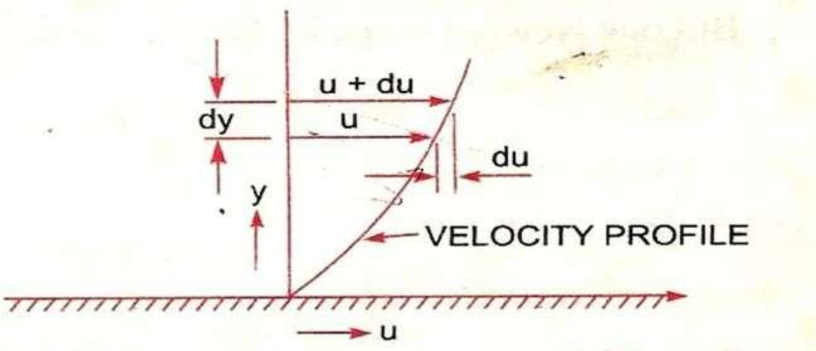
$$w = \frac{W}{0.001} \text{ or } 6867 = \frac{W}{0.001}$$

$\therefore$ $W = 6867 \times 0.001 = \mathbf{6.867 \ N}$. **Ans.**

Viscosity

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

Let two layers of a fluid at a distance dy apart, move one over the other at different velocities u and u + du.



Velocity variation near a solid boundary.

The viscosity together with the with the relative velocity between the two layers while causes a shear stress acting between the fluid layers, the top layer causes a shear stress on the adjacent lower layer while the lower layer causes a shear stress on the adjacent top layer.

This shear stress is proportional to the rate of change of velocity with respect to y. It is denoted by r.

.

Mathematically $$r \;\alpha \frac{du}{dy}$$

$$r \;= \mu \frac{du}{dy}$$

Where μ = co-efficient of dynamic viscosity or constant of proportionality or viscosity

$\frac{du}{dy}$ = rate of shear strain or velocity gradient

$$\mu = \frac{c}{\frac{du}{dy}}$$

If $\frac{du}{dy} = 1$,

then $\mu = r$

Viscosity is defined as the shear stress required to produce unit rate of shear strain.

Unit of viscosity in S.I system - $\frac{Ns}{m^2}$

in C.G.S – $\frac{Dyne\ s}{cm^2}$

In MKS - $kgfs/cm^2$

$$\frac{Dyne\ s}{cm^2} = 1 \text{ Poise}$$

$$1\ \frac{Ns}{m^2} = 10 \text{ poise}$$

$$1 \text{ Centipoise} = \frac{1}{100} \text{ poise}$$

Kinematic Viscocity:

It is defined as the ratio between the dynamic viscosity and density of fluid.

It is denoted by ϑ.

Mathematically

$$\nu = \frac{\text{Viscosity}}{\text{Density}} = \frac{\mu}{\rho} \qquad \text{...(1.4)}$$

The units of kinematic viscosity is obtained as

$$\nu = \frac{\text{Units of } \mu}{\text{Units of } \rho} = \frac{\text{Force} \times \text{Time}}{(\text{Length})^2 \times \frac{\text{Mass}}{(\text{Length})^3}} = \frac{\text{Force} \times \text{Time}}{\frac{\text{Mass}}{\text{Length}}}$$

$$= \frac{\text{Mass} \times \frac{\text{Length}}{(\text{Time})^2} \times \text{Time}}{\left(\frac{\text{Mass}}{\text{Length}}\right)} \qquad \left\{\begin{aligned} \because\ \text{Force} &= \text{Mass} \times \text{Acc.} \\ &= \text{Mass} \times \frac{\text{Length}}{\text{Time}^2} \end{aligned}\right\}$$

$$= \frac{(\text{Length})^2}{\text{Time}}.$$

In MKS and SI, the unit of kinematic viscosity is metre^2/sec or m^2/sec while in CGS units it is written as cm^2/s. In CGS units, kinematic viscosity is also known stoke.

Thus, one stoke $= \text{cm}^2/\text{s} = \left(\frac{1}{100}\right)^2 \text{m}^2/\text{s} = 10^{-4}\ \text{m}^2/\text{s}$

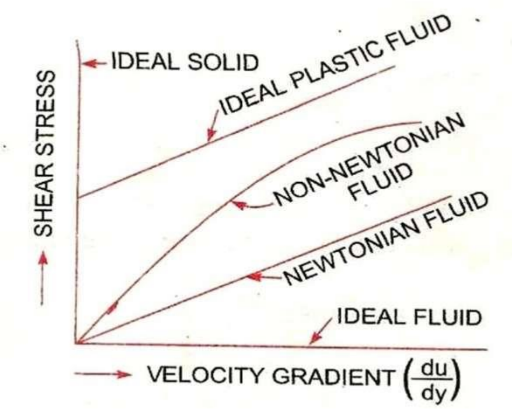
Centistoke means $= \frac{1}{100}$ stoke.

Newton's law of viscosity:

It states that the shear stress on a fluid element layer is directly proportional to the rate of shear stear strain. The constant of proportionality is called the co-efficient of viscosity.

Mathematically $$r = \mu \frac{du}{dy}$$

Fluids which obey the above equation or law are known as Newtonian fluids & the fluids which do not obey the law are called Non-Newtonian fluids.



Surface tension:

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a stretched membrane under tension. The magnitude of this force per unit length of the free will has the same value as the surface energy per unit area.

It is denoted by σ

Mathematically $\sigma = \frac{F}{L}$

Unit in si system is N/m

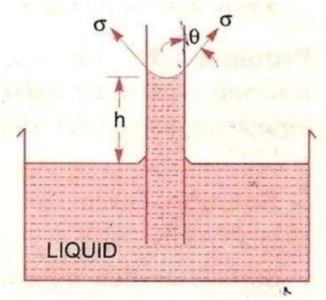
CGS system is Dyne/cm

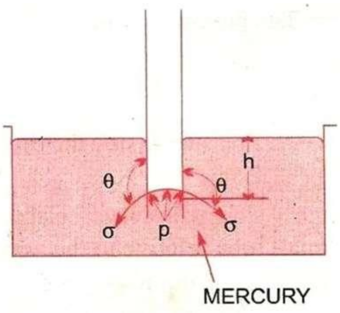
MKS system is kgf/m

Capillarity:

Capillarity is defined as a phenomenon of rise or fall of a liquid surface in a small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid. The rise of liquid surface is is known as capillary rise while the fall of the liquid surface is known as capillary depression.

It is expressed in terms of cm or mm of liquid





Its value depends upon the specific weight of the liquid, diameter of the tube and surface tension of the liquid.

Chapter-2

Fluid Pressure And It's Measurements

Pressure of a Fluid:

When a fluid is contained in a vessel, it exerts force at all points on the sides & bottoms of the container. The force exerted per unit area is called pressure.

If P = Pressure at any point

F = Total force uniformly distributed over an area

A = unit area

P = F/A

Unit of pressure - $\frac{kgf}{m^2}$ in M.K.S.

- $\frac{N}{m^2}$ in S.I.

- $\frac{Dyne}{cm^2}$

1pascal = 1N/m^2

1 kpa = 1000 N/m^2

Pressure head of a liquid:

A liquid is subjected to pressure due to pressure due to its own weight, this pressure increases as the depth of the liquid increases.

Let a bottomless cylinder stand in the liquid

Let w = specific weight of the liquid.

H = height of the liquid in the cylinder.

A = Area of the cylinder.

$$P = \frac{F}{A} = \frac{weight\ of\ the\ liquid\ in\ the\ cylinder}{Area\ of\ the\ cylinder}$$

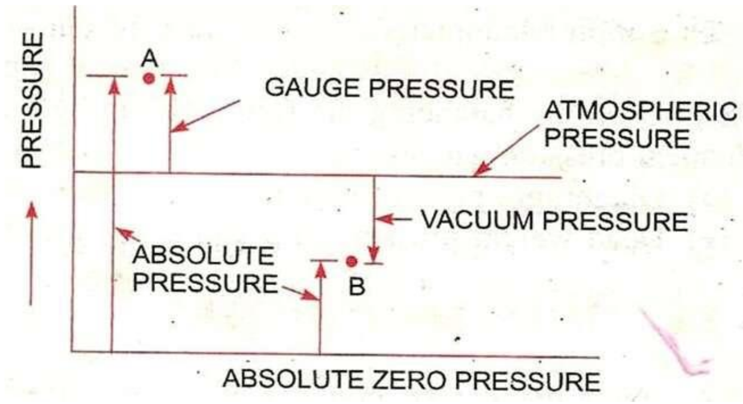
$$= \frac{\mathrm{W} \times A\ h}{A}$$

= Wh

= ρgh

So intensity of pressure at any point in a liquid is proportional to it depth.

ABSOLUTE, GAGUE, ATOMOSPHERIC, AND VACCUME PRESSURES:



Atmospheric Pressure:

The atmospheric air exerts a normal pressure upon all surfaces with which It is in contact & known as atmospheric pressure.

Absolute pressure:

It is defined as the pressure which is measured with reference to absolute vacuum pressure or absolute zero pressure.

Gauge pressure:

It is defined as the pressure which is measured with the help of a pressure measuring instrument in which the atmospheric pressure is taken as datum. The atmospheric pressure on the scale is marked as zero.

Vacuum pressure:

It is defined as the pressure below the atmospheric pressure.

Mathematically:

Absolute pressure = Atmospheric pressure + gauge pressure

Or $P_{abs} = P_{atm} + P_{gauge}$

Vacuum pressure = Atmospheric pressure – Absolute pressure

$P_{vacuum} = P_{atm} - P_{abs}$

Pressure Measuring Instruments:

The pressure of a fluid is measured by the following devices :

1. **Manometers**
2. **Mechanical Gauges**.

Manometers:

Manometers are defined as the device used for measuring the pressure at a point in a fluid by balancing the collomn of fluid by the same another column of the fluid. They are classified as:

(a) Simple manometers.
(b) Differential Manometers.

Mechanical Gauges:

Mechanical gauges are defined as the device used for measuring the pressure by balancing the fluid column by the spring or dead weight. Commonly used mechanical pressure gauges are :

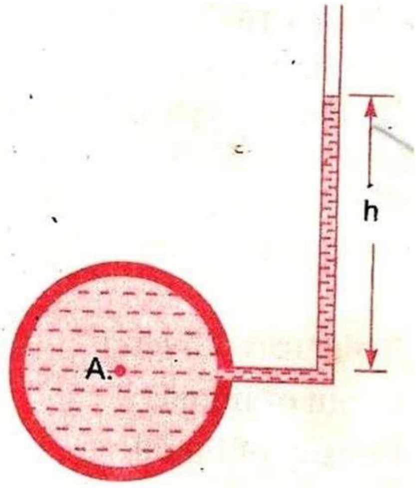
- **Diaphragm pressure gauge**
- **Bourdon tube pressure gauge**
- **Dead –weight pressure gauge**
- **Bellow pressure gauge**

Simple Manometres:

A simple manometer of a glass tube having one of its ends connected to a point where pressure is to be measured and other end remains open to atmosphere. Common types of simple manometers are :

- **Piezometer**
- **U- tube Manometer**
- **Single Column Manometer**

Piezometer:

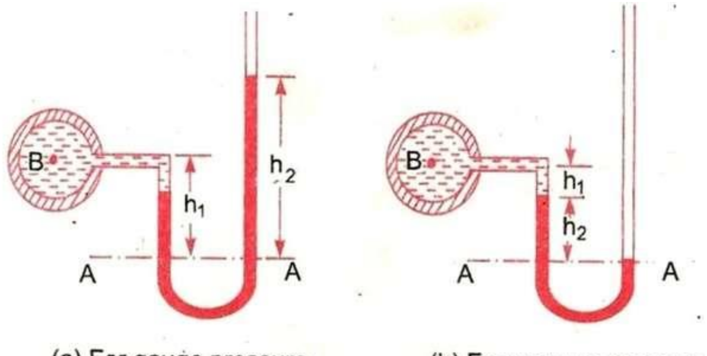


It is the simple form of manometer used for measuring gauge pressures. One end of this manometer is connected to the point where pressure is to be measured and other end is open to the atmosphere as shown in Figure. The rise of liquid gives the pressure head at that point A. Then pressure at A

$$\mathbf{P_A = \rho g h}$$

U – tube Manometer:

It consist of glass tube bent in U- shape , one end of which is connected to a point at which pressure is to be measured and other end remains open to the atmosphere as shown in figure. The tube generally contains mercury.



(a) For gauge pressure (b) For vacuum pressure

(a) For Gauge Pressure:

Let be is the point which is to be measured, whose value is p. The datum line is A-A.

Let h_1= Height of light liquid above the datum line

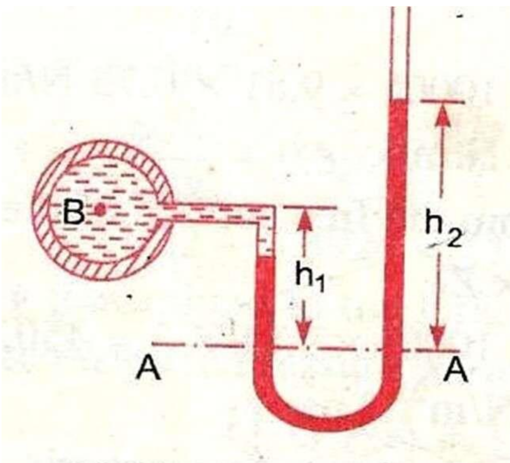
h_2= Height of heavy liquid above the datum line

S_1 = Sp. gr. of light liquid

ρ_1 = Density of light liquid = 1000× S_1

S_2 = Sp. Gr. Of heavy weight

ρ_2 = density of heavy weight = 1000×S_2



(a) For gauge pressure

Pressure is same in a horizontal surface. Hence pressure above the horizontal datum surface line A-A in the left column and in the right column of U-tube manometer should be same pressure above A-A in the left column

$$= p_A + \rho_1 \times g \times h_1$$

Pressure above A-A in the right column

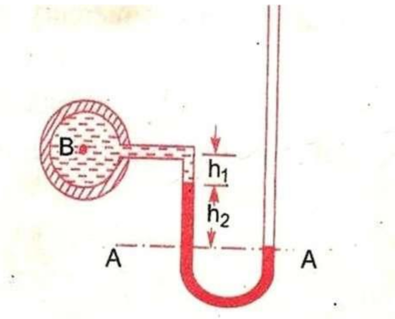
$$= \rho_2 \times g \times h_2$$

Hence equating the two pressures

$$p_A + \rho_1 g h_1 = \rho_2 g h_2$$

$$p_A = (\rho_2 g h_2 - \rho_1 g h_1).$$

(b) For Vacuum Pressure:



For measuring vacuum pressure, the level of the heavy liquid in the manometer will be as shown in figure. Then Pressure above A-A in the left column

$$= \rho_2 g h_2 + \rho_1 g h_1 + p_A$$

Pressure head in the right column above A - A = 0

$$\rho_2 g h_2 + \rho_1 g h_1 + p_A = 0$$

$$p_A = -(\rho_2 g h_2 + \rho_1 g h_1)$$

<u>Single Column Manometer:</u>

Single column Manometer is modified form of a U- tube manometer in which a reservoir, having a large cross- sectional area (about 100 times as compared to the area of the tube) is connected to one of the limbs (say left limb)of the manometer as shown in figure. Due to large cross- sectional area of the reservoir, for any variation in pressure, the change in the liquid level in the reservoir will be very small which may be neglected and hence the pressure is given by the height of liquid in the other limb. The other limb may be vertical or inclined. Thus there are two types of single column manometer as:

- **Vertical Single Column Manometer**
- **Inclined Single Column Manometer**

1. Vertical Single Column Manometer:

Let X-X be the datum line in the reservoir and in the right limb of the manometer, when it is not connected to the pipe. When the manometer is connected to the pipe, due to high pressure at A, the heavy liquid in the reservoir will be pushed downward and will rise in the right limb.

Let Δh = Fall of heavy liquid in reservoir

H_2 = rise of heavy liquid in right limb

H_1 = height of center of pipe above X-X

P_A = Pressure at A, which is to be measured

A = Cross – sectional area of the reservoir

a = Cross sectional area of the right limb

S_1 = Sp.gr.of liquid in pipe

S_2 = Sp.gr. of heavy weight liquid in reservoir and right limb

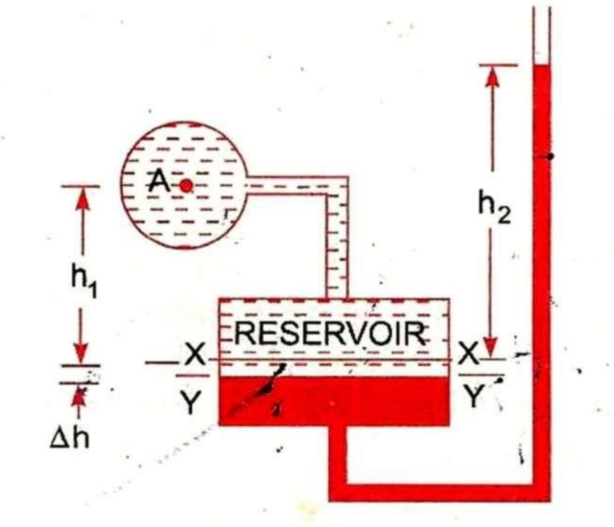
P_1 = Density in liquid in pipe

P_2 = Density of liquid in the reservoir

Fall of heavy liquid in the reservoir will cause a rise of heavy liquid level in the right limb.

$\therefore \quad A \times \Delta h = a \times h_2$

$\therefore \quad \Delta h = \frac{a \times h}{A}$ ……………………(i)



Now consider the datum line Y-Y as shown in Fig 2.15.Then pressure in the right limb above Y-Y.

$$= \rho_2 \times g \times (\Delta h + h_2)$$

Pressure in left limb above Y-Y $\quad = \rho_1 \times g \times (\Delta h + h_1) + p_A$

Equating the pressure, we have

$$\rho_2 \times g \times (\Delta h + h_2) = \rho_1 \times g \times (\Delta h + h_1) + P_A$$

$$P_A = \rho_2 g\,(\Delta h + h_1) - \rho_1 g\,(\Delta h + h_1)$$

$$= \Delta h\,[\rho_2 g - \rho_1 g] + h_2\,\rho_2 g - h_1\,\rho_1 g$$

But from equation (i), $\quad \Delta h = \dfrac{a \times h}{A}$

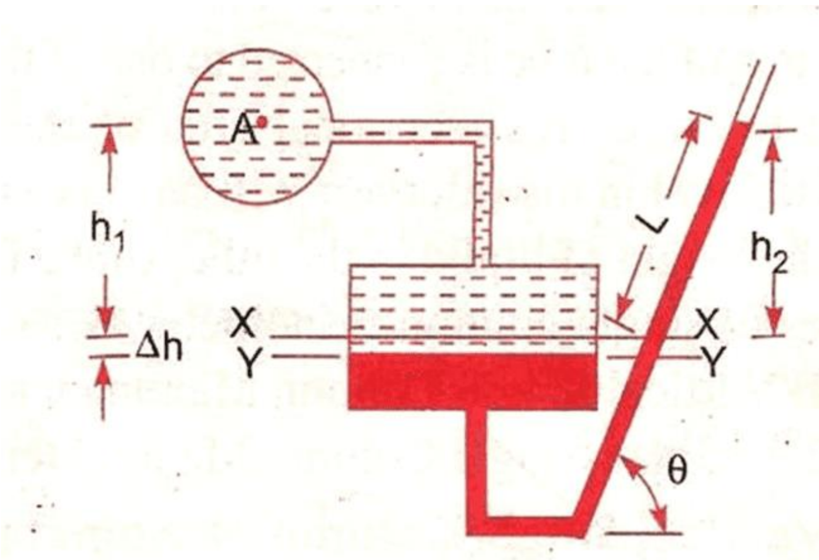
So, $P_A = \dfrac{a \times h}{A}[\rho_2 g - \rho_1 g] + h_2\,\rho_2 g - h_1\,\rho_1 g$

As the area A is very large as compared to a, hence ratio $\frac{a}{A}$ becomes very small and can be neglected.

Then $P_A = h_2\,\rho_2 g - h_1\,\rho_1 g$

2. Inclined Single Column Manometer:

The given figure shows the inclined single column manometer which is more sensitive. Due to inclination the distance moved by the heavy liquid in the right limb will be more.



Let L = length of heavy liquid moved in right limb from X-X

θ = Inclination of right limb with horizontal

h_2 = Vertical rise of heavy liquid in right limb from X-X

$= L \times \sin\theta$

From the above equation for the pressure in the single column manometer the pressure at A is

$$P_A = h_2 \rho_2 g - h_1 \rho_1 g .$$

Substituting the value of h_2, we get

$$P_A = \sin\theta \rho_2 g L - h_1 \rho_1 g .$$

DIFFERENTIAL MANOMETERS:

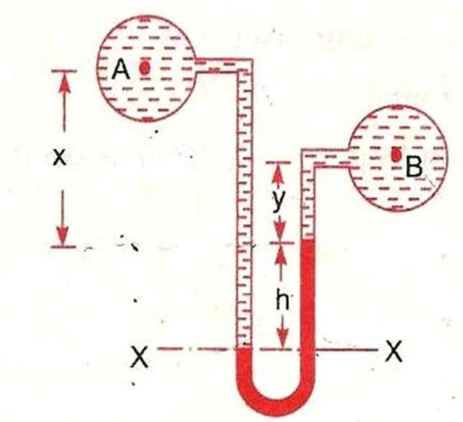
Differential manometers are the device use for measuring the difference of pressures between two points in a pipe or in two different pipes. A differential manometer consists of a U- tube, containing a heavy liquid, whose two ends are connected to the points, whose difference of pressure is to be measured. Most commonly used differential manometers are :

1. **U-tube differential manometer**
2. **Inverted U-tube differential manometer**

U-tube differential manometer:

Two points A and B are at different level

The given figure shows the differential manometers of U-tube type.



Let the two points A and B are at different level also contains liquids of different sp.gr. These points are connected to the U-tube differential manometer. Let the pressure at A and B are P_A and P_B.

Let h = Difference of mercury level in the U- tube.

y = Distance of the center of B, from the mercury level in the right limb.

ρ_1 = Density of liquid at A.

ρ_2 = Density of liquid at B.

ρ_g = Density of heavy liquid or mercury.

Taking datum line at X-X .

Pressure above X-X in the limb

$= \rho_1 g(h + x) + P_A$

Where pressure P_A = Pressure at A.

Pressure above X-X in the right limb

$= \rho_g \times g \times h + \rho_2 \times g \times y + p_B$

Where pressure p_B = pressure at B.

Equating the two pressure, we have

$P_1 g(h + x) + P_A = p_g \times g \times h + p_2 g y + p_B$

$\therefore$ $P_A - p_B = \rho_g \times g \times h + \rho_2 g y - \rho_1 g (h + x)$

$= h \times g(\rho_g - \rho_1) + \rho_2 g y - \rho_1 g x$

$\therefore$ Different of pressure at A and B

$= h \times g(\rho_g - \rho_1) + \rho_2 g y - \rho_1 g x$

Two points A and B are at same level

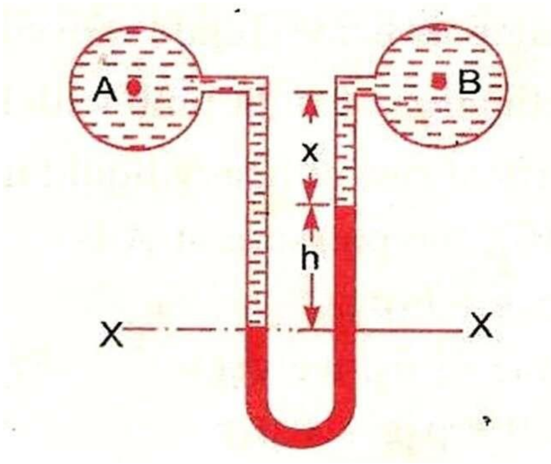
In the given figure A and B are the same level and contains the same liquid of density ρ_1, then

Pressure above X-X in right limb

$= \rho_g \times g \times h + \rho_1 \times g \times X + p_B$

Pressure above X-X in left limb

$= P_1 \times g \times (h + x) + P_A$



Equating the two pressure

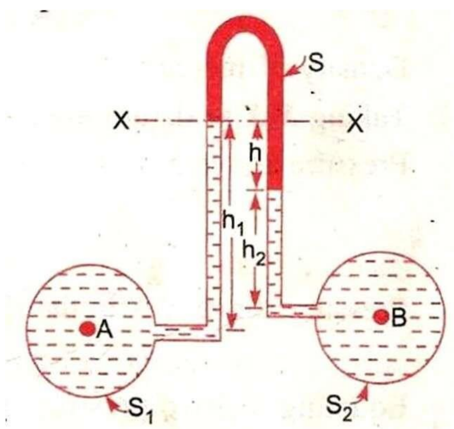
$p_g \times g \times h + P_1 \times g \times X + p_B = P_1 \times g \times (h + x) + P_A$

$\therefore \quad P_A - p_B = P_g \times g \times h + P_1 g x - P_1 g \times (h + x)$

$= g \times h\,(P_g - P_1)$

Inverted U-tube Differential Manometer:

It consists of an inverted U-tube, containing a light liquid. The two ends of the U-tube are connected to the points whose difference of pressure is to be measured. It is used for measuring difference of low pressures. Fig 2.21 shows an inverted U-tube differential manometer connected to the points A and B. Let the pressure at A is more than the pressure at B.



Let h_1=Height of liquid in the left limb bellow the datum line X-X

h_2= Height of liquid in the right limb

h= Difference of light liquid

p_1=Density of liquid at A

p_2=Density of liquid at B

p_s= Density of light liquid

p_A=*Pressure at A*

p_B= Pressure at B.

Taking X-X datum line.

Then pressure in the left limb below X-X

$$= P_A - \rho_1 \times g \times h_1.$$

Pressures in the right limb below X-X

$$= P_B - \rho_2 \times g \times h_2 - \rho_S \times g \times h$$

Equating the two pressure

$P_A - \rho_1 \times g \times h_1 = P_B - \rho_2 \times g \times h_2 - \rho_S \times g \times h$

$P_A - P_B = \rho_1 \times g \times h_1 - \rho_2 \times g \times h_2 - \rho_S \times g \times h$

Bourdon's Tube Pressure Gauge:

- The pressure above or below the atmospheric pressure may be easily measured with the help of Burdon tube pressure gauge.
- It consists of an elliptical tube ABC bent into an arc of a circle. This bent up tube is called Burdon tube.
- When the gauge tube is connected to the C, the fluid under pressure flows into the tube the bourdon tube as a result of the increased pressure tends to straighten itself.
- Since the tube is encased in a circular cover therefore.it tends to become circular instrad of straight.
- The elastic beforemation of the bourdon rotates the pointer.
- The pointer moves over a calibrates which directly gives the pressure.

Chapter-3

Hydrostatics

Hydrostatics:

Hydrostatics means the study of pressure exerted by thye liquid at rest & the direction of such a pressure is always right angle to the surface on which it acts.

Total pressure and center of pressure:

Total pressure

Total pressure is defined as the force exerted by a static fluid on a surface either plane or curved when the fluid comes in contact with surfaces. This force always acts normal to the surface.

Center of pressure:

Center of pressure is defined as the point of application of the total pressure on the surface.

There are four cases of submerged surfaces on which the total pressure force and center of pressure is to be determined. The submerged surfaces may be:

1. **Vertical plane surface**

2. **Horizontal plane surface**
3. **Inclined plane surface**
4. **Curved surface.**

Vertical plane surface submerged in liquid

Consider a plane vertical surface of arbitrary shape immersed in a liquid as shown in figure

Let A = total area of the surface

H = distanced of C.G. of the area from free surface of liquid

G = center of gravity ofplane surface

P = center of pressure

h* = distance of center of pressure from free surface of liquid.

Total pressure(F)

The total pressure on the surface may be determined by dividing the entire surface into a number of small parallel strips. The force on surface is then calculated by integrating the force on small strip.

Consider a strip of thickness dh & width b at a depth of h form free surface of liquid.

Pressure intensity on the strip

$$p = \rho gh$$

Area of the strip, $dA = b \times dh$

Total pressure forceon strip, $dF = \rho dA$

$$= \rho gh \times b \times dh$$

Total pressure force on thge whole surface

$$F = \int dF = \int \rho gh \times b \times dh$$

$$= \rho g \int h \times b \times dh$$

$\int h \times dA$ = moment of surface area about the free surface of liquid

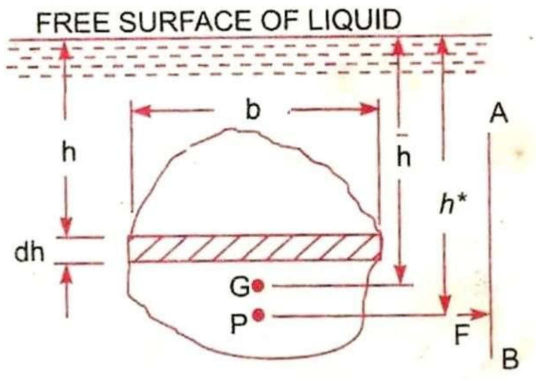
= Area of surface × distance of C.G. from the free surface

$= A \times \bar{h}$

So, $F = \rho g A \bar{h}$

<u>Centre of the pressure:(</u> h*)

Centre of pressure is calculated by using the principle of moments which states that the moment of resultant force about an axis is equal to the sum of moments of the components about the same axis.



The resultant force F is acting at P, at a distance **h*** from the free surface of liquid.

Hence moment of force F about free surface of liquid = F × h*

But moment force dF acting on a strip about the free surface of liquid = dF × h

Sum of moments of all such forces about free surface of liquid

$$= \int \rho g h \times b \times dh \times h$$

$$= \rho g \int h \times b \times dh \times h$$

$$= \rho g \int b h^2 \, dh$$

$$= \rho g \int h^2 \, dA$$

$\int h^2 \, dA$ = moment of inertia of the surface area about the free surface of liquid = Io

Sum of the moments about free surface

$= \rho g\ Io$

$F \times h^* = \rho g\ Io$

$\rho g A\bar{h} \times h^* = \rho g\ Io$

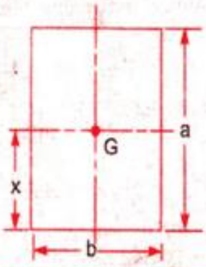
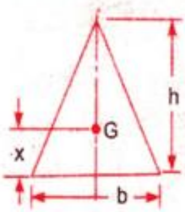
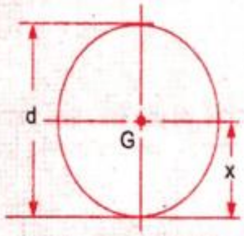
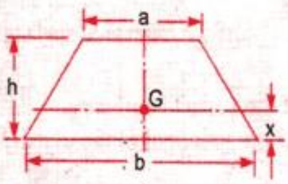
$$h^* = \frac{\rho g\ Io}{\rho g A\bar{h}}$$

$$= \frac{Io}{A\bar{h}}$$

By the parallel axis theorem, we have

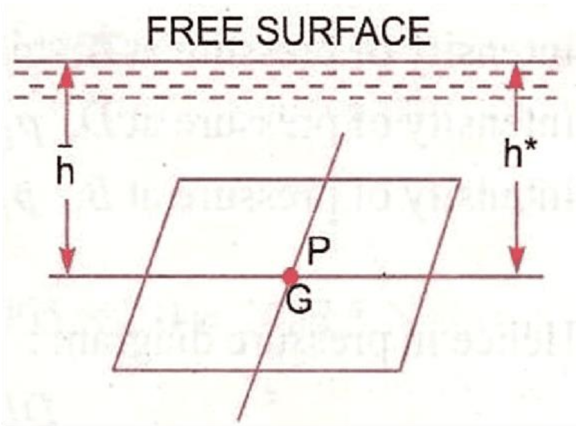
$Io = I_G + A \times (\bar{h})^2$

$$h^* = \frac{I_G + A\bar{h}^2}{A\bar{h}} = \frac{I_G}{A\bar{h}} + \bar{h}$$

Plane surface	C.G. from the base	Area	Moment of inertia about an axis passing through C.G. and parallel to base (I_G)	Moment of inertia about base (I_0)
1. Rectangle 	$x = \frac{d}{2}$	bd	$\frac{bd^3}{12}$	$\frac{bd^3}{3}$
2. Triangle 	$x = \frac{h}{3}$	$\frac{bh}{2}$	$\frac{bh^3}{36}$	$\frac{bh^3}{12}$
3. Circle 	$x = \frac{d}{2}$	$\frac{\pi d^2}{4}$	$\frac{\pi d^4}{64}$	—
4. Trapezium 	$x = \left(\frac{2a+b}{a+b}\right)\frac{h}{3}$	$\frac{(a+b)}{2} \times h$	$\left(\frac{a^2+4ab+b^2}{36(a+b)}\right) \times h^3$	—

Horizontal plane surface submerged in liquid:

Consider a plane horizontal surface immersed in a static fluid as every point of the surface is at the same depth from the free surface of the liquid, the pressure intensity will be equal on the entire surface.



$P = \rho g\bar{h}$

A = total area

$F = P \times A$

$= \rho g A\bar{h}$

Archimedes principle:

When a body is immersed in a fluid either wholly or partially, it is buoyed or lifted up by a force, which is equal to the weight of fluid displaced by the body.

Buoyancy:

Whenever a body is immersed wholly or partially in a fluid it is subjected to an upword force which tends to lift itup. This tendency for an immersed body to be lifted up in the fluid due to an upward force opposite to action of gravity is known as buoyancy this upward force is known as force of buoyancy.

Centre of Buoyancy:

It is defined as the point through which the forced of buoyancy is supposed to act. The force of buoyancy is a vertical force and is equal to the weight of the fluid displaced by the body.

Canter of buoyancy will be the centre of gravity of the fluid displaced.

Problem-1:

Find the volume of the water displaced & position of centre of duoyancy for a wooden block of width 2.5m & of depth 1.5m when it flats horizontally in water. The density of wooden block is 6540 kg/m3.& its length 6.0m.

Solution:

Width = 2.5 m

Density of wooden block = 650kg/m^3

Depth = 1.5m

Length = 6m

Volume of the block

$= 2.5\times 1.5 \times 6$

$=22.50 m^3$

Volume of the block = Wt of water displaced

$= W\times V$

$=\rho g \times V$

$= 650\times 9.81 \times 6$

$=143471$ N

Volume of water displaced

$$= \frac{weight}{\rho w\times g}$$

$$= \frac{143471}{1000 \times 9.81}$$

$= 14.625\ m^3$

Position of centre of buoyancy

Volume of wooden block in water = volume of water displaced

$$2.5 \times 6 \times h = 14.625$$

$$\Rightarrow h = \frac{14.625}{2.5 \times 6}$$

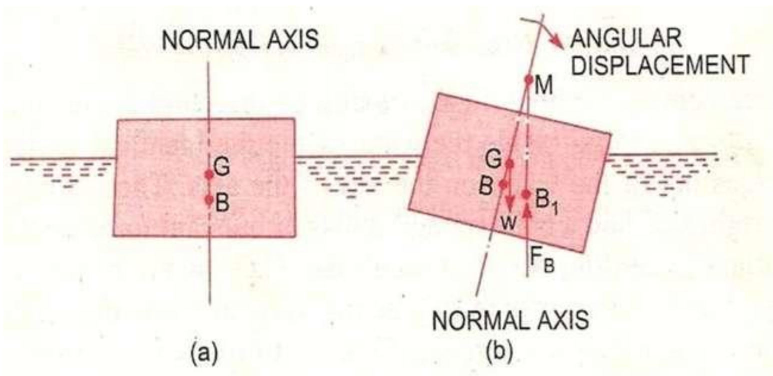
$= 0.975m$

Centre of buoyancy = $\frac{0.975}{2}$

$= 0.4875$ m from base.

Meta-centre;

It is defined as the point about which a body starts oscillating when the body is tilted by a small angle. The mate centre may also be defined as the point at which the lme of action of the force of buoyancy will melt the normal axis. Of the body when the body is given a small angular displacement.



Mate centre height:

The distance between the meta centre of a floating body and the centre of gravity of the body is called meta-centric height i.e the distance MG.

Concept of flotation:

Flotation:

When a body is immersed in any fluid, it experiences two forces. First one is the weight of body W acting vertically downwards, second is the buoyancy force F_β acting vertically upwards in case W is greater than F_β, the weight will cause the body to sink in the fluid. In case W = F_β the body will remain in equilibrium at any level. In case W is small than F_β the body will move upwards in fluid. The body moving up will come to rest or top moving up in fluid when the fluid displaced by it's submerged part is equal to its weight W, the body in this situation is said to be floating and this phenomenon is known as flotation.

Chapter-4

Kinamatics of Flow

Introduction

This chapter includes the study of forces causing fluid flow. The dynamics of fluid flow is the study of fluid motion with the forces causing flow. The dynamic behaviour of the fluid flow is analysed by the Newton second law of motion, which relates the acceleration with the forces. The fluid is assumed to be incompressible and non-viscous.

TYPES OF FLOW

The fluid flow is classified as follows:

- **STEADY AND UNSTEADY FLOW**
- **UNIFORM AND NON- UNIFORM FLOWS**
- **LAMINAR AND TURBULANT FLOWS**
- **COMPRESSIBLE AND INCOMPRESSIBLE FLOWS**
- **ROTATIONAL AND IRROTATIONAL FLOWS**
- **ONE, TWO, THREE DIMENSIONAL FLOW**

➢ **STEADY AND UNSTEADY FLOW**

1. **Steady flow:-**

Steady flow is defined as that type of flow in which the fluid characteristics like velocity, pressure, density at a point do not change with time.

Thus, mathematically

$$\left(\frac{6v}{6t}\right)_{x_0,y_0,z_0} = 0$$

$$\left(\frac{6p}{6t}\right)_{x_0,y_0,z_0} = 0$$

$$\left(\frac{6\rho}{6t}\right)_{x_0,y_0,z_0} = 0$$

Where x_0, y_0, z_0 is a point in fluid flow .

2. **Unsteady flow:-**

Unsteady flow is defined as that type of flow in which the velocity, pressure, and density at a point changes w.r.t time.
Thus, mathematically

$$\left(\frac{6v}{6t}\right)_{x_0,y_0 z_0} \neq 0,$$

$$\left(\frac{6p}{6t}\right)_{x_0,y_0 z_0} \neq 0,$$

$$\left(\frac{6\rho}{6t}\right)_{x_0,y_0 z_0} \neq 0$$

➢ **UNIFORM AND NON- UNIFORM FLOWS:-**

1. **Uniform flow:-**

It is defined as the flow in which velocity of flow at any given time does not change w.r.t length of flow or space.

Mathematically,

$$\left(\frac{dv}{ds}\right)_{t=constant} = 0$$

where ∂v = velocity of flow ,

∂s = length of flow ,

T = time

2. **<u>Non- uniform flows</u>:-**

It is defined as the flow in which velocity of flow at any given time changes w.r.t length of flow.

Mathematically,

$$\left(\frac{dv}{ds}\right)_{t=constant} \neq 0$$

LAMINAR AND TURBULANT FLOWS:-

1. **Laminar flow**:-

Laminar flow is that type of flow in which the fluid particles are moved in a well defined path called streamlines. The paths are parallel and straight to each other.

2. **Turbulent flow**:-

Turbulent flow is that type of flow in which the fluid particles are moved in a zig-zag manner.

For a pipe flow the type of flow is determined by Reynolds number (R_e)

Mathematically

$$R_e = \frac{VD}{v}$$

Where V = mean velocity of flow

D = diameter of pipe

V = kinematic viscosity

If R_e< 2000, then flow is laminar flow.

If R_e> 4000, then flow is turbulent flow.

If R_e lies in between 2000 and 4000, the flow may be laminar or turbulent.

- **COMPRESSIBLE AND INCOMPRESSIBLE FLOWS** :-

1. **Compressible flow**:-

Compressible flow is that type of flow in which the density of fluid changes from point to point.

So, $\partial \neq$ constant.

2. **Incompressible flow**:-

Incompressible flow is that type of flow in which the density is constant for the fluid flow.

So, $\partial =$constant

- **ROTATIONAL AND IRROTATIONAL FLOWS**:-

1. **Rotational flow:-**

Rotational flow is that of flow in which the fluid particles while flowing along stream lines also rotate about their own axis.

2. **Ir-rotational flow**:-

Irrotational flow is that type of flow in which the fluid particles while flowing along streamlines do not rotate about their own axis.

- **ONE, TWO, THREE DIMENSIONAL FLOW**:-

1. **One dimensional flow**:-

One dimension flow is defined as that type of flow in which velocity is a function of time and one space co-ordinate only.

For a steady one dimensional flow, the velocity is a function of one space co-ordinate only.

So, $U = f(x)$,

$V = 0$,

$W = 0$

U, V, W are velocity components in x, y, z direction respectively.

2. **Two-dimensional flow**:-

Two-dimensional flow is the flow in which velocity is a function of time and 2- space co- ordinates only. For a steady 2- dimensional flow the velocity is a function of two – space co-ordinate only.

So, $U = f_1(x,y)$,

$V = f_2(x,y)$,

$W = 0$

3. **Three-dimensional flow**:-

Three – dimensional flow is the flow in which velocity is a function of time and 3- space co-ordinates only. For steady three- dimensional flow, the velocity is a function of three space co-ordinates only.

So $U = f_1(x, y, z)$

$V = f_2(x, y, z)$

$W = f_3(x, y, z)$

RATE OF FLOW OR DISCHARGE

It is defined as the quantity of a fluid flowing per second through a section of pipe.

For an incompressible fluid the rate of flow or discharge is expressed as the volume of fluid flowing across the section per second.

For compressible fluids, the rate of flow is usually expressed as the weight of fluid flowing across the section.

$$Q = A.V$$

Where A = cross sectional area of the pipe

V = velocity of fluid across the section

Unit:-

1. For incompressible fluid

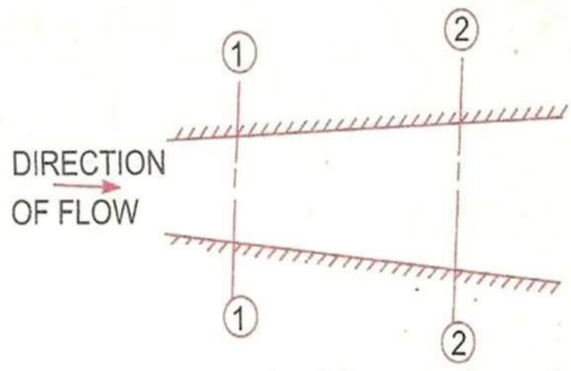
$$\frac{m3}{sec} \text{ or } \frac{litre}{sec}$$

2. For compressible fluid:

$$\frac{newton}{sec} \text{ (S.I units), } \frac{kgf}{sec} \text{ (M.K.S units)}$$

EQUATION OF CONTINUITY:-

It is based on the principle of conservation of mass. For a fluid flowing through the pipe at all the cross-section, the quantity of fluid per second is constant.



Fluid flowing through a pipe.

Let V_1= average velocity at cross-section 1-1.

ρ_1 = density at cross-section 1-1

A_1 = area of pipe at section 1-1

V_2= average velocity at cross-section 2-2

ρ_2 = density at cross-section 2-2

A_2 = area of pipe at section 2-2

The rate of flow at section 1-1 =$\rho_1 A_1 V_1$

The rate of flow at section 2-2 =$\rho_2 A_2 V_2$

According to laws of conservation of mass rate of flow at section 1-1 is equal to the rate of flow at section 2-2 ,

$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$

This is called continuity equation.

If the fluid is compressible, then $\rho_1 = \rho_2$,

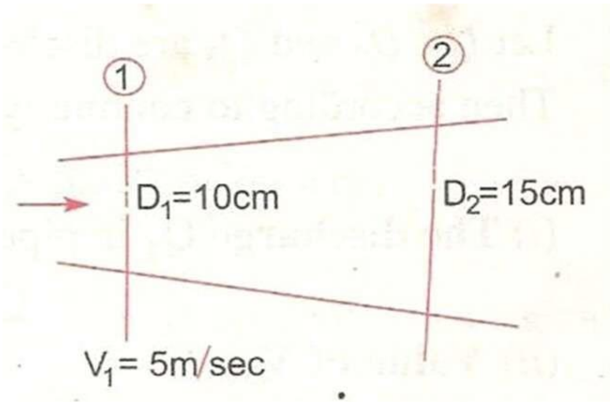
so $A_1 V_1 = A_2 V_2$

"If no fluid is added removed from the pipe in any length then the mass passing across different sections shall be same"

Simple Problems

Problem:-1

The diameters of a pipe at the sections 1 and 2 are 10cm and 15cm respectively. Find the discharge through the pipe if the velocity of the water flowing through the pipe at section 1 is 5m/s. Determine also the velocity at section 2.



Solution. Given :

At section 1, $D_1 = 10 \text{ cm} = 0.1 \text{ m}$

$$A_1 = \frac{\pi}{4}(D_1^2) = \frac{\pi}{4}(.1)^2 = .007854 \text{ m}^2$$

$$V_1 = 5 \text{ m/s.}$$

At section 2, $D_2 = 15 \text{ cm} = 0.15 \text{ m}$

$$A_2 = \frac{\pi}{4}(.15)^2 = 0.01767 \text{ m}^2$$

(*i*) Discharge through pipe is given by equation (5.1)

or $$Q = A_1 \times V_1$$

$$= .007854 \times 5 = \mathbf{0.03927 \text{ m}^3\text{/s. Ans.}}$$

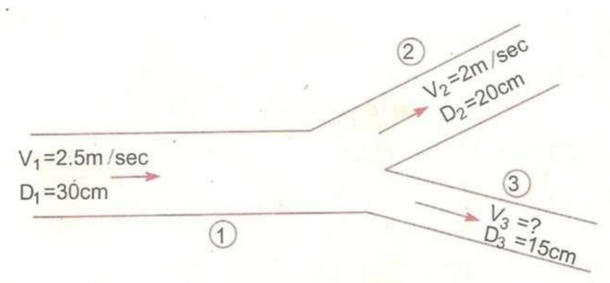
Using equation (5.3), we have $A_1 V_1 = A_2 V_2$

(*ii*) $\therefore$ $$V_2 = \frac{A_1 V_1}{A_1} = \frac{.007854}{.01767} \times 5.0 = \mathbf{2.22 \text{ m/s.}}$$

Problem:-2

A 30m diameter pipe conveying water branches into two pipes of diameter 20cm and 15cm respectively. If the average velocity in the 340cm diameter pipe is 2.5 m/s, find the discharge in this pipe. Also determine the velocity in 15cm pipe if the average velocity in 20cm diameter pipe is 2m/s

Solution:



Given Data:

D_1 = 30cm = 0.30m

$A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (0.3)^2 = 0.07068 \text{ m}^2$

V_1 = 2.5 m/s

D_2 = 20cm = 0.2m

$A_2 = \frac{\pi}{4} 0.2^2 = 0.0314 \text{ m}^2$

V_2 = 2m/s

D_3 = 15cm = 0.15m

$A_3 = \frac{\pi}{4} 0.15^2 = 0.01767 \text{ m}^2$

Let Q_1, Q_2, Q_3 are discharges in pipe 1, 2, 3 respsctively

$$Q_1 = Q_2 + Q_3$$

The discharge Q_1 in pipe 1 is given as

$Q_1 = A_1 V_1$

$= 0.07068 \times 2.5 \text{ m}^3/\text{s}$

$Q_2 = A_2 V_2$

$= 0.0314 \times 2.0\ 0.0628 \text{ m}^3/\text{s}$

Substituting the values of Q_1 and Q_2 on the above equation we get

$0.1767 = 0.0628 + Q_3$

$Q_3 = 0.1767 - 0.0628$

$= 0.1139$ m3/s

Again $Q_3 = A_3 V_3$

$= 0.01767 \times V_3$

Or $0.1139 = 0.01767 \times V_3$

$$V_3 = \frac{0.1139}{0.01767}$$

$= 6.44$m/s

Problem:-3

Water through a pipe AB 1.2 m diameter at 3 m/s and then passes through a pipe BC 1.5 m diameter. At C, the pipe branches. Branch CD is 0.8 m in diameter and carrier one third of the flow in AB. The flow velocity in branch` CE is 2.5 m/s. Find the volume rate of flow in AB, the velocity in BC, the velocity in CD and the diameter of CE.

Solution:

Given Data:

Diameter of pipe AB, $D_{AB} = 1.2$m

Velocity of flow through AB, $V_{AB} = 3.0$m/s

Dia, of pipe BC $D_{BC} = 1.5m$

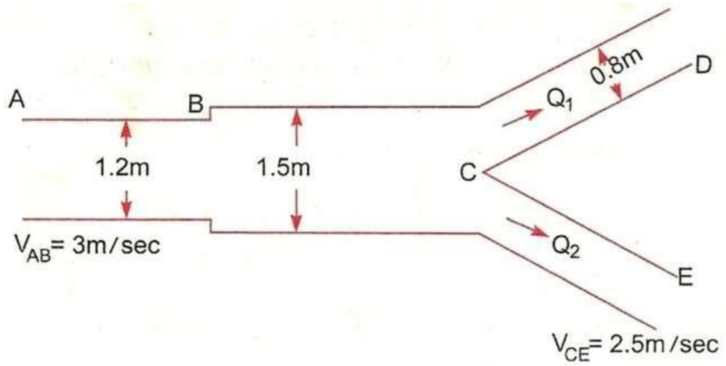
Dia of branched pipe CD = $V_{CD} = 0.8m$

Velocity of flow in pipe CE, $V_{CE} = 2.5m/s$

Let flow rate in pipe AB = Qm^3/s

Velocity of flow in pipe BC = V_{BC} m/s

Velocity of flow in pipe CD = V_{CD}



Diameter of pipe $CE = D_{CE}$

Then flow rate through $CD = Q/3$

and flow rate through $CE = Q - Q/3 = \frac{2Q}{3}$

(*i*) Now volume flow rate through $AB = Q = V_{AB} \times$ Area of AB

$$\doteq 3.0 \times \frac{\pi}{4} (D_{AB})^2 = 3.0 \times \frac{\pi}{4} (1.2)^2$$

= 3.394m3/s

(*ii*) Applying continuity equation to pipe *AB* and pipe *BC*,

$$V_{AB} \times \text{Area of pipe } AB = V_{BC} \times \text{Area of pipe } BC$$

or $$3.0 \times \frac{\pi}{4} (D_{AB})^2 = V_{BC} \times \frac{\pi}{4} (D_{BC})^2$$

or $$3.0 \times (1.2)^2 = V_{BC} \times (1.5)^2$$

or $$V_{BC} = \frac{3 \times 1.2^2}{1.5^2} = \mathbf{1.92\ m/s.\ Ans.}$$

(*iii*) The flow rate through pipe

$$C_D = Q_1 = \frac{Q}{3} = \frac{3.393}{3} = 1.131 \text{ m}^3/\text{s}$$

$\therefore$ $$Q_1 = V_{CD} \times \text{Area of pipe } C_D \times \frac{\pi}{4} (C_{CD})^2$$

or $$1.131 = V_{CD} \times \frac{\pi}{4} \times .8^2 = 0.5026\ V_{CD}$$

$\therefore$ $$V_{CD} = \frac{1.131}{0.5026} = \mathbf{2.25\ m/s.\ Ans.}$$

(*iv*) Flow rate through *CE*,

$$Q_2 = Q - Q_1 = 3.393 - 1.131 = 2.262 \text{ m}^3/\text{s}$$

$\therefore$ $$Q_2 = V_{CE} \times \text{Area of pipe } CE = V_{CE} \frac{\pi}{4} (D_{CE})^2$$

or $$2.263 = 2.5 \times \frac{\pi}{4} \times (D_{CE})^2$$

or $$D_{CE} = \sqrt{\frac{2.263 \times 4}{2.5 \times \pi}} = \sqrt{1.152} = 1.0735 \text{ m}$$

$\therefore$ Diameter of pipe *CE* = **1.0735 m. Ans.**

Problem:-4

A 25 cm diameter pipe carries oil of sp. Gr. 0.9 at a velocity of 3m/s. At another section the diameter is 20cm. Find the velocity at this section and also mass rater of flow of oil.

Solution. Given :

at section 1, $D_1 = 25 \text{ cm} = 0.25 \text{ m}$

$$A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} \times .25^2 = 0.049 \text{ m}^3$$

$V_1 = 3 \text{ m/s}$

at section 2, $D_2 = 20 \text{ cm} = 0.2 \text{ m}$

$$A_2 = \frac{\pi}{4} (.2)^2 = 0.0314 \text{ m}^2$$

$V_2 = ?$

Mass rate of flow of oil = ?

Applying continuity equation at sections 1 and 2,

$$A_1 V_1 = A_2 V_2$$

or $$0.049 \times 3.0 = 0.0314 \times V_2$$

$$\therefore \quad V_2 = \frac{0.049 \times 3.0}{.0314} = \mathbf{4.68 \text{ m/s. Ans.}}$$

Mass rate of flow of oil $= \text{Mass density} \times Q = \rho \times A_1 \times V_1$

Sp. gr. of oil $= \dfrac{\text{Densit of oil}}{\text{Densit of water}}$

$\therefore$ Density of oil = Sp. gr. of oil × Density of water

$$= 0.9 \times 1000 \text{ kg/m}^3 = \frac{900 \text{ kg}}{\text{m}^3}$$

$\therefore$ Mass rate of flow $= 900 \times 0.049 \times 3.0 \text{ kg/s} = \mathbf{132.23 \text{ kg/s. Ans.}}$

Bernoulli's equation:

Statement: It states that in a steady ideal flow of an in compressible fluid, the total energy at any point of flow is constant.

The total energy consists of pressure energy, kinetic energy & potential energy or datum energy. These energies per unit weight are

Pressure energy $= \frac{P}{\rho g}$

Kinetic energy $= \frac{v^2}{\rho g}$

Datum energy $= z$

Mathematically

$$\frac{P}{\rho g} + \frac{v^2}{\rho g} + z = \text{Constant}$$

Derivation:

Consider a perfect incompressible liquid, flowing through a non uniform pipe the pipe is running full & there

Let us consider two sections AA& BB of the pipe

Now assume that the pipe is running full & there is a continuity of flow between the two sections

Let Z_1 = Height of AA

P_1 = Pressure of AA

V_1 = Velocity of liquid of AA

Q_1 = Cross sectional area of the pipe of AA

& Z_2, P_2 , V_2 , Q_2 are the corresponding values at BB.

Let the liquid between the two sections AA & BB move to AA' & BB' through very small lenth dl_1 & dl_2

Let W is the weight of the liquid between AA & A_1A_1 & BB & B_1B_1 as the flow is continuous

$$W = wa_1dl_1 = wa_2dl_2$$
$$= a_1dl_1 = \frac{W}{\omega} = a_2dl_2$$

The work done by pressure of AA in moving the liquid $A^/A^/$

$$= \text{Force X distance}$$
$$= P_1Q_1dl_1$$

Similarly

Work done by pressure at BB

$$= - P_2Q_2dl_2$$

Total work done by pressure

$$= P_1A_1dl_1 - P_2Q_2dl_2$$

$$= P_1A_1dl_1 - P_2Q_1dl_1$$

$$= a_1dl_1(P_1 – P_2)$$

$$= \frac{W}{\omega}(P_1 – P_2)$$

Loss of Potential energy

$$= w(Z_1 – Z_2)$$

Gain in Kinetic energy

$$= \frac{W}{2g}(V_2^2 - V_1^2)$$

Loss of potenteial energy + work done by pressure

= Gain in kinetic energy

$$w(Z_1 - Z_2) + \frac{w}{\omega}(P_1 - P_2) = \frac{w}{2g}(V_2^2 - V_1^2)$$

$$Z_1 - Z_2 + \frac{P_1}{\omega} - \frac{P_2}{\omega} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

$$\frac{P_1}{\omega} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\omega} + \frac{V_2^2}{2g} + Z_2$$

Limitations:

1. the velocity of the liquid particle at the center of cross section is maximum. And the velocity gradually decreases towards the periphery of the pipe due to friction offered by the walls of the pipe line but in Bernoulli's equation it has been assumed that the velocity of liquid particle at any point across section is uniform.
2. Lass of energy due to pipe friction during flow of liquid, from one section to another are neglected in Bernoulli's equation.
3. Bernoulli's equation does not take into consideration loss of energy due to turbulent flow.
4. Bernoulli's equation does not take into consideration the loss of energy due to change of direction.

Problem:- 5

Water is flowing through a pipe of 5cm diameter under a pressure of 29.43 N/cm2 (gauge) and with mean velocity of 2.0 m/s. Find the total head or total energy per unit weight of the water at a cross-section, which is 5m above the datum line.

Solution. Given :

Diameter of pipe $= 5 \text{ cm} = 0.5 \text{ m}$

Pressure, $p = 29.43 \text{ N/cm}^2 = 29.43 \times 10^4 \text{ N/m}^2$

Velocity, $v = 2.0 \text{ m/s}$

Datum head, $z = 5 \text{ m}$

Total head $=$ pressure head + kinetic head + datum head

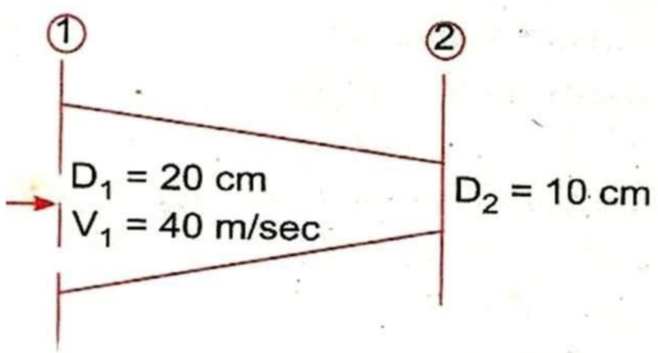
Pressure head $= \dfrac{p}{\rho g} = \dfrac{29.43 \times 10^4}{1000 \times 9.81} = 30 \text{ m}$ $\left\{ \rho \text{ for water} = 1000 \dfrac{\text{kg}}{\text{m}^3} \right\}$

Kinetic head $= \dfrac{v^2}{2g} = \dfrac{2 \times 2}{2 \times 9.81} = 0.204 \text{ m}$

$\therefore$ Total head $= \dfrac{p}{\rho g} + \dfrac{v^2}{2g} + z = 30 + 0.204 + 5 =$ **35.204 m. Ans.**

Problem:- 6

A pipe, through which water is flowing, is having diameters, 20cm and 10cm at the cross sections 1 and 2 respectively. The velocity of water at section 1 is given 4.0 m/s. Find thevelocity head at sections 1 and 2 and also rate of discharge.



Solution. Given :

$$D_1 = 20 \text{ cm} = 0.2 \text{ m}$$

$\therefore$ Area, $$A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4} (.2)^2 = 0.0314 \text{ m}^2$$

$$V_1 = 4.0 \text{ m/s}$$

$$D_2 = 0.1 \text{ m}$$

$\therefore$ $$A_2 = \frac{\pi}{4} (.1)^2 = .00785 \text{ m}^2$$

(*i*) Velocity head at section 1

$$= \frac{V_1^2}{2g} = \frac{4.0 \times 4.0}{2 \times 9.81} = \mathbf{0.815 \text{ m. Ans.}}$$

(*ii*) Velocity head at section 2 = $V_2^2/2g$

To find V_2, apply continuity equation at 1 and 2

$\therefore$ $$A_1V_1 = A_2V_2 \quad \text{or} \quad V_2 = \frac{A_1V_1}{A_2} = \frac{.0314}{.00785} \times 4.0 = 16.0 \text{ m/s}$$

$\therefore$ Velocity head at section 2 $= \dfrac{V_2^2}{2g} = \dfrac{16.0 \times 16.0}{2 \times 9.81} = \mathbf{83.047 \text{ m. Ans.}}$

(*iii*) Rate of discharge $= A_1V_1$ or A_2V_2

$$= 0.0314 \times 4.0 = 0.1256 \text{ m}^3\text{/s}$$

Application of Bernoulli's equation:

Bernoulli's equation is applied in all problems of incompressible fluid flow where energy consideration are involved.
It is also applied to following measuring devices

1. **Venturimeter**
2. **Orifice meter**
3. **Pitot tube**

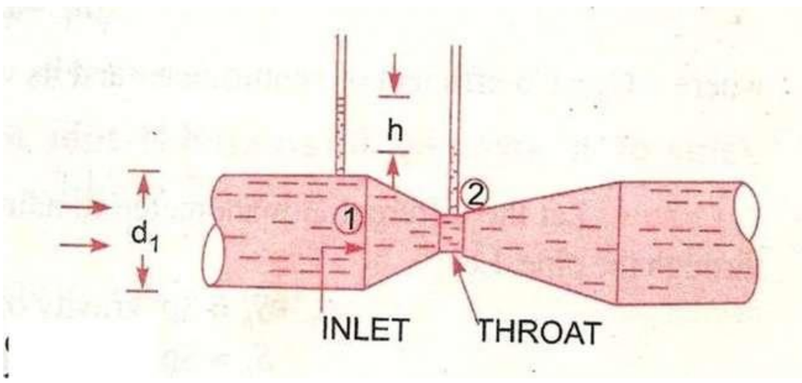
Venturimeter:

A venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe it consists of three parts.

I. **Short converging part**
II. **Throat**
III. **Diverging part**

Expression for rate of flow through venturimeter:

Consider a venturimeter is fitted in a horizontal pipe through which a fluid flowing



Let d_1 = diameter at inlet or at section (i)-(ii)

P_1 = pressure at section (1)-(1)

V_1 = velocity of fluid at section (1) – (1)

A_1= area at section (1) – (1) $= \frac{\pi}{4} d_1^2$

D_2, p_2 , v_2 , a_2 are corresponding values at section 2 applying Bernouli's equation at sections 1 and 2 we get

$$\therefore \quad \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

As pipe is horizontal, hence $z_1 = z_2$

$$\therefore \quad \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} \quad \text{or} \quad \frac{p_1 - p_2}{\rho g} = \frac{v_2^2}{2g} - \frac{v_1^2}{2g}$$

But $\frac{P_1 - P_2}{\rho g}$ is the difference of pressure heads at sections 1 and 2 and it is equal to h

$$\text{So, } h = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

Now applying continuity equation at sections 1 & 2 $a_1 v_1 = a_2 v_2$

$$\text{Or } v_1 = \frac{a_2 v_2}{a_1}$$

Substituting this value

$$h = \frac{v_2^2}{2g} - \frac{\left(\frac{a_2 v_2}{a_1}\right)^2}{2g} = \frac{v_2^2}{2g}\left[1 - \frac{a_2^2}{a_1^2}\right] = \frac{v_2^2}{2g}\left[\frac{a_1^2 - a_2^2}{a_1^2}\right]$$

$${v_2}^2 = 2gh \frac{a_1^2}{a_1^2 - a_2^2}$$

$$v_2 = \sqrt{2gh \frac{a_1^2}{a_1^2 - a_2^2}} = \frac{a_1}{\sqrt{a_1^2 - a_2^2}}\sqrt{2gh}$$

$$Q = a_2 v_2$$

$$= a_2 \frac{a_1}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh} = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

Where Q = Theoretical discharge

Actual discharge will be less than theoretical discharge

$$Q_{act} = C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

Where C_d = co-efficient of venturimetre and value is less than 1

Value of 'h' given by differential U-tube manometer:

Case-i:

Let the differential manometer contains a liquid which is heavier than the liquid flowing through the pipe

Let S_h = Sp. Gravity of the heavier liquid

S_0 = Sp. Gravity of the liquid flowing through pipe

x = difference of the heavier liquid column in U-tube

$P_A - P_B = gx(\rho_g - \rho_0)$

$$\frac{P_A - P_B}{\rho_0 g} = x\left(\frac{\rho_g}{\rho_0} - 1\right)$$

$$h = x\left[\frac{S_h}{S_0} - 1\right]$$

Case-ii

If the differential manometer contains a liquid lighter than the liquid flowing through the pipe

Where S_l = Specific gravity of lighter liquid in U-tube nanometre

So = Specific gravity of fluid flowing through in U-tube nanometre

x = Difference of lighter liquid columns in U- tube

The value of h is given by

$$h = x\,[1 - \frac{Sl}{S_0}]$$

Case-iii:

Inclined venturimetre with differential U-tube manometre

Let the differential manometer contains heavier liquid

Then h is given as

$$h = [\frac{P1}{\rho g} + z_1] - [\frac{P2}{\rho g} + z_2]$$

$$= x\,[\frac{Sh}{S_0} - 1]$$

Case-iv:

Similarly for inclined venturimetre in which differential manometer contaoins a liquid which is kighter than the liquid flowing through the pipe. Then

$$\mathbf{h} = [\frac{P1}{\rho g} + z_1] - [\frac{P2}{\rho g} + z_2]$$

$$\mathbf{h} = \mathbf{x}\,[1 - \frac{Sl}{S_0}]$$

Limitations:

- Bernoulli's equation has been derived underthe assumption that no external force except the gravity force is acting on the liquid. But in actual practice some external forces always acting on the liquid when effect the flow of liquid
- If the liquid is flowing in a curved path the energy due to centrifugal force should also be taken into account.

Pitot-tube:

It is a device used for measuring the velocity of flow at any point in a pipe or a channel.

It is based on the principle that if the velocity flow at a point becomes zero, the pressure there is increased due to conversion of the kinetic energy into pressure energy.

The pitot-tube consists of a glass tube, bent an right angles

Consider two points 1 and 2 at te same level. Such a ay that 2 is at he inlet of pitot tube and one is the far away from the tube

Let P_1 = pressure at point 1

V_1 = velocity of fluid at point 1

P_2 = pressure at 2

V_2 = velocity of fluid at point 2

H = Depth of tube in the liquid

h = Rise of the liquid in the tube above the free surface

Applying Bernoulli's theorm

$$\frac{P_1}{\rho g} + \frac{{V_1}^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{{V_2}^2}{2g} + Z_2$$

$$\frac{P_1}{\rho g} = H \qquad \frac{P_2}{\rho g} = (h + H)$$

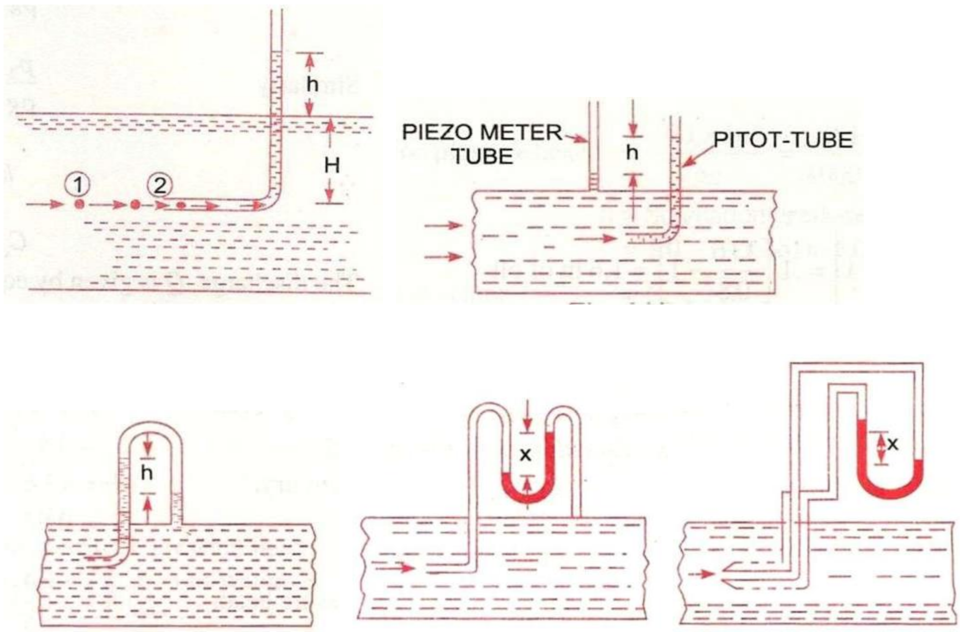
$$H + \frac{V_1^2}{2g} = h + H$$

$$V_1 = \sqrt{2gh}$$

Actual velocity, $V_{act} = C_v \sqrt{2gh}$

C_v = co-efficient of Pitot-tube

Different Arrangement of Pitot tubes



Numerical Problems:

Problem:- 7

Water is flowing through a pipe of 5cm diameter under a pressure of 29.43 N/cm^2 (gauge) and with mean velocity of 2.0 m/s. Find the total head or total energy per unit weight of the water at a cross-section, which is 5m above the datum line.

Solution. Given :

Diameter of pipe $= 5 \text{ cm} = 0.5 \text{ m}$

Pressure, $p = 29.43 \text{ N/cm}^2 = 29.43 \times 10^4 \text{ N/m}^2$

Velocity, $v = 2.0 \text{ m/s}$

Datum head, $z = 5 \text{ m}$

Total head $=$ pressure head $+$ kinetic head $+$ datum head

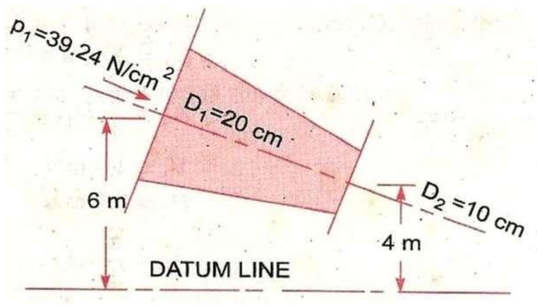
Pressure head $$= \frac{p}{\rho g} = \frac{29.43 \times 10^4}{1000 \times 9.81} = 30 \text{ m} \qquad \left\{ \rho \text{ for water} = 1000 \frac{\text{kg}}{\text{m}^3} \right\}$$

Kinetic head $$= \frac{v^2}{2g} = \frac{2 \times 2}{2 \times 9.81} = 0.204 \text{ m}$$

$\therefore$ Total head $$= \frac{p}{\rho g} + \frac{v^2}{2g} + z = 30 + 0.204 + 5 = \mathbf{35.204 \text{ m. Ans.}}$$

Problem:- 8

The water is flowing through a pipe having diameters 20 cm and 10 cm at sections 1 and 2 respectively. The rate of flow through pipe is 35lit/s. The section 1 is 6m above datum and sedction 2 is 4m aboved datum. If the pressure at section 1 is 39.24 N/cm^2. Find the intensity of pressure at section 2



Solution:

Given

At section 1, $D_1 = 20 \text{ cm} = 0.2 \text{ m}$

$$A_1 = \frac{\pi}{4} (.2)^2 = .0314 \text{ m}^2$$

$$p_1 = 39.24 \text{ N/cm}^2 = 39.24 \times 10^4 \text{ N/m}^2$$

$$z_1 = 6.0 \text{ m}$$

At section 2, $D_2 = 0.10 \text{ m}$

$$A_2 = \frac{\pi}{4} (0.1)^2 = .00785 \text{ m}^2$$

$$z_2 = 4 \text{ m}$$

$$p_2 = ?$$

Rate of flow, $Q = 35 \text{ lit/s} = \frac{35}{1000} = .035 \text{ m}^3\text{/s}$

Now $Q = A_1 V_1 = A_2 V_2$

$\therefore$ $V_1 = \frac{Q}{A_1} = \frac{.035}{.0314} = 1.114 \text{ m/s}$

and $V_2 = \frac{Q}{A_2} = \frac{.035}{.00785} = 4.456 \text{ m/s}$

Applying Bernoulli's equation at sections 1 and 2, we get

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

or $$\frac{39.24 \times 10^4}{1000 \times 9.81} + \frac{(1.114)^2}{2 \times 9.81} + 6.0 = \frac{p_2}{1000 \times 9.81} + \frac{(4.456)^2}{2 \times 9.81} + 4.0$$

or $$40 + 0.063 + 6.0 = \frac{p_2}{9810} + 1.012 + 4.0$$

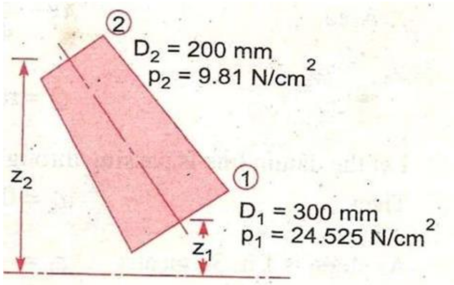
or $$46.063 = \frac{p_2}{9810} + 5.012$$

$\therefore$ $$\frac{p_2}{9810} = 46.063 - 5.012 = 41.051$$

$\therefore$ $$p_2 = 41.051 \times 9810 \text{ N/m}^2 = \frac{41.051 \times 9810}{10^4} \text{ N/cm}^2 = \mathbf{40.27 \text{ N/cm}^2}.$$

Problem:- 9

Water is flowing through a pipe having diameter 300mm and 200 mm at the buttom and upper end respectively. The intensity of pressure at the bottom end is 9.81N/m^2. Determine the difference in datum head if the rate of flow through pipe is 40 lit/s



Solution. Given :

Section 1, $D_1 = 300 \text{ mm} = 0.3 \text{ m}$

$p_1 = 24.525 \text{ N/cm}^2 = 24.525 \times 10^4 \text{ N/m}^2$

Section 2, $D_2 = 200 \text{ mm} = 0.2 \text{ m}$

$p_2 = 9.81 \text{ N/cm}^2 = 9.81 \times 10^4 \text{ N/m}^2$

Rate of flow $= 40$ lit/s

or $$Q = \frac{40}{1000} = 0.04 \text{ m}^3/\text{s}$$

Now $$A_1V_1 = A_2V_2 = \text{rate of flow} = 0.04$$

$$\therefore \quad V_1 = \frac{.04}{A_1} = \frac{.04}{\frac{\pi}{4}D_1^2} = \frac{0.04}{\frac{\pi}{4}(0.3)^2} = 0.5658 \text{ m/s}$$

$$\simeq 0.566 \text{ m/s}$$

$$V_2 = \frac{.04}{A_2} = \frac{.04}{\frac{\pi}{4}(D_2)^2} = \frac{0.04}{\frac{\pi}{4}(0.2)^2} = 1.274 \text{ m/s}$$

Applying Bernoulli's equation at (1) and (2), we get

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

or $$\frac{24.525 \times 10^4}{1000 \times 9.81} + \frac{.566 \times .566}{2 \times 9.81} + z_1 = \frac{9.81 \times 10^4}{1000 \times 9.81} + \frac{(1.274)^2}{2 \times 9.81} + z_2$$

or $$25 + .32 + z_1 = 10 + 1.623 + z_2$$

or $$25.32 + z_1 = 11.623 + z_2$$

$$\therefore \quad z_2 - z_1 = 25.32 - 11.623 = 13.697 = 13.70 \text{ m}$$

$\therefore$ Difference in datum head $= z_2 - z_1 =$ **13.70 m. Ans.**

Problem:- 10

A horizontal venturimetre with inlet and throat diameters 10cm and 15 cm respectively is used to measure the flow of water. The reading of differential manometer connected to the inlet and throat is 20cm of mercury. Determine the rate of flow. Take $C_d = 0.98$

Solution. Given :

Dia. at inlet, $d_1 = 30$ cm

$\therefore$ Area at inlet, $a_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4}(30)^2 = 706.85 \text{ cm}^2$

Dia. at throat, $d_2 = 15$ cm

$\therefore$ $a_2 = \frac{\pi}{4} \times 15^2 = 176.7 \text{ cm}^2$

$C_d = 0.98$

Reading of differential manometer $= x = 20$ cm of mercury.

$\therefore$ Difference of pressure head is given by (6.9)

or
$$h = x\left[\frac{S_h}{S_o} - 1\right]$$

where S_h = Sp. gravity of mercury = 13.6, S_0 = Sp. gravity of water = 1

$$= 20\left[\frac{13.6}{1} - 1\right] = 20 \times 12.6 \text{ cm} = 252.0 \text{ cm of water.}$$

The discharge through venturimeter is given by eqn. (6.8)

$$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

$$= 0.98 \times \frac{706.85 \times 176.7}{\sqrt{(706.85)^2 - (176.7)^2}} \times \sqrt{2 \times 9.81 \times 252}$$

$$= \frac{86067593.36}{\sqrt{499636.9 - 31222.9}} = \frac{86067593.36}{684.4}$$

$$= 125756 \text{ cm}^3/\text{s} = \frac{125756}{1000} \text{ lit/s} = \mathbf{125.756 \text{ lit/s.}}$$

Problem:- 11

An oil of Sp.gr. 0.8 is flowing through a horizontal venturimrtre having inlet diameter 20cm and throaty diameter 10 cm. The oil mercury differential manometer shows a reading of 25cm. Calculate the discharge of oil through the horizontal venturimetre. Take Cd = 0.98

Solution. Given :

Sp. gr. of oil, $S_o = 0.8$

Sp. gr. of mercury, $S_h = 13.6$

Reading of differential manometer, $x = 25$ cm

$\therefore$ Difference of pressure head, $h = x\left[\dfrac{S_h}{S_o} - 1\right]$

$$= 25\left[\frac{13.6}{0.8} - 1\right] \text{ cm of oil} = 25\,[17 - 1] = 400 \text{ cm of oil.}$$

Dia. at inlet, $d_1 = 20$ cm

$$\therefore \quad a_1 = \frac{\pi}{4} d_1^2 = \frac{\pi}{4} \times 20^2 = 314.16 \text{ cm}^2$$

$$d_2 = 10 \text{ cm}$$

$$\therefore \quad a_2 = \frac{\pi}{4} \times 10^2 = 78.54 \text{ cm}^2$$

$$C_d = 0.98$$

$\therefore$ The discharge Q is given by equation (6.8)

or
$$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - 7a_2^2}} \times \sqrt{2gh}$$

$$= 0.98 \times \frac{314.16 \times 78.54}{\sqrt{(314.16)^2 - (78.54)^2}} \times \sqrt{2 \times 981 \times 400}$$

$$= \frac{21421375.68}{\sqrt{98696 - 6168}} = \frac{21421375.68}{304} \text{ cm}^3/\text{s}$$

$= 70465$ cm^3/s = **70.465 litres/s. Ans.**

Problem:- 12

A horizontal venturimrtre with inlet and throat diameters 20cm and 10 cm respectively is used to measure the flow of oil of Sp. gr. The discharge of oil through venturimetre is 60lit/s . Find thereading of oil-mercury differential manometer. Take C_d = 0.98

Solution. Given : $d_1 = 20$ cm

$\therefore$ $$a_1 = \frac{\pi}{4}\, 20^2 = 314.16\ \text{cm}^2$$

$$d_2 = 10\ \text{cm}$$

$\therefore$ $$a_2 = \frac{\pi}{4} \times 10^2 = 78.54\ \text{cm}^2$$

$$C_d = 0.98$$

$$Q = 60\ \text{litres/s} = 60 \times 1000\ \text{cm}^3/\text{s}$$

Using the equation (6.8), $$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

or $$60 \times 1000 = 9.81 \times \frac{314.16 \times 78.54}{\sqrt{(314.16)^2 - (78.54)^2}} \times \sqrt{2 \times 981 \times h}$$

$$= \frac{1071068.78\sqrt{h}}{304}$$

or $$\sqrt{h} = \frac{304 \times 60000}{1071068.78} = 17.029$$

$\therefore$ $$h = (17.029)^2 = 289.98 \text{ cm of oil}$$

But $$h = x\left[\frac{S_h}{S_o} - 1\right]$$

where S_h = Sp. gr. of mercury = 13.6

S_o = Sp. gr. of oil = 0.8

x = Reading of manometer

$\therefore$ $$289.98 = x\left[\frac{13.6}{0.8} - 1\right] = 16x$$

$\therefore$ $$x = \frac{289.98}{16} = 18.12 \text{ cm.}$$

$\therefore$ Reading of oil-mercury differential manometer = **18.12 cm.**

Problem:-13

A static pitot-tube placed in the centre of a 300 mm pipe line has one orifice pointing upstream and is perpendicular to it. The mean velocity in the pipe is 0.80 of the central velocity. Find the discharge through the pipe if the pressure difference between the two orifices is 60mm of water. Take C_v = 0.98

Solution. Given :

Dia. of pipe, $d = 300 \text{ mm} = 0.30 \text{ m}$

Diff. of pressure head, $h = 60 \text{ mm of water} = .06 \text{ m of water}$

$C_v = 0.98$

Mean velocity, $\overline{V} = 0.80 \times \text{Central velocity}$

Central velocity is given by equation (6.14)

$$= C_v\sqrt{2gh} = 0.98 \times \sqrt{2 \times 9.81 \times .06} = 1.063 \text{ m/s}$$

$\therefore$ $$\overline{V} = 0.80 \times 1.063 = 0.8504 \text{ m/s}$$

Discharge, $$Q = \text{Area of pipe} \times \overline{V}$$

$$= \frac{\pi}{4}d^2 \times \overline{V} = \frac{\pi}{4}(.30)^2 \times 0.8504 = \mathbf{0.06\ m^3/s.\ Ans.}$$

Orifice:

Orifice is a small opening of any Cross-section (such as triangular, rectangular etc) on the side or at the bottom of a tank, though which a fluid is flowing. Orifices are used for measuring the rate of flow of fluid.

Applying Bernoulli's theorem at 1 and 2

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$H + 0 = 0 + \frac{V_2^2}{2g}$$

$$V_2 = \sqrt{2gh}$$

Orifice Co-efficients:

The Orifice co-efficients are

- **Co-efficient of velocity C_v**
- **Co-efficient of contraction C_c**
- **Co-efficient of discharge C_d**

Co-efficient of velocity C_v:

It is defined as the ratio between the actual velocity of a jet of liquid at vena-contra and the theoretical velocity of jet. It is denoted by C_v and Mathematically C_v is given as

$$C_v = \frac{Actual\ velocity\ of\ jet\ at\ vena-contra}{Theoretical\ velocity}$$

$$= \frac{V}{\sqrt{2gh}}$$

Where V = actual velocity

$\sqrt{2gh}$ = theoretical velocity

The value of C_v varies from o.95 to 0.99 for dofferent orificial depending on the shape, size of the orifice.

Co-efficient of contraction:

It is defined as the ratio of the area of the jet at vena-contra to the area of the orifice.

It is denoted by Cc

a = area of orifice

a_c = area of jet at vena-contra

$$C_c = \frac{\text{area of jet at vena}-\text{contra}}{\text{area of orifice}}$$

$$= \frac{a_c}{\text{a}}$$

The value of cc varies from 0.61 to 0.69 depending on shape and size of the orifice.

Co-efficient of Discharge:

It is the ratio of the actual discharge from an orifice to the theoretical discharge from the orifice. It is denoted by C_d

If Q is the actual discharge and Qth is the theoretical discharge then

$$C_d = \frac{Q_{act}}{Q_{th}}$$

$$= \frac{Actual\ velocity \times Actual\ area}{Theoretical\ velocity \times Theoretical\ area}$$

$$= C_c \times C_v$$

The value of C_d arries from 0.61 0.65

For general purpose Cd is 0.62

Classification

Oriffices are classified on the basis of their size, shape and nature of discharge

According to size

- Small orifice (If the head of liquid above the centre of orifice is more than 5 times the depth of orifice)
- Large orifice (If head is less than 5 times the depth of oriffice)

According to shape

1. **Circular**
2. **Triangular**
3. **Rectangular**
4. **Square**

According to the shape of upstream edge:

- Sharp edged orifice
- Bell mouthed orifice

According to nature of discharge:

- Free discharge orifices
- Drowned or submerged orifices
  - Partially submerged orifices
  - Fully submerged orifices

Orofice Meter or Orifice Plate:

It is advice used for measuring the rate flow of a fluid through a pipe. It is a cheaper device as compare to venturimetre. It also works on the same principle as that of venturimetre . It consists iof a flat circular plate which has a circular sharp edge hole called orifice, which is concentric with the pipe. The orifice diameter is kept gene rally 0.5 times the diameter of the pipe, through it may vary 0.4 to 0.8 times the pipe diameter.

A differential manometer is connected at section 1which is at a distance of about 1.5 to 2.0 times time pipe diameter of upstream of the orifice plate and at section 2., which at a distance about half the diameter of the orifice on the down stream side from the orifice plate

Let p_1 = pressure at section (1),
v_1 = velocity at section (1),
a_1 = area of pipe at section (1), and

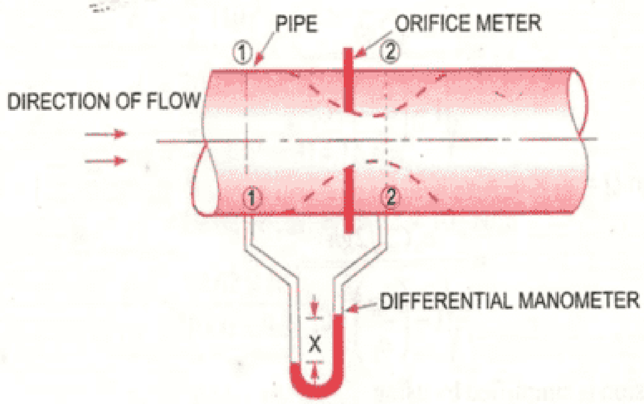


Fig. 6.12. *Orifice meter.*

p_2, v_2, a_2 are corresponding values at section (2). Applying Bernoulli's equation at sections (1) and (2), we get

$$\frac{p_1}{\rho g}+\frac{v_1^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{v_2^2}{2g}+z_2$$

or $$\left(\frac{p_1}{\rho g}+z_1\right)-\left(\frac{p_2}{\rho g}+z_2\right)=\frac{v_2^2}{2g}-\frac{v_1^2}{2g}$$

But $$\left(\frac{p_1}{\rho g}+z_1\right)-\left(\frac{p_2}{\rho g}+z_2\right)=h=\text{Differential head}$$

$\therefore$ $$h=\frac{v_2^2}{2g}-\frac{v_1^2}{2g}\quad\text{or}\quad 2gh={v_2}^2-{v_1}^2$$

or $$v_2=\sqrt{2gh+v_1^2} \qquad \text{...}(i)$$

Now section (2) is at the vena contracta and a_2 represents the area at the vena contracta. If a_0 is the area of orifice then, we have

$$C_c=\frac{a_2}{a_0}$$

where C_c = Co-efficient of contraction

$\therefore$ $$a_2=a_0\times C_c \qquad \text{...}(ii)$$

By continuity equation, we have

$$a_1v_1=a_2v_2\quad\text{or}\quad v_1=\frac{a_2}{a_1}v_2=\frac{a_0\,C_c}{a_1}v_2 \qquad \text{...}(iii)$$

Substituting the value of v_1 in equation (i), we get

$$v_2=\sqrt{2gh+\frac{a_0^2C_c^2v_2^2}{a_1^2}}$$

or $$v_2^2 = 2gh + \left(\frac{a_0}{a_1}\right)^2 C_c^2 v_2^2 \text{ or } v_2^2 = \left[1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2\right] = 2hg$$

$\therefore$ $$v_2 = \frac{\sqrt{2gh}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$\therefore$ The discharge $Q = v_2 \times a_2 = v_2 \times a_0\, C_c$

$$= \frac{a_0 C_c \sqrt{2gh}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

The above expression is simplified by using

$$C_d = C_c \frac{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$\therefore$ $$C_c = C_d \frac{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2}}$$

Substituting this value of C_c in equation (*iv*), we get

$$Q = a_0 \times C_d \frac{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2}} \times \frac{\sqrt{2gh}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$$= \frac{C_d a_0 \sqrt{2gh}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2}} = \frac{C_d a_0 a_1 \sqrt{2gh}}{\sqrt{a_1^2 - a_0^2}}.$$

where C_d = Co-efficient of discharge for orifice meter.

The co-efficient of discharge for orifice meter is much smaller than that for a venturimeter.

Chapter-5

NOTCHES & WEIRS

INTRODUCTION

A **notch** is a device used for measuring the rate of flow of a liquid through a small channel or a tank. It may be defined as an opening in the side of a tank or a small channel in such a way that the liquid surface in the tank or channel is below the top edge of the opening.

A weir is a concrete or masonary structure, placed in an open channel over which the flow occurs. It is generally in the form of vertical wall, with a sharp edge at the top, running all the way across the open channel. The notch is of small size while the weir is of a bigger size. The notch is generally made of metallic plate while weir is made of concrete or masonary structure.

1. Nappe or Vein. The sheet of water flowing through a notch or over a weir is called Nappe or Vein.

2. Crest or Sill. The bottom edge of a notch or a top of a weir over which the water flows, is known as the sill or crest.

CLASSIFCATlON OF NOTCHES AND WIElRS

The notches are classified as :

1. According to the shape of the opening :
   (a) Rectangular notch,
   (b) Triangular notch,
   (c) Trapezoidal notch, and
   (d) Stepped notch.
2. According to the effect of the sides on the nappe :
   (a) Notch with end contraction.
   (b) Notch without end contraction or suppressed notch.

Weirs are classified according to the shape of the opening, the shape of the crest, the effect of the sides on the nappe and nature of discharge. The following are important classifications.

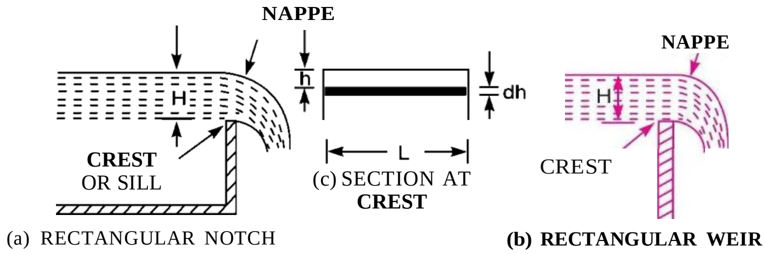
(a) According to the shape of the opening :
   (i) Rectangular weir, *(ii)* Triangular weir, and
   (iii) Trapezoidal weir (Cipolletti weir)

(b) According to the shape of the crest :
   (i) Sharp-crested weir, *(ii)* Broad-crested weir,
   (iii) Narrow-crested weir, and *(iv)* Ogee-shaped weir.

(c) According to the effect of sides on the emerging nappe :
(i) Weir with end contraction, and (ii) Weir without end contraction.

DISCHARGE OVER A RECTANGULAR NOTCH OR WEIR

The expression for discharge over a rectangular notch or weir is the same.



Rectangular notch and weir.

Consider a rectangular notch or weir provided in a channel carrying water as shown in Fig. 8.1. Let H -- Head of water over the crest

L = Length of the notch or weir

For finding the discharge of water flowing over the weir or notch, consider an elementary horizontal strip of water of thickness dh and length L at a depth /i from the free surface of water as shown in Fig. 8.1(c).

The area of strip = L x dh

and theoretical velocity of water flowing through strip =$(2gh)^{0.5}$

$$dQ = C_d \times \text{Area of strip} \times \text{Theoretical velocity}$$
$$= C_d \times L \times dh \times \sqrt{2gh}$$

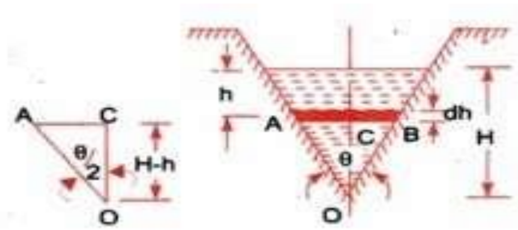
Total discharge i.e. Q over a rectangular notch or weir

$$Q = \int_0^H C_d \,.\, L \,.\, \sqrt{2gh} \,.\, dh = C_d \times L \times \sqrt{2g} \int_0^H h^{1/2}\, dh$$

$$= C_d \times L \times \sqrt{2g} \left[\frac{h^{1/2+1}}{\frac{1}{2}+1} \right]_0^H = C_d \times L \times \sqrt{2g} \left[\frac{h^{3/2}}{3/2} \right]_0^H$$

$$= \frac{2}{3} C_d \times L \times \sqrt{2g}\ [H]^{3/2}$$

DISCHARGE OVER A TRIANGULAR NOTCH OR WEIR



Discharge through the strip $dQ = C_d \times$ Area of the strip $\times$ Velocity (Theoritical)

$= C_d \times 2\,(H - h)\tan\theta/2 \times dh \times (2gh)^{1/2}$

Total discharge Q

$$= 2 \times C_d \times \tan\frac{\theta}{2} \times \sqrt{2g}\left[\frac{2}{3}H.H^{3/2} - \frac{2}{5}H^{5/2}\right] =$$

$$= 2 \times C_d \times \tan\frac{\theta}{2} \times \sqrt{2g}\left[\frac{2}{3}H^{5/2} - \frac{2}{5}H^{5/2}\right]$$

$$= 2 \times C_d \times \tan\frac{\theta}{2} \times \sqrt{2g}\left[\frac{4}{15}H^{5/2}\right]$$

$$= \frac{8}{15}C_d \times \tan\frac{\theta}{2} \times \sqrt{2g} \times H^{5/2}$$

For a right-angled V-notch, if $C_d = 0.6$

$$\theta = 90°, \quad \therefore \quad \tan\frac{\theta}{2} = 1$$

Discharge

$$Q = \frac{8}{15} \times 0.6 \times 1 \times \sqrt{2 \times 9.81} \times H^{5/2}$$

$$= 1.417\, H^{5/2}$$

Chapter-6

Flow through pipe

Pipe

A pipe is a closed conduit , generally of circular cross-section used to carry watter or any other flui.

When the pipe is running full, the flow is under pressure but if the pipe is not running full the flow is nit unsder pressure (culverts, sewer pipes)

<u>Loss of fluid friction</u>:

The frictional resisytance of a pipe depends upon the roughness of the inside surface of the pipe more the roughness more is the resistance. This friction is known as fluid friction and the resistance is known as frictional resistance

<u>According Froude</u>

The frictional resistance varies with the square of the velocity.

The friction resistance varies with the natural of the surface.

Among varies laws, the Darcy-weisbatch formula & Chezy's formula.

<u>Loss of energy in pipes</u>:

When a fluid is flowing through a pipe, the fluid experiences some, resistance due to which some if energy is loss.Energy losses:major energy losses - it is calculated by Darcy Weisbach formula and Chezy's formula.

minor energy lossesdue to friction - 1-subben expansion of pipe

2-sudden contraction of

3-bend in pipe

4-pipe fittings etc

5-an obstruction in pipe.

<u>Darcy- weisbatch formula</u>:

The loss of head in pipes due to friction calculated from darcy-weisbath equation.

$h_f = \frac{4FLV^2}{2gd}$

h_f = loss of head due to friction

F = coefficient of friction (function of reylond's number)

$= \frac{16}{R_e}$ for R_e <2000(viscous flow)

$= \frac{0.079}{R_e^{\frac{1}{4}}}$ for R_e varying from 4000 to 10^6

L = length of the pipe

V = mean velocity of flow

D = diameter of the pipe.

<u>Chezy's formula:</u>

$h_f = \frac{f'}{\rho g} \times \frac{P}{A} \times L \times V^2$

h_f = loss of head due to friction.

P = wetted perimeter of pipe

A = C.S area of pipe

L = length of pipe

V = m mean velocity of flow.

$M = \frac{A}{P} = \frac{area\ of\ flow}{perimeter}$

= hydraulic mean depth or hydraulic radius

$$\Rightarrow M = \frac{A}{p} = \frac{\frac{\pi}{4}d^2}{\pi d} = \frac{d}{4}$$

Substituting $\frac{P}{A} = \frac{I}{M}$

$$h_f = \frac{f^1}{\rho g} \times \frac{1}{M} \times L \times V^2$$

$$v^2 = h_f \times \frac{\rho g}{f^1} \times M \times \frac{1}{L}$$

$$V = C\,(MI)^{1/2}$$

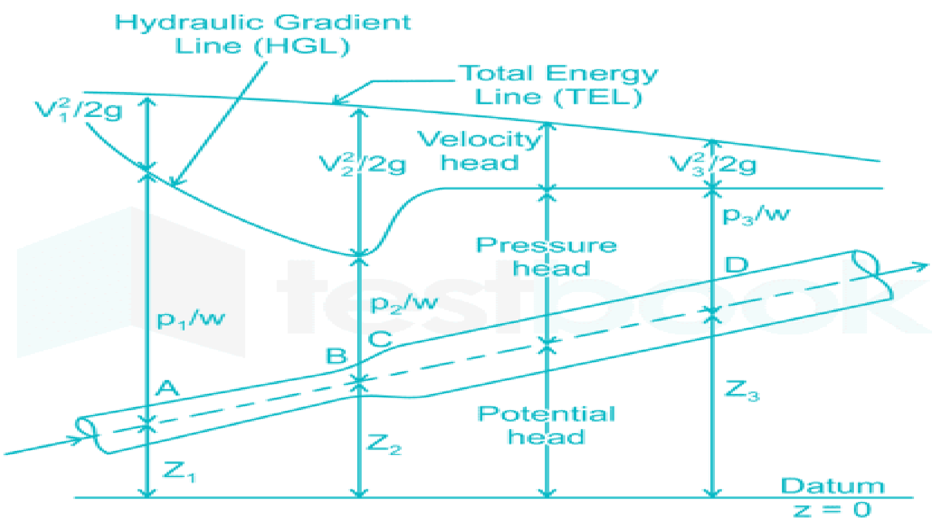
4

Hydraulic gradient line:

It is defined as the line which gives the sum of pressure head P/W & datum head (Z) if a flowing fluid in a pipe with respect to the reference line or it is the line which is obtained by joining of the top of all vertical ordinates showing pressure head (P/W)of a flowing fluid in a pipe from the centre of the pipe. It is briefly written as H.G.L .

Total energy line:

It is defined as the line which gives the sum of pressure head, dutum head & kinetic head of a flowing fluid in a pipe with respect to some reference line or it is the line which is obtained by joining the tops of all vertical orbinates showing the sum of pressure head & kinetic head from the centre of the pipe. It is also written as T.E.L



Hydraulic gradient and total energy line

CHAPTER -7

Impact of jets

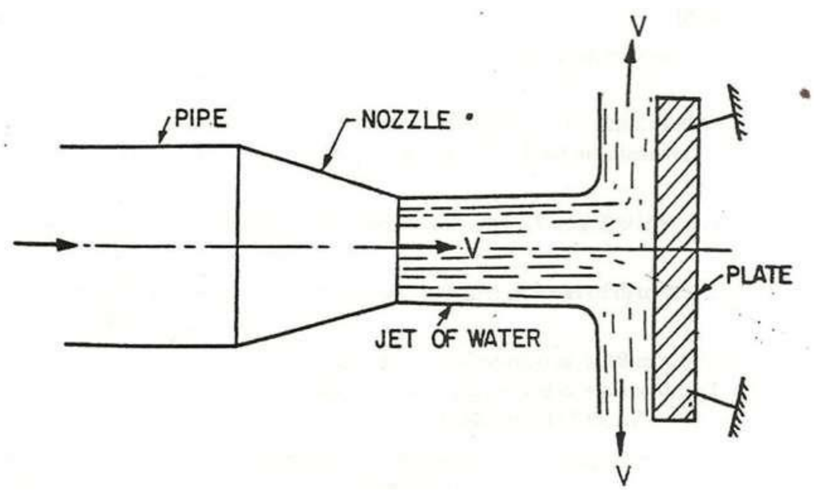
Introduction:

Impact of jet means the force exerted by the jet on a plate which may be stationary or moving

The various cases of impact of jet are:

1. force exerted by the jet on a staticnary plate when
   1)plate is vertical to the jet
   2)plate is inclined to the jet
   3)plate is curved
2. force exerted by the jet on a moving plate when-
   1.plate is vertical to jet
   2.plate is inclined to the jet
   3.plate is curved

Impact of jet flat surface :



Force exerted by jet on fixed vertical plate

Consider a jet of water coming out from the noiile strikes a flat vertical plate

Let v = velocity of the jet

d = diameter of jet

a = area of cross –section of the jet

$= \frac{\pi}{4} d^2$

As the plate is fixed, the jet after striking will get deflected through 90^0

Hence the component of the velocity of jet ,in the direction of jet, after striking will be zero.

The force exerted by the jet on the plate in the direction of jet

F_x = rate of change of momentum in the direction of force

$$= \frac{\text{initial momentum} - \text{final momentum}}{Time}$$

$$= \frac{\text{mass} \times \text{initial velocity} - \text{mass} \times \text{Final velocity}}{Time}$$

$$= \frac{\text{mass}}{Time}(\text{Initial velocity} - \text{Final velocity})$$

$= \frac{\text{mass}}{sec}$ (velocity of jet before striking – Final velocity of jet after striking)

$= \rho av\ [v - 0]$

$= \rho a v^2$

NOTE: In the above equation initial velocity minus final velocity is taken as because force exerted by the jet on the plate is is calculated if force exerted on the jet is to be calculated then final velocity is taken.

NUMERICAL PROBLEMS

Problem-1

Find the force exerted by a jet of water of diameter 75mm on a stationary flat plate when the jet strikes the plate normally with a velocity of 20m/s.

Solution .

Given:

Diameter of jet = d = 75mm

= 0.075m

Velocity of jet = 20m/s

Area = a = $\frac{\pi}{4}d^2$

= $\frac{\pi}{4}(0.075)^2$

= 0.004417 m^2

The force exerted by the jet of water on a stationary vertical plate is given by

F = $\rho a v^2$

= $1000\times 0.004417 \times 20^2$

= 1766.8 N

Problem-2

Water is flowing through a pipe at the end of which a nozzle is fitted . the diameter of the nozzle is 100m and the head of water at the centre of nozzle 100m . find the force exerted by the jet of water on a fined vertical plate . the co-efficient of velocity is given as 0.95

SOLUTION:

Ggiven:

Diameter of nozzle = d = 100mm = 0.1m

Head of water , H = 100m

Co- efficient of velocity ,Cv = 0.95

Area of nozzle a = $\pi/4\ d^2 = \pi/4\ (0.1)^2$ = 0.007854 m^2

Theoretical velocity of jet of water is given as $V_{th} = \sqrt{2gH}$
$= \sqrt{2 \times 9.81 \times 100} = 44.294$ M/S

But , $Cv = \dfrac{\text{actual velocity}}{\text{Theoretical velocity}}$

∴Actual velocity of jet of water (v) $= c_v \times v_{th}$

$V = 0.95 \times 44.294$

$= 42.08$ M/S

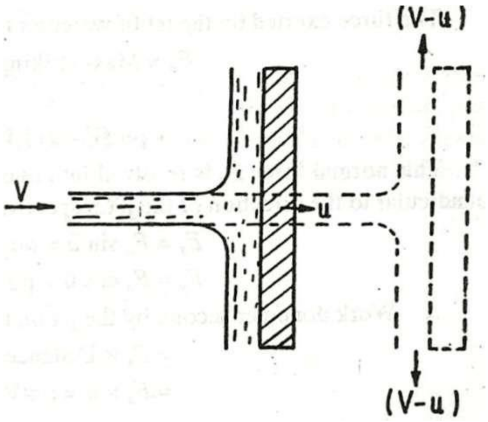
Force exerted on a field vertical plate is given by

$F = \rho a v^2$

$= 1000 \times 0.07854 \times (42.08)^2 \quad (\rho = 1000 \text{ kg/m})$

$= 13907.2$ N = 13.9 KN ans

Impact of jet on moving flat plate:



Jet striking a flat vertical moving plate

Consider a jet of water striking a flat vertical plate moving with a uniform velocity away from the jet ..

Let V = velocity of the jet (absolute)

A = area of cross –section of the jet

U = velocity of flat plate

In this case the jet strikes the plate with a relative velocity , which is equal to the absolute velocity of jet of water minus the velocity of the plate .

Hence relative velocity of the jet with respect to plate =v-u
Mass of water striking the plate per sec

$= \rho \times area\ of\ jet\ \times velocity\ (relative)$

$= \rho a \times\ [v - u]$

Force exerted by the jet on the moving flat plate in the direction of motion of jet

Fx = mass of water striking /sec $\times$ $[initial\ velocity - final\ velocity]$

$= \rho a(v - u)[(v - u) - 0]$

$=\rho a(v - u)^2$(final velocity in the direction of jet is zero)

In this case ,the work will be done by the jet on plate as the plate is moving

Work done per second by the jet on the plate

$$= \text{force} \times \frac{distance\ inthe\ cirection\ of\ force}{time}$$

$= f_x \times u$

$= \rho a(v - u)^2 \times u$

Jet striking a series of plates

In this case, a large number of flat platus are mounted on the rim of a wheel fixed distance apart. The jet strikes a plate and due to the force exerted by the jet on the plate, the wheel starts moving and the 2nd plate mounted on the wheel appears before the jet, which again exerts the force on the 2nd plate.

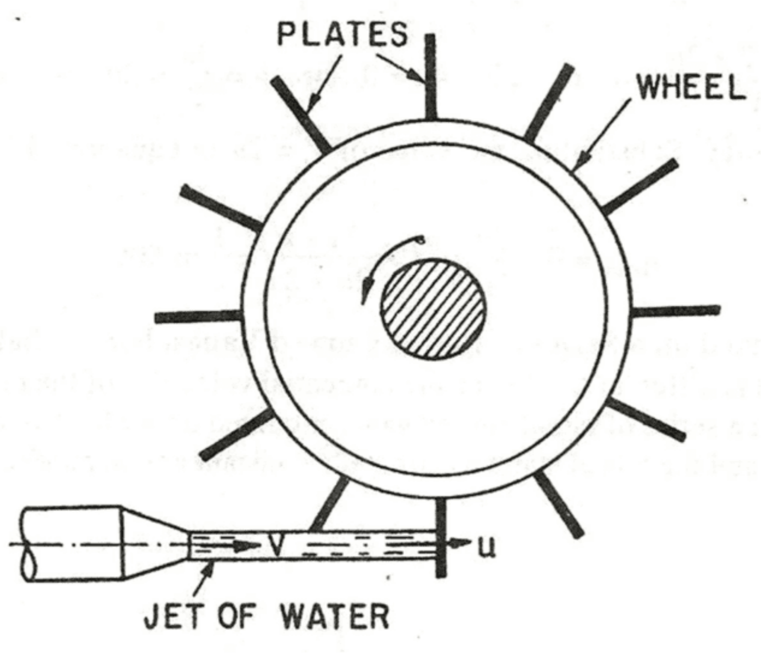
Thus each plate appears successively be for the jet s the jet exerts force on each plate. The wheel states moving at a constant speed

Late V = velocity of jet

D = diameter of jet

A = cross – sectional area of jet

u = velocity of plate



In this case the mass of water coming out from the nozzle per second is always in connect with the plates when all the plate are considered

Hence mass of water/sec = ρav

The jet strikes the plkate with velocity = v – u

The Force exeted by the jet in the direction of the motion of plate

$F_x = \frac{\text{mass}}{Time}$(Initial velocity – Final velocity)

$= \rho av[(v - u) - 0]$

$= \rho av(v - u)$

Work done per second by the jet on the series of the plate per sec

$= F x\, u$

$= \rho av(v - u)\, u$

Kinetic energy of the jet per second

$= \frac{1}{2} mv^2$

$= \frac{1}{2} (\rho av) v^2$

$= \frac{1}{2} \rho a v^3$

Efficiency, $= \frac{Work\ done/sec}{Kinetic\ energy/sec}$

$$= \frac{\rho av(v - u)\, u}{\frac{1}{2}\rho a v^3}$$

$$= \frac{2u(v - u)}{v^2}$$

Condition for maximum Efficiency

For a given jet velocity v, the efficiency will be maximum when

$$\frac{d}{du} = 0$$

$$\Rightarrow \frac{d[\frac{2u(v - u)}{v2}]}{du} = 0$$

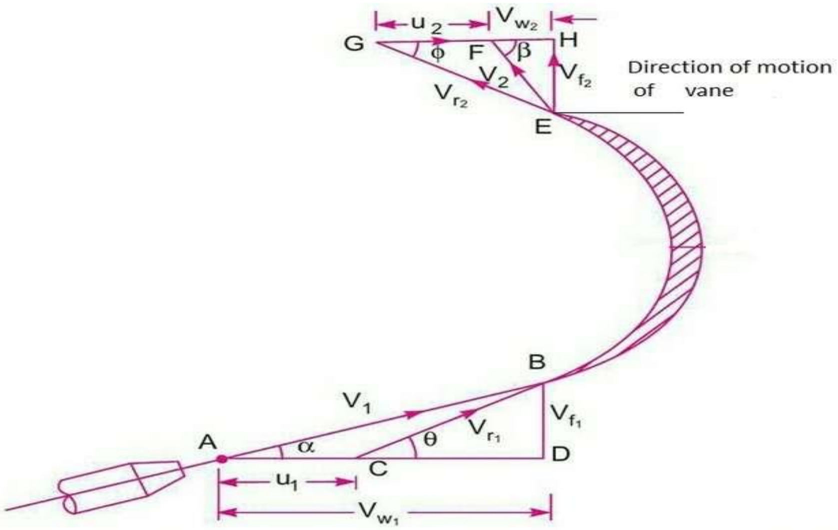
$$\Rightarrow \frac{d[\frac{2uv - u^2)}{v2}]}{du} = 0$$

$$\Rightarrow \frac{2v - 4u}{v^2} = 0$$

$$\Rightarrow 2v - 4u = 0$$

$$\Rightarrow u = \frac{v}{2}$$

IMPACT OF JET ON A MOVING CURVED PLATE WHEN JET STRIKES TANGENTISLY AT ONE OF THE TIPS:



Consider a jet of water striking a moving cuirved vane tangentialy at one of its tips. In this case as plate is moving, the velocity with which jet of aater is equal to the relative velocity of the jeyt withrerspectg to the plate

Let v_1 = velocity of the jet at inlet

u_1 = velocity of the plate at inlet

V_{r1} = Relative velocity of the jet & plate at inlet

α = guide blade angle

θ = vane angle made by relative velocity V_{r1} with the direction of motion of inlet

V_{w1} & v_{f1}` = Components of V_1 in the direction of motion &

perpendicular to the direction of motion of vane respectively

V_{w1} = Whirl veloicity at inlet

V_{f1} = velocity at inletr

V_2 = velocity of the jet at outlet

u_2 = velocity of vane at out let

V_{r2} = relative of the jet at out let

β = Angle made by the velocity v2 with the direction of the motion of vane at outlet

$\emptyset$ = vane angle at outlet

V_{w2} = velocity of whirl at oputlet

V_{f2} = velocity of whirl at oputlet

The triangles ABD & EGH are called the velocity triangle at inlet & outlet

If the vane is smooth & having velocity in the direction of motion at inlet & outlet equal then we have

$u_1 = u_2 = u$

$V_{r1} = v_{r2}$

But initial velocity with which jet strikes thge vane = v_{r1}

The component of this velocity inthe direction of motion

$= v_{r1}\cos\theta$

$= (V_{w1} – u_1)$

Similarly the component of relative velocity vr2 at outlet in the direction of motion = - $v_{r2}\cos\emptyset$

$= - [u_2 + v_{w2}]$

(- ve sign is taken as the component of vr2 is in opposite direction)

Substituting these values in the above equation

$$F_x = \rho a V r_1 [(v_{w1} – u_1) – \{ - (u_2 + v_{w2})\}]$$

$$= \rho\ aVr_1 [v_{w1} – u_1 + u_2 – v_{w2}]$$

$$= avr1(v_{w1}+ v_{w2})$$

This equation is ture only when β is actue when

$$\beta = 90^0$$

$$V_{w2} = 0$$

$$F_x = av_{r1}(v_{w1})$$

When $\beta > 90^0$ (obtuse)

$$F_x = av_{r1}(v_{w1} - v_{w2})$$

In equation fx is written as

$$F_x = av_{r1}(v_{w1} \pm v_{w2})$$

Work down/ sec on the vane by the jet

$$= Fx \times u$$

$$= \rho av_{r1}(v_{w1} \pm v_{w2}) \times u$$

Work done/sec/ unit weight of fluid striking/sec

$$= \frac{\rho a v_{r1}[v_{w1} \pm v_{w2}] \times u}{\rho a v_{r1} \times g}$$

$$= \frac{[v_{w1} \pm v_{w2}] \times u}{g}$$

Work done/sec/unit mass of water striking/ sec

$$= \frac{\rho a v_{r1}[v_{w1} \pm v_{w2}] \times u}{\rho a v_{r1}}$$

$$= [v_{w1} \pm v_{w2}] \times u$$

Efficiency of jet

$$= \frac{\text{Work done per second on the vane}}{Initial\ Kinetic\ energy/\sec of\ the\ jet}$$

$$= \frac{\rho a v_{\mathrm{r1}}[v_{\mathrm{w1}} \pm v_{\mathrm{w2}}] \times u}{\frac{1}{2} m\, v^2}$$

$$= \frac{\rho a v_{\mathrm{r1}}[v_{\mathrm{w1}} \pm v_{\mathrm{w2}}] \times u}{\frac{1}{2} \rho a v_1 \times v^2}$$

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

POWER STATION ENGINEERING

5TH SEMESTER

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INTRODUCTION

A power plant can be considered as a machinery set up that produces and delivers a flow of mechanical or electrical energy. Generators are considered as the main equipment for the electric power generation. It generates electricity when it is driven by a prime mover. On the basis of the types of prime movers used, power plants are classified.

The major power plants are,

- Steam power plant
- Diesel power plant
- Gas turbine power plant
- Nuclear power plant
- Hydroelectric power plant

Sources of Energy:

Energy sources are classified as:

- Conventional Energy Sources or Non-Renewable Energy Sources
- Non-conventional Energy Sources or Renewable Energy Sources

Conventional Energy Sources:

These sources are finite and exhaustible. Once consumed, these sources cannot be replaced. Examples of these sources are energy from Coal, timber, petroleum, lignite, natural gas, fossil fuels, nuclear fuels etc.

Non-conventional Energy Sources:

These sources are continuous and non-exhaustible. Examples of these sources are geothermal energy, wind energy, tidal energy, nuclear fusion, bio-energy, solar energy etc. These sources give energy continuously without depletion.

Captive power stations:

An electricity generation station which is used by an industrial or commercial energy consumer for its own energy consumption is known as a Captive power station. Captive power plants can exchange their surplus energy with the grid.

Central stations:

An electricity generation station which is not made for the self uses of the industries is known as a Central power station. It generates more power than the captive power plant. It is suitable for large scale power generation. These stations are located outside of the end users and connected to a high voltage transmission network. The electricity generated from these stations are purchased by the consumers.

Classification of Power Plants:

Conventional Power Plants	Non-Conventional Power Plant
➢ Steam/Thermal Power Plants ➢ Diesel Power Plants ➢ Gas Turbine Power Plants ➢ Hydro-Electric Power Plants ➢ Nuclear Power Plants	➢ Solar base power plant ➢ Wind Energy Power Plant ➢ Geothermal Energy ➢ Tidal Wave Energy Power Plant ➢ Ocean Thermal energy conversion Plant ➢ Biogas, Biomass Energy Power Plant ➢ Thermoelectric Generator

Importance of Electrical Power:

The importance of electricity now day is many more than our imagination. In every field there is necessity of electricity. The importance of electric power can be understood from its wide area of application. Some of the most notable uses of electricity are: Entertainment, Healthcare, Engineering, Transport and Communication, Outdoors, Household, Commercial, Office, Fuel and Space etc.

Overview of Method of Electrical Power Generation:

The various sources which are used to generate electric power are discussed below.

Steam Power:

- Steam power plants known as Coal-fired power plants use steam as a source to generate electricity. But the flue gas emitted by the plant to the atmosphere possesses harmful gases and therefore it is not environment friendly.
- But it is now a major electricity generating plant.

Hydro Power:

- The gravitational force of flowing water is utilized in hydro power plants to run the turbines. In these plants, water is forced to possess kinetic and pressure energy which is converted into mechanical energy on the rotation of runner of the hydraulic turbine.
- It is a clean and renewable resource of from which electricity is obtained.
- As compared to fossil fuel-powered energy plants, hydroelectric power plants emit fewer greenhouse gases.
- The construction of hydroelectric power plants and dams requires huge investment.

Nuclear Power:

- Nuclear power plants generate a high amount of electricity from a nuclear fission reaction using uranium as fuel.
- Nuclear power plants require low quantities of fuel but produce a large amount of power. Once started, it run efficiently.
- It is more reliable compared to renewable sources of energy such as solar and wind.
- In these plants, water is converted into steam after receiving heat energy from the nuclear reaction and this steam is used in the turbine for energy conversion.

Diesel engine power:

- This is used for small-scale production of electric power by using diesel as fuel.
- Diesel is a non-renewable source of energy which makes these plants non-durable.
- They are installed in places where there is no easy availability of alternative power sources and are mainly used as a backup for uninterrupted power supply whenever there are outages.
- It is considered as unsuitable for high maintenance costs and diesel prices.

Wind Power:

- Wind turbines capture kinetic energy from wind and convert it into electricity. The amount of energy depends on speed of the wind.
- It is a renewable source of energy.
- Wind power projects typically require huge capital expenditure. After the wind turbines are built, operational costs involved in maintaining wind power plants are low and they are generally considered to be relatively cost-effective.

Solar Power:

- Solar energy plants convert energy from the sun into thermal or electrical energy. It gives the renewable energy sources.
- They do not require high maintenance and last for about 20 to 25 years but requires high initial cost for installation.

Tidal Power:

- Tidal energy is generated from converting energy from the force tides into power. This power is created when tides rotate submerged turbines.
- Its production is considered more predictable compared to wind energy and solar power.
- Tidal power is still not widely used.

Biomass:

- Burning organic materials produces high pressure gas that can drive a turbine-generator to make electricity.

Geothermal energy:

- Geothermal power plants utilize the internal heat of earth's crust to heat water to produce steam. This steam gives energy to the turbine-generator to produce electricity.
- Geothermal power plants are considered to be environmentally friendly and emit lower levels of harmful gases compared with coal-fired power plants.

THERMAL POWER STATION

A thermal power station or a coal fired thermal power plant uses coal as the primary fuel. Heat released from the burning of coal is used to boil the water to make superheated steam for driving the steam turbine. It is the most conventional method of generating electric power with high efficiency.

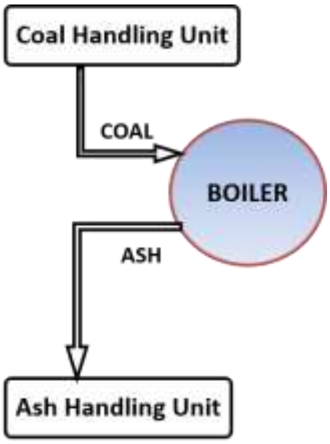
Steam Power Plant Layout:

The different types of systems and components used in steam power plant are as follows:

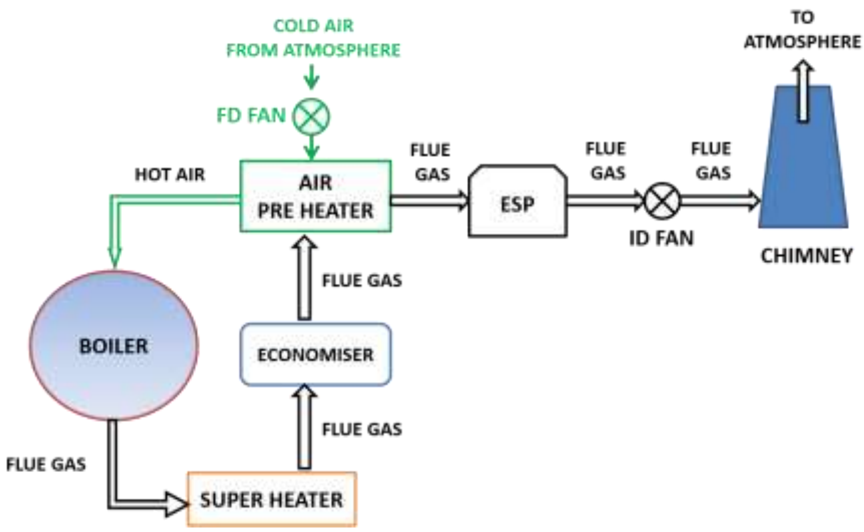
- Boiler
- Turbine
- Condensers
- Cooling tower
- Coal handling system
- Ash handling system
- Draught system
- Feed water treatment plant
- Pumping system
- Mountings like Safety valve, stop valve, pressure gauge and water gauge.
- Accessories like Air preheater, economizer, super heater and feed heaters
- Generator, Transformer and Electricity storage and distribution system

Layout of thermal plant can be easily understood by dividing the plant components into four circuits.

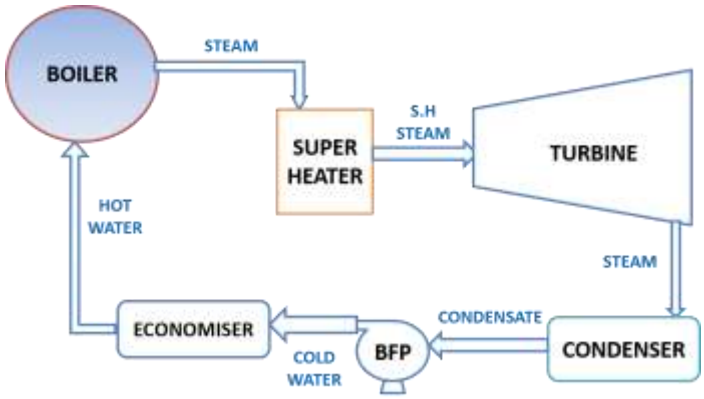
- **Coal and ash circuit**
  - Coal and Ash circuit in a thermal power plant layout mainly takes care of supplying the boiler with coal from the storage for combustion and collect the ash from the boiler. Coal storage, preparation and supply to the boiler mainly handled by the coal handling plant whereas the ash collection, storage and disposal mainly handled by the ash handling plant.



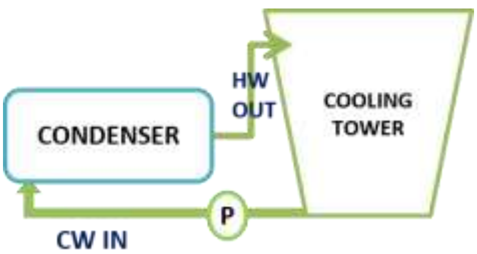
- **Air and gas circuit**
  - Air and gas circuit in a thermal power plant layout mainly takes care of supplying preheated air obtained from the Air preheater to the furnace and releasing the exhaust gas from the furnace after the combustion of fuel.
  - Atmospheric air is drawn into the Air preheater through the forced draught fan where air is heated by the hot flue gas coming out from the furnace.
  - Flue gas having very high temperature is used in the super heater, economizer and air preheater where its heat is recovered. After that the flue gas is passes through the electrostatic precipitator for removing dust from the gas and then gas is drawn into the chimney by the induced draught fan to release the gas to atmosphere.



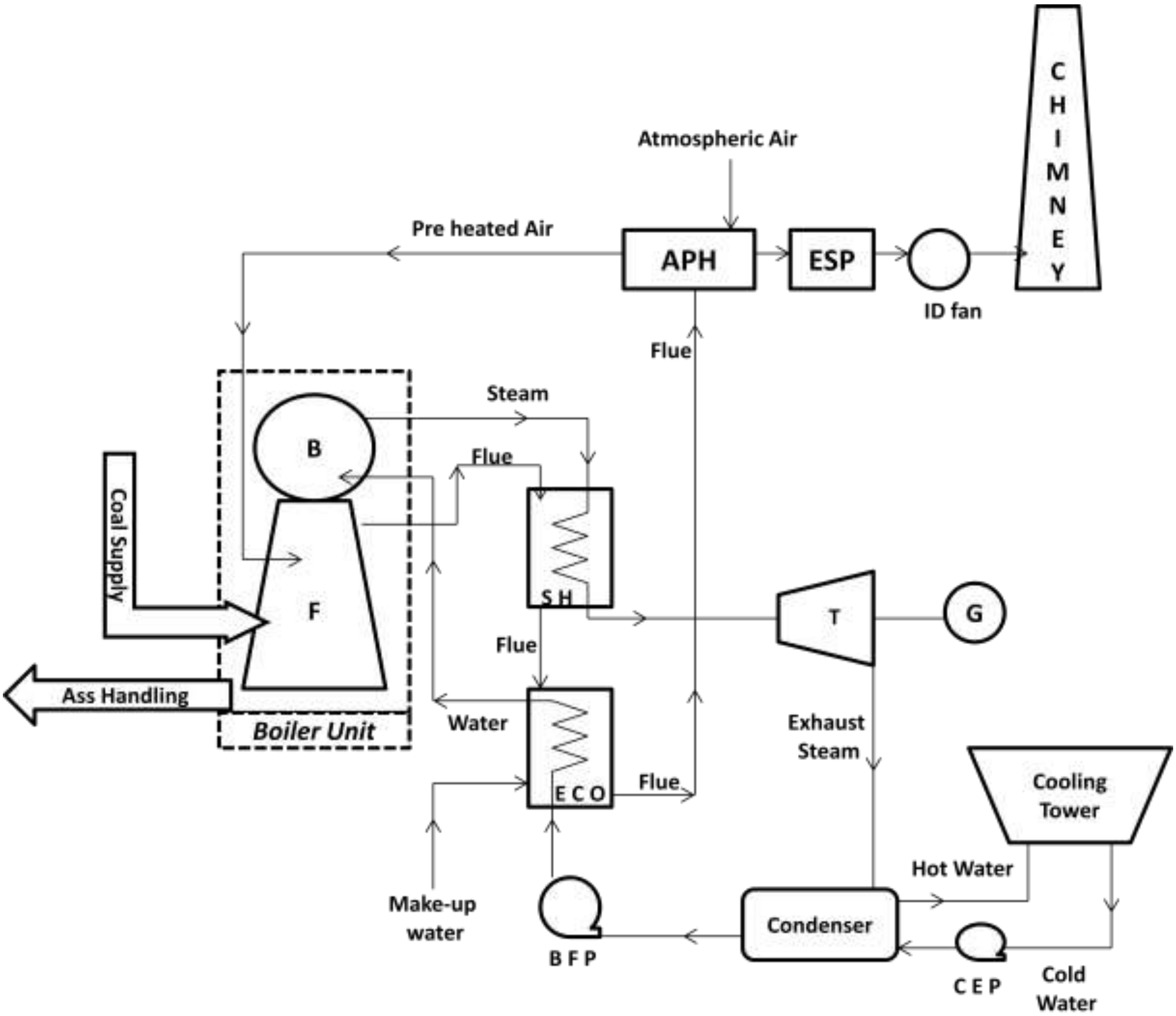
- **Feed water and steam circuit**
  - The water and steam circuit in a thermal power plant layout mainly takes care of feeding hot water obtained from the economizer to the boiler and supplying steam obtained from the boiler to the turbine to generate power.
  - The steam that is expelled by the prime mover in the thermal power plant layout is then condensed in a condenser for re-use in the boiler. The condensed water is forced through a pump into the feed water heaters. Pre heated water is supplied into the boiler. To make up for the lost steam and water make up water is feed to the boiler.



- **Cooling water circuit**
  - Cooling water is passed through the condenser where the steam is condensed. The water after being heated by steam is discharged to Cooling tower. Cooling water circuit can also be a closed system where the cooled water is sent through cooling towers for re-use in the power plant. The cooling water circulation in the condenser of a thermal power plant layout helps in maintaining a low pressure in the condenser.

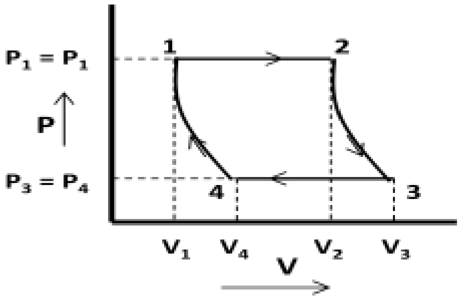


In a steam power plant, Steam is generated in a boiler, expanded in the prime mover and condensed in the condenser and fed into the boiler again. The layout of steam power plant is given below.

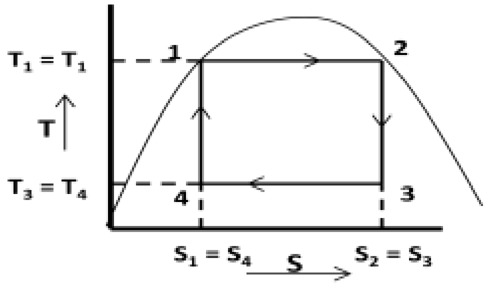


Carnot vapour power cycle:

The P-V and T-s diagram for Carnot vapor cycle is shown below.



(P-V diagram)



(T-s diagram)

Carnot vapor cycle consists of the four processes as described below.

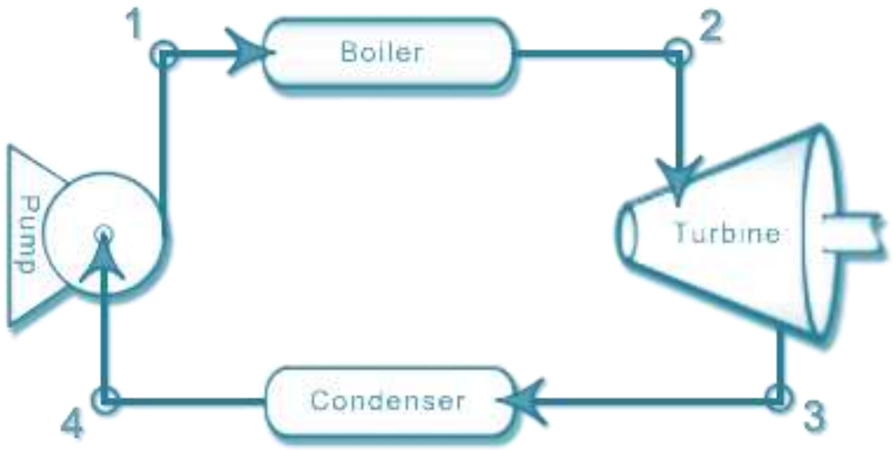
- **Isothermal expansion**:
  In figure process 1-2 shows the isothermal expansion process. In this process water gets heated in the boiler at constant temperature ($T_1 = T_2$) and pressure ($P_1 = P_2$) and gets converted into steam. Entropy increases from s_1 to s_2 and dry steam is collected at state 2.
  Heat absorbed by water (Q_{1-2}) = T_1 (s_2-s_1)

- **Reversible adiabatic expansion**:
  In figure process 2-3 shows the reversible adiabatic expansion process. In this process steam expands inside the turbine at constant entropy ($s_1 = s_2$) and produce shaft power. Steam becomes wet at state 3. Pressure and temperature get changed from state 2-3.
- **Isothermal compression**:
  In figure process 3-4 shows the isothermal compression process. In this process steam gets condensed in the condenser at constant temperature ($T_3 = T_4$) and pressure ($P_3 = P_4$). Entropy decreases from s_3 to s_4 and wet steam is collected at state 3.
  Heat rejected from steam (Q_{3-4}) = T_3 (s_3-s_4) = T_3 (s_2-s_1)
- **Reversible adiabatic compression**:
  In figure process 4-1 shows the reversible adiabatic compression process. In this process wet steam at state 4 gets compressed to state 1 at constant entropy ($s_4 = s_1$) in feed pump. Pressure and Temperature get changed from state 4-1.

Efficiency of Carnot Cycle:

$$\text{Efficiency} = \eta_{carnot} = \frac{Workdone}{Heat\,Supplied} = \frac{Heat\ \ su\ pplied - heat\,rejected}{Heat\,Supplied}$$

$$= \frac{Q_{1-2} - Q_{3-4}}{Q_{1-2}} = \frac{T_1(s_2 - s_1) - T_3(s_2 - s_1)}{T_1(s_2 - s_1)} = \frac{T_1 - T_3}{T_1} = 1 - \frac{T_3}{T_1}$$



(Simple steam power plant working on Carnot cycle)

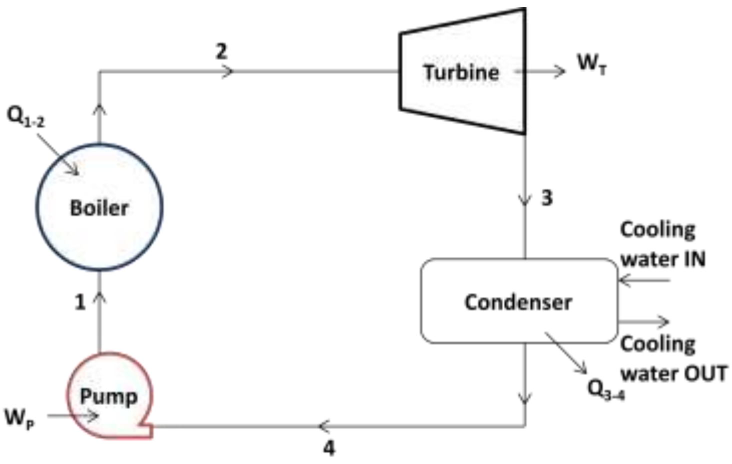
The limitations of Carnot vapor cycle are

- ♣ It is difficult to compress a wet vapor isentropically to the saturated state (process 4-1).
- ♣ It is difficult to control the quality of the condensate coming out of the condenser.
- ♣ The efficiency of the Carnot cycle is greatly affected by the temperature T_1.
- ♣ The cycle is still more difficult to operate in practice with superheated steam.

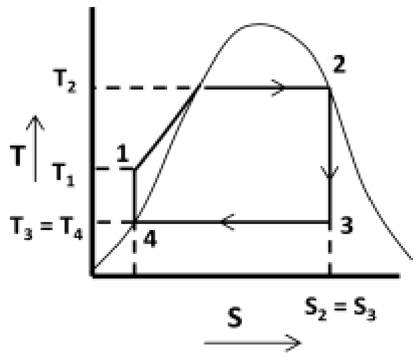
Rankine cycle:

A steam power plant using steam as working substance works basically on Rankine cycle.

The T-S diagram for Rankine cycle is shown below.



(Rankine Cycle)



(T-s diagram)

Rankine cycle consists of the four processes as described below.

- **Isothermal expansion**:
  In figure process 1-2 shows the isothermal expansion process. In this process saturated water at state 1 is converted into dry saturated steam at state 2 in a steam boiler at constant pressure ($P_1 = P_2$). Water absorbs the latent heat of vaporization ($h_{fg1} = h_{fg2}$) and converted into dry saturated steam.

  Amount of heat absorbed in process 1-2 = $h_{fg2} = h_2 - h_{f2}$ (for dry steam: $h_2 = h_{fg2} + h_{f2}$)

- **Reversible adiabatic or Isentropic expansion process**:
  In figure process 2-3 shows the reversible adiabatic or isentropic expansion process. In this process dry saturated steam at state 2 expands isentropically in turbine to state 3. Steam at state 3 is wet.

  Work done in the process 2-3 = Turbine work = $h_2 - h_3$

- **Isothermal compression process**:
  In figure process 3-4 shows the isothermal compression process. In this process exhaust steam of turbine is cooled by cold water in the condenser at constant pressure ($P_3 = P_4$) and constant temperature ($T_3 = T_4$). Steam releases latent heat of vaporization and converted into saturated water.

  Amount of heat rejected in process 3-4 = $h_{fg3} = h_3 - h_{f4}$

- **Reversible adiabatic or Isentropic process**:
  In figure process 4-1 shows the reversible adiabatic or isentropic process. In this process saturated water is drawn by the pump and feed into the boiler.

  Work done in this process 4-1 = Pump work = $h_1 - h_{f4}$

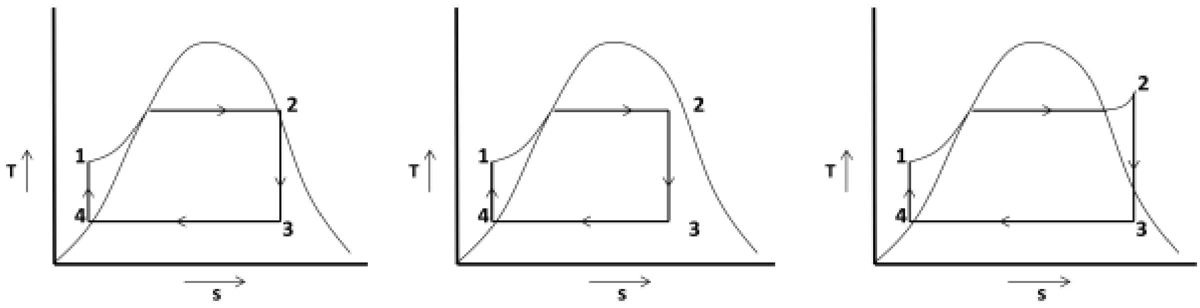
Efficiency of Rankine cycle:

$$\text{Efficiency} = \frac{Net\,Workdone}{Heat\,Supplied} = \frac{W_T - W_P}{Q_{1-2}} = \frac{(h_2 - h_3) - (h_1 - h_{f4})}{(h_2 - h_{f1})}$$

If pump work is neglected then $W_P = 0$

Various end conditions of steam:

The T-S diagram for various end conditions of steam can be discussed by the Rankine cycle.



(Steam is dry at state 2) (Steam is wet at state 2) (Steam is superheated at state 2)

- **Efficiency ratio:**

  It is the ratio of thermal efficiency to Rankine efficiency or actual cycle efficiency to ideal cycle efficiency.

  Efficiency ratio = $\dfrac{Thermal\,efficiency}{Rankine efficiency}$

- **Thermal efficiency:**

  Thermal efficiency = $\dfrac{3600 \times P}{m(h_2 - h_{f3})}$

  Where, P = power developed in kW and

  m = mass of steam supplied

- **Work ratio:**

  It is the ratio of net work done to the turbine work.

  Work ratio = $\dfrac{Turbine\ work - Compressor\ work}{Turbine\ work}$

- **Specific steam consumption:**

  It is defined as the mass of steam supplied to the turbine to develop unit power output. It is also known as steam rate or specific rate of flow of steam.

  Specific steam consumption = $\dfrac{3600}{h_2 - h_3}\ \ kg / kWh$

Problems:

Q.1) In a steam power cycle, the steam supply is at 15 bar and dry and saturated. The condenser pressure is 0.4 bar. Calculate the Carnot and Rankine efficiencies of the cycle. Neglect pump work.

Q.2) A simple Rankine cycle works between pressures 28 bar and 0.06 bar, the initial condition of steam being dry saturated. Calculate the cycle efficiency, work ratio and specific steam consumption.

Q.3) A steam turbine receives steam at 15 bar and 350^0 C and exhausts to the condenser at 0.6 bar. For the ideal Rankine cycle operating between these two limits, determine the (i) heat supplied, (ii) heat rejected, (iii) net work done (iv) thermal efficiency.

Q.4) Steam at 50 bar and 400^0 C expands in a Rankine cycle to 0.5 bar. For a mass flow rate of 150 kg/s of steam determine (i) power developed, (ii) thermal efficiency, (iii) specific steam consumption.

Q.5) Dry and saturated steam at 15 bar is supplied to a steam turbine working in Rankine cycle. The exhaust takes place at 1 bar. Calculate (i) Rankine efficiency, (ii) steam consumption per kWh if the efficiency ratio is 0.65.

Q.6) A turbine working on a Rankine cycle is supplied with dry saturated steam at 25 bar and exhaust takes place at 0.2 bar. For a steam flow rate of 10 kg/s, estimate – (i) quality of steam at the end of expansion, (ii) turbine shaft work, (iii) power required to drive the pump, (iv)work ratio, (v) Rankine efficiency, (vi) heat flow in condenser.

Boiler Accessories:

Boiler accessories are the set of devices that are used to increase the efficiency of the boiler. These devices improve the boiler operation.

The following are some of the accessories which are used in boiler.

- **Air pre heater:**
  - It is a heat exchanger which converts the cold air into hot air from the heat exchange between atmospheric air and flue gas.
  - It recovers heat from the flue gas coming out of the Economizer.
  - It is installed between the economiser and the chimney.
  - The air required for the purpose of combustion is drawn through the air preheater where its temperature is raised. It is then passed through ducts to the furnace.
  - The preheated air gives higher furnace temperature which results in more heat transfer to the water and thus increases the evaporative capacity per kg of fuel. It increases the boiler efficiency.
- **Economizer:**
  - It is a heat exchanger which converts the cold water into hot water from the heat exchange between feed water and flue gas.
  - It recovers heat from the flue gas coming out of the superheater.
  - It improves the economy of the steam boiler.
- **Super heater:**
  - It is a heat exchanger which converts the steam coming from the boiler into superheated steam from the heat exchange between steam and flue gas.
  - It recovers heat from the flue gas coming out of boiler.
  - Its purpose is to increase the temperature of saturated steam without raising its pressure. It is generally an integral part of a boiler which is located in the path of hot flue gases from the furnace.
- **Electrostatic precipitator:**
  - It uses electrostatic forces to separate dust particles from exhaust gases.
  - The contaminated exhaust gas flow through the passage formed by a number of high-voltage, direct-current discharge electrodes and grounded collecting electrodes.
  - The airborne particles receive negative charge while passing through the ionized field between the discharge and collecting electrodes.
  - These charged particles get attracted towards the positively charged grounded or collecting electrode and adhere to it.
  - The collected material on the collecting electrodes is removed by rapping or vibrating the collecting electrodes.

Need of boiler mountings:

Boiler mountings are the set of safety devices installed on the boiler for its safe operation. These are very essential for a boiler to operate it safely.

The following are some of the mountings which are used in boiler.

- *Pressure Gauge*: It is used to measure the pressure of steam inside the boiler.
- *Water level Indicator*: It is used to indicate the water level in the boiler.
- *Safety Valve*: It is used to blows off the excess steam when steam pressure reaches above safety level.
- *Steam Stop Valve*: It is used to stop the steam in the boiler and transfer steam when it is required.
- *Blow off Valve*: It is used to blow off the impurities or sediments settled down in the boiler.
- *Feed check Valve*: It is used to control the flow of water from feed pump to the boiler.

Operation of boiler:

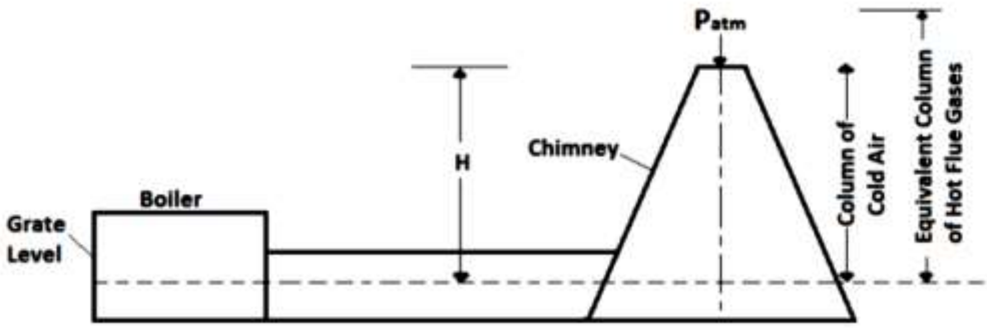
- The boiler is a closed vessel. The basic function of boiler is to convert water into steam. Water is supplied into the boiler drum where it is heated by hot gases that are formed by burning fuel in the furnace. When the steam at required pressure is generated inside the boiler, the steam stop valve releases the steam. This steam is superheated in a superheater before it is supplied into the turbine.
- The various mountings and accessories of boiler helps to run the boiler safely and to improve plant efficiency respectively.

Draught systems:

- Boiler draught is the pressure difference between absolute gas pressure within a furnace or chimney and atmospheric pressure which causes the flow of gas.
- Draught can be obtained by the use of chimney, fan, steam or air jet or a combination of these.
- Boiler Draught provide an adequate supply of air for fuel combustion. It can throw out the exhaust gases of combustion from the combustion chamber. It can discharge flue gases to the atmosphere through the chimney.
- The draughts may be classified as Natural Draught and Artificial Draught.

Natural Draught:

- When the draught is produced with the help of chimney only, it is known as Natural Draught.
- Natural draught system employs a tall chimney and don't require any external power for producing draught.



Natural Draught

- **Advantages of Natural Draught**

  - It is produced with the help of chimney only. It does not require any external power for producing the draught.
  - It has low capital and maintenance cost.
  - Simple in design and construction.
  - It has a long life. It leaves the flue gas at a high level.

- **Disadvantages of Natural Draught**

  - Maximum pressure available for producing draught by the chimney is less.
  - The available draught decreased with increase in outside air temperature.
  - Flue gases have to be discharged at high temperature which lowers the plant overall efficiency.

Artificial Draught:

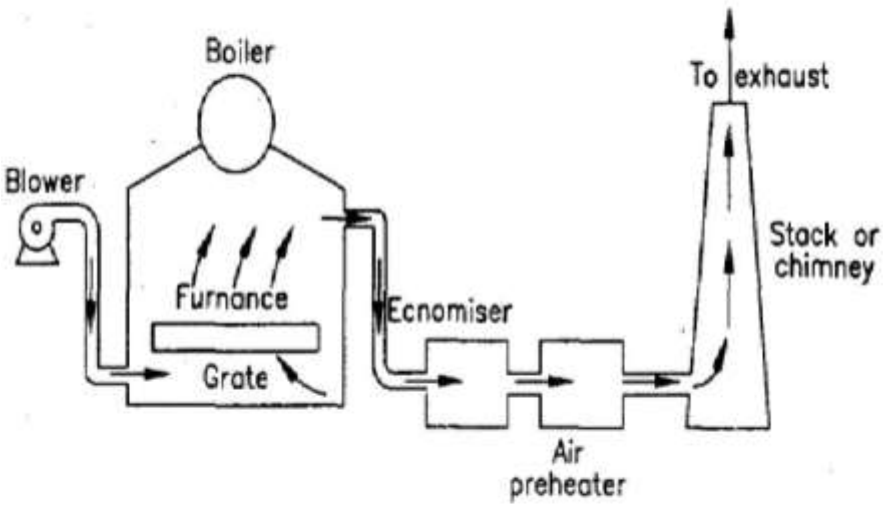
- When the draught is produced by any other means except chimney it is known as Artificial Draught.
- To meet the high draught demand, artificial draught system is used which is classified as steam jet draught and mechanical draught.

Mechanical Draught:

- It is an artificial draught where draught is produced by the help of fans or blowers.
- It is more economical and its control is easy,
- It increases the rate of combustion by which low-grade fuel can also be used.
- It reduces fuel consumption and makes boiler operation cheaper.
- It can be classified as Forced draught, Induced draught and Balanced draught.

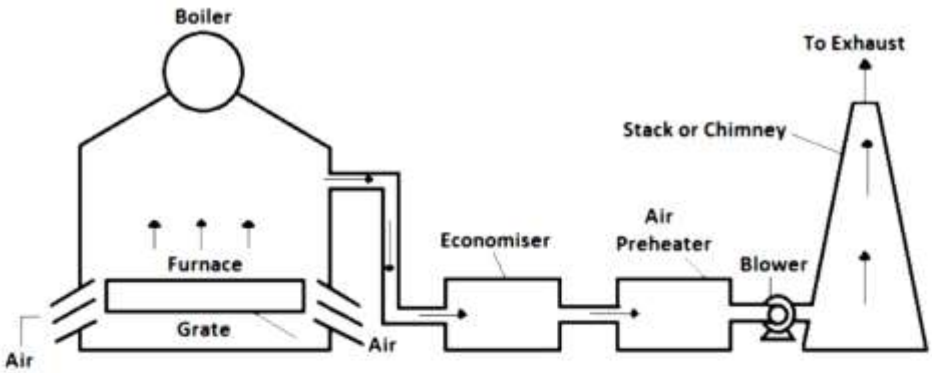
Forced draught:

- In this type of draught, a blower known as forced draught fan (FD fan) is placed before the grate. It forces the air into the grate through the closed ash pit. Air is forced to flow through the entire system under pressure.



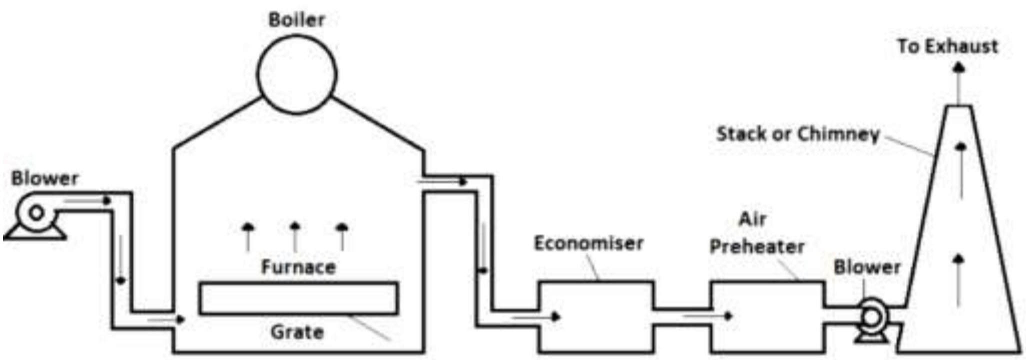
Induced draught:

- In this type of draught, a centrifugal fan known as induced draught fan (ID fan) is placed near the base of the chimney. The ID fan draws the furnace flue gas and forces the gas up through the chimney. Its action is similar to that of the natural draught.



Balanced draught:

- Balanced draught is the combination of forced draught and induced draught.
- It overcomes the difficulties that are seen by using the forced draught or induced draught alone. It maintains the balance.
- The forced draught fan supplies the combustion air for better combustion of fuel and overcomes the resistance of fuel bed.
- The induced draught removes the flue gas and excess air from the furnace and helps to release it through chimney. It helps to maintain the pressure inside the furnace below atmospheric.
- If the forced draught is applied alone, there will be high pressure in the furnace. It causes difficulties in lightening and inspecting the boiler. There is possibility of blowing out of fire from the furnace which may disable the furnace work.
- If the induced draught is used alone, there will be difficulties in inspecting the boiler because cold air may rush into the furnace as the pressure inside the furnace is under atmospheric pressure.



Advantages of Artificial or Mechanical Draught

- It increases the rate of combustion for which low-grade fuel can be used in the furnace. So, fuel cost is reduced.
- The desired value of draught can be produced, which is not obtained in natural draught.
- It reduces the smoke level and reduces the height of chimney.
- It is more economical and its control is easy.
- It saves the energy. It improves plant efficiency as maximum heat can be utilized.
- It reduces fuel consumption and makes boiler operation cheaper.

Disadvantages of Artificial or Mechanical Draught:

- The initial cost is high.
- The running cost is also high due to consumption of electricity but it is compensated by other savings.
- Fans and blowers produce noise.

Steam prime movers or Steam Turbine:

The steam turbine is used to convert the thermal energy of steam into mechanical energy by means of rotation of turbine shaft. This mechanical energy is used by generator to produce electrical energy.

The steam coming from the boiler rotates the turbine runner when strikes on it. Thus, mechanical energy is produced due to rotation of shaft of the turbine. When the turbine shaft rotates, the generator shaft coupled to the turbine shaft is also rotated.

Advantages of steam turbine:

- It has higher thermal efficiency.
- It can provide a good range of uniform brake horse power.
- It is properly balanced and so, vibration problem is minimised.
- It gives high rpm.
- It is reliable and durable.
- It needs no lubrication.

Disadvantages of steam turbine:

- It is less responsive to changes in power demand compared to reciprocating engines and gas turbines.
- It takes long start up time compared to reciprocating engines and gas turbines.
- It is less efficient at part load conditions than reciprocating engines and gas turbines.

Classification of steam turbine:

The steam turbines may be classified into the following types:

- According to the mode of steam action
    - Impulse turbine
    - Reaction turbine
- According to the direction of steam flow
    - Axial flow turbine
    - Radial flow turbine.
- According to the exhaust condition of steam
    - Condensing turbine
    - Non-considering turbine
- According to the pressure of steam
    - High pressure turbine
    - Medium pressure turbine
    - Low pressure turbine
- According to the number of stages
    - Single stage turbine
    - Multi stage turbine

Elements of steam turbine:

The components of steam turbine are

- **Steam Chest and Casing:**
  - The casing contains the rotor and nozzles through which the steam is expanded.
  - The steam chest is connected with the higher pressure and low-pressure steam lines.
  - The steam chest and casing protect the turbine from surrounding.
  - It encloses the steam inside the turbine.
- **Nozzles:**
  - These are used to increase the kinetic energy of steam.
- **Rotor:**
  - The rotor consists of disc mounted on a shaft. Number of blades are mounted on the periphery of the disc.
  - The shaft extends beyond the casing. One end of the shaft is connected with the governor and other end is coupled with the shaft of the generator.
  - The main function of the rotor is to convert the thermal energy of the incoming steam into kinetic energy.
- **Blades**
  - Number of blades mounted on the periphery of the disc are used to receive the steam on it. These are used for energy conversion and pressure and velocity variation.
- **Governor**
  - It is used to maintain the mean equilibrium speed of the steam turbine.

Difference between Impulse and reaction turbine:

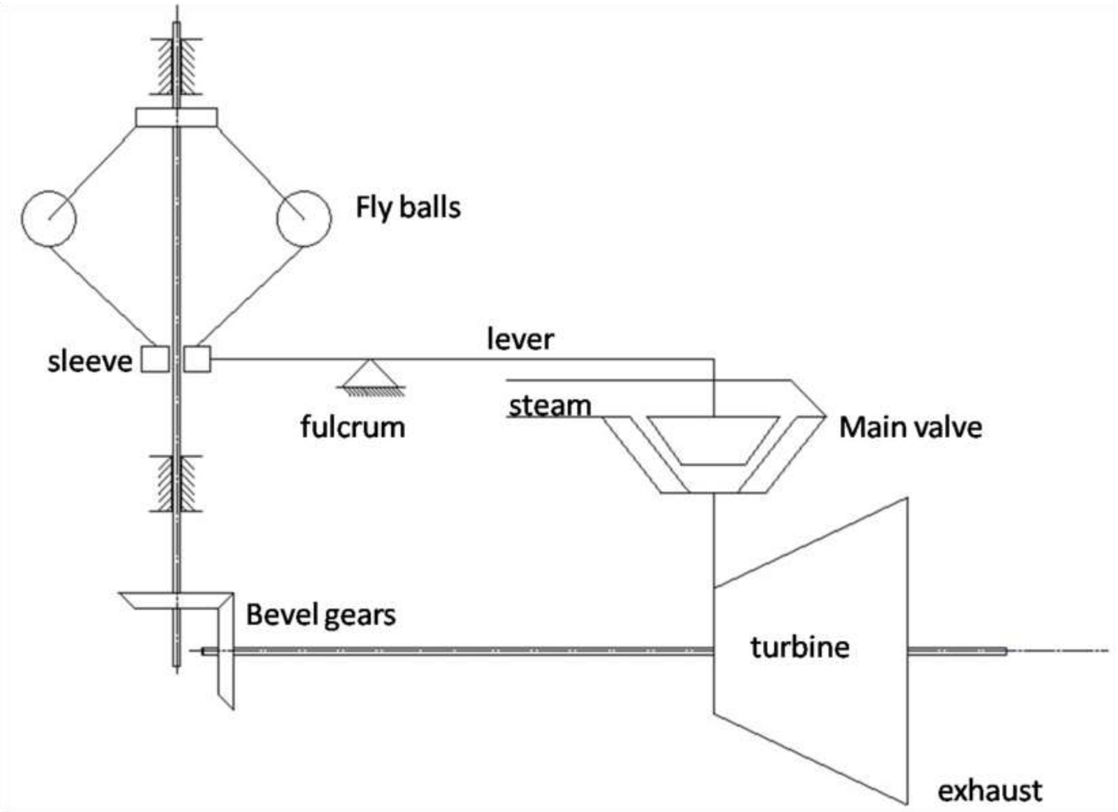
	Impulse turbine		**Reaction turbine**
1.	The steam flows through the nozzles and impinges on the moving blades.	**1.**	The steam flows first through guide mechanism and then through the moving blades.
2.	The steam impinges on the buckets with kinetic energy.	**2.**	The steam glides over the moving vanes with pressure and kinetic energy.
3.	The steam may or may not be admitted over the whole circumference.	**3.**	The steam must be admitted over the whole circumference.
4.	The steam pressure remains constant during its flow through the moving blades.	**4.**	The steam pressure is reduced during its flow through the moving blades.
5.	The negative velocity of steam while gliding over the blades remains constant.	**5.**	The relative velocity of steam while gliding over the moving blades increase
6.	The blades are symmetrical.	**6.**	The blades are not symmetrical
7.	The number of stages required is less for the same power developed.	**7.**	The number of stages required is more for the same power developed.

Governing of Steam turbine:

- The function of a governor is to control the fluctuation of speed of a steam turbine.
- When the steam turbine is connected to drive an alternator, there may be variation of load. According to the load on the alternator, turbine speed fluctuates. This fluctuation can be overcome by using a governing method.
- The different governing methods are:
    - Throttle governing
    - By-pass governing
    - Nozzle governing

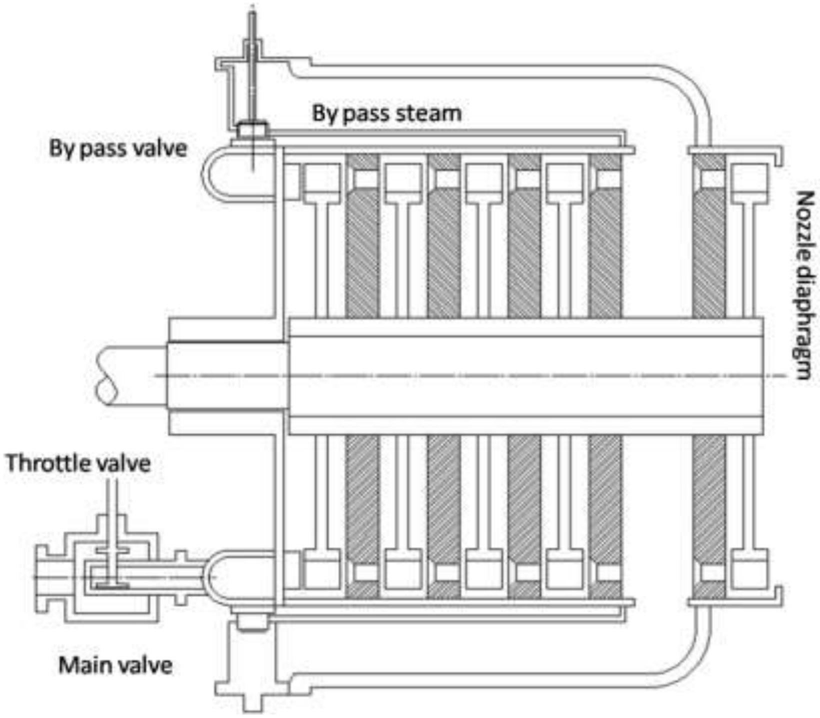
Throttle Governing:

- This method is very simple and less costly. This is used to reduce inlet steam pressure by throttle valve operated by governing mechanism on part loads.
- An oil relay is used to operate the throttle valve.
- When the turbine works on less than full load condition, the load on the turbine suddenly released, governor speed increases with rotor speed and sleeve moves upward. So, relay piston under oil pressure moves downward and partially closes throttle valve. Then the sleeve comes to its position when equilibrium speed is obtained.



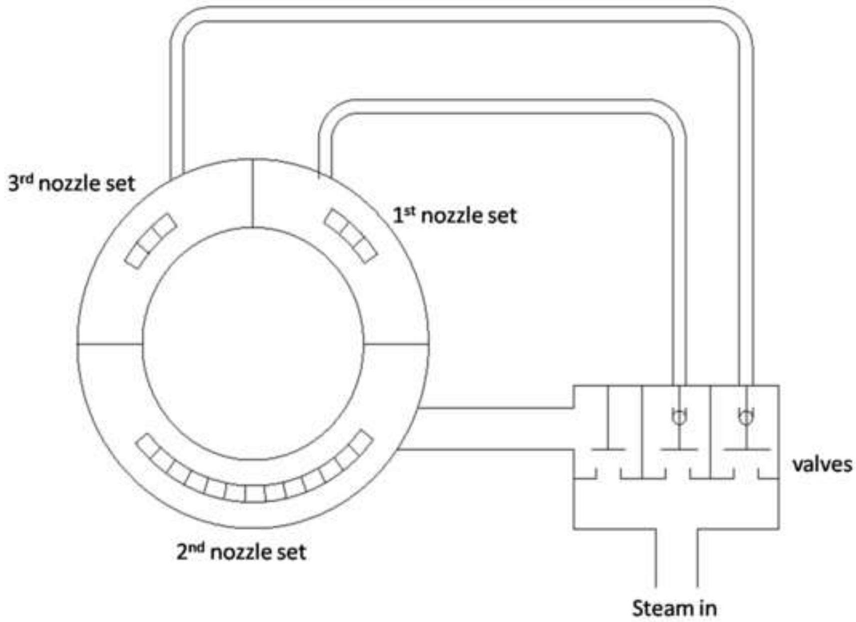
By-pass Governing:

- This method is used in modern impulse turbine operating at a very high pressure.
- In this method the whole steam enters the nozzle box through a throttle valve. This valve controls the speed of turbine for all load up to economical load. For the loads more than economical load, the by-pass valve opens and allows the steam to pass from the first stage nozzle box into steam belt and so into the fourth stage nozzle. When the load stabilizes, the valve closes.



Nozzle Control Governing:

- It is basically used for part load condition.
- In this method, some set of nozzles are grouped together and steam flow to each group of the nozzle is controlled by valves. Actually, nozzle control governing is restricted to the first stage of turbine whereas the subsequent nozzle area in other stage remains constant.
- In this governing rate of steam flow is depending on the opening and closing of set of nozzles rather than regulating its pressure.



Performance of steam turbine:

- **Blade efficiency or Diagram efficiency:**

It is the ratio of the work done on the blades per kg of steam to the energy supplied to the blades per kg of steam.

Mathematically: Blade efficiency $(\eta_b) = \left(\frac{V_{w_1}+V_{w_2}}{\frac{V_1^2}{2}}\right) \times V_b = \left(\frac{V_{w_1}+V_{w_2}}{V_1^2}\right) \times 2V_b$

- **Stage efficiency:**

It is the ratio of the work done on the blade in heat unit to the total heat energy supplied per stage.
If ΔH is the total heat energy drop in the nozzle ring, then the total energy supplied per stage is $J \times \Delta H$.

Mathematically: Stage efficiency (η_s) $= \frac{(V_{w_1}+V_{w_2})V_b}{W.\ J.\ \Delta H}\left(\frac{w}{g}\right) = \frac{(V_{w_1}+V_{w_2})}{J.\ \Delta H} \times \left(\frac{V_b}{g}\right)$

- **Nozzle efficiency:**

It is the ratio between actual heat drop of steam in the nozzle and adiabatic or isentropic heat drop of steam in the nozzle.

Mathematically: Nozzle efficiency $(\eta_N) = \frac{\Delta H_{act}}{\Delta H_{th}}$

- **Relation between efficiencies:**

Stage efficiency (η_s) = Blade efficiency (η_b) $\times$ Nozzle efficiency (η_N)

Steam Condenser:

- A steam condenser is a closed vessel into which the steam is exhausted, and condensed after doing work in the turbine. A steam condenser has the following two objectives.
- The main object of condenser is to maintain a low pressure (below atmospheric pressure) so as to draw the maximum possible energy from steam. So, the efficiency of plant can be increased.
- It is used to supply pure feed water to the hot well, from where it is pumped back to the boiler.

Classification of Condensers:

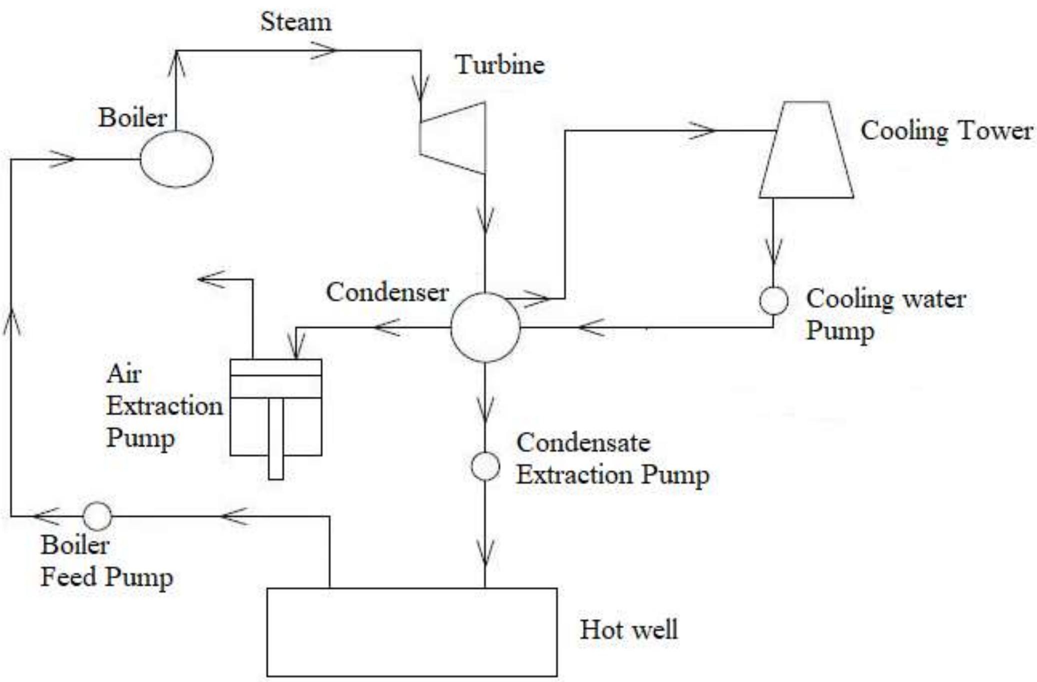
The steam condensers may be broadly classified into the following types:

- Jet condensers or mixing type condensers
  - Parallel flow jet condenser
  - Counterflow or low-level jet condenser
  - Barometric or high-level jet condenser, and
  - Ejector condenser
- Surface condensers or non-mixing type condensers.
  - Down flow surface condenser
  - Central flow surface condenser
  - Regenerative surface condenser
  - Evaporative condenser.

Elements of Steam Condensing Plant:

A steam condensing plant consists of the following elements.

- **Condenser**
  - A condenser is the heat exchanger in which heat exchange occurs between the hot exhaust steam of turbine and cold water. It works at a low pressure.
- **Air Extraction Pump**
  - It is used to maintain the vacuum pressure inside of the condenser.
- **Condensate Extraction Pump**
  - It is a low-pressure pump which is used to remove the condensed from the condenser and to supply it into the hot well.
- **Cooling Water Circulating Pump**
  - It is used to circulate the cooling water from cooling tower to condenser.
- **Hot Well**
  - It is a tank which stores the condensate which comes from the condenser.
- **Cooling Tower**
  - It is a heat exchanger in which hot water extracted from the condenser transfers heat to the cold atmospheric air and gets converted into cold water. This cold water is supplied into the condenser by cooling water pump to remove heat from steam. Some amount of water gets vaporized in the cooling tower.
- **Boiler Feed Pump**
  - It is a pump which is used to supply the water from hot well to the boiler.
- **Makeup Water Pump**
  - When there is deficiency of cooling water, makeup water needs to be added by the help of the makeup water pump to deliver fresh water from a sump to the condensing plant.



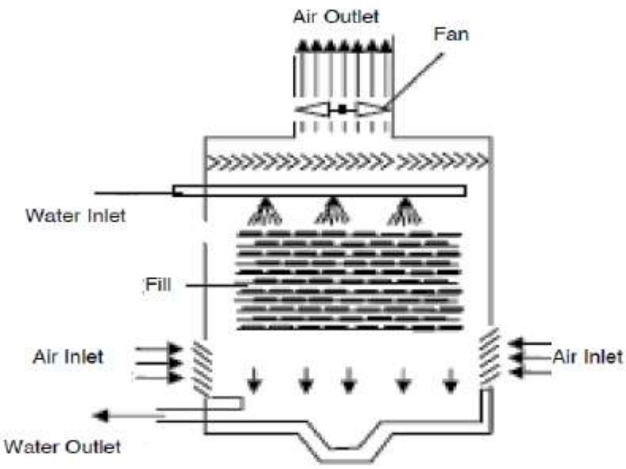
Cooling Tower:

- Cooling tower is used to reject heat into the atmosphere.
- The cold water exits from the cooling tower is sent into the condenser. This water is converted into hot water after receiving heat from the steam inside the condenser. Hot water is extracted from the condenser and supplied to the cooling tower where it is cooled by the atmospheric air.

Types of cooling tower:

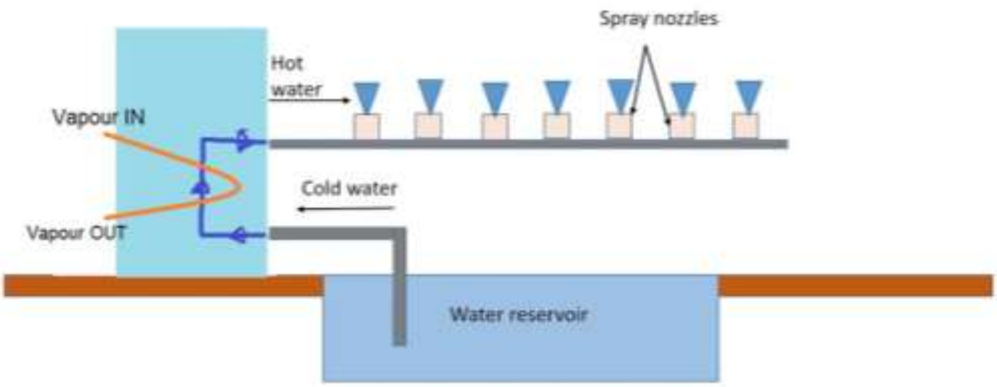
Cooling towers can be classified on the basis of method of air circulation. Such as:

- Natural draught colling tower
- Mechanical draught cooling tower
    - Forced draught cooling tower
    - Induced draught cooling tower



Spray pond:

- A spray pond is a reservoir in which warmed water is cooled before reuse by spraying the warm water with nozzles into the cooler air.
- In spray type cooling method, a large surface of water is exposed for evaporation.
- The hot water extracted from the condenser is supplied to the surface of the cooling tank and is projected into thin horizontal sheets. Nozzles are fitted on the sheets. These nozzles brake up the water into drops. Water droplets gets cooled due to conduction and convection. Cold water is collected at the bottom of the tank.



List of thermal power plants in Odisha:

Sl.No.	Name of the Plant	Capacity in MW
1.	Jindal Steel and Power Ltd	810
2.	NALCO Ltd., Captive Power Plant	1200
3.	GMR Energy	1050
4.	Vedanta Ltd., IPP and CPP	2400 and 1215
5.	Talcher Super Thermal Power Station	3000
6.	Jindal India Thermal Power Ltd	1200
7.	Rourkela Steel Plant (CPP-I)	100
8.	Thermal Power Station (OPGC	420
9.	HINDALCO Industries Ltd (CPP),	467
10.	TATA Bhushan Power & Steel Ltd.	370

Site Selection for thermal power plants:

The following points should be taken into consideration while selecting the site for a steam power station.

- Availability of raw material
- Nature of land
- Cost of land
- Availability of water
- Transport facilities
- Ash disposal facilities
- Availability of labour
- Size of the plant
- Load centre
- Public problem
- Future extension

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NUCLEAR POWER STATION

A power plant that uses nuclear reactor as heat source is known as nuclear power plant. Nuclear power is a clean and efficient way for producing steam from water. The steam produced is used to turn the turbine to develop mechanical power, which can be used by the generator to produce electricity.

Nuclear power plants use low enriched uranium fuel to produce electricity through a process called fission— the splitting of uranium atoms in a nuclear reactor.

Nuclear Fuel:

Nuclear fuel should be fissionable material. It can be defined as an element or isotope that undergo nuclear fission to produce chain reaction by means of bombardment of neutrons to the nucleus of heavy atoms. Examples of some important nuclear fuels are U233, U235 and Pu239.

Some materials are not fissionable by themselves. These can be converted into fissionable material by means of nuclear reaction. These materials are known as *fertile materials*. These are converted into fissile material before undergo fission reaction. Some materials can undergo fission reactions directly. These are known as *fissile materials*. The process of transmutation of fertile materials into fissile materials is referred to as *fuel breeding*. Examples of fertile material are Pu239 and U233.

U235 is most unstable material. It is capable to sustain chain reaction. It is considered as primary fuel. U233 and Pu239 are artificially produced from Th232 and U238 respectively. These are called secondary fuel.

Nuclear Fission:

Nuclear fission is the process where the nucleus of a heavy atom splits into fragments of lighter nuclei with the release of energy. It is carried out by the bombardment of neutrons to the nucleus of heavy atoms. This reaction produces energy as well as neutrons. These neutrons can be used to split other atoms further in the chain reaction.

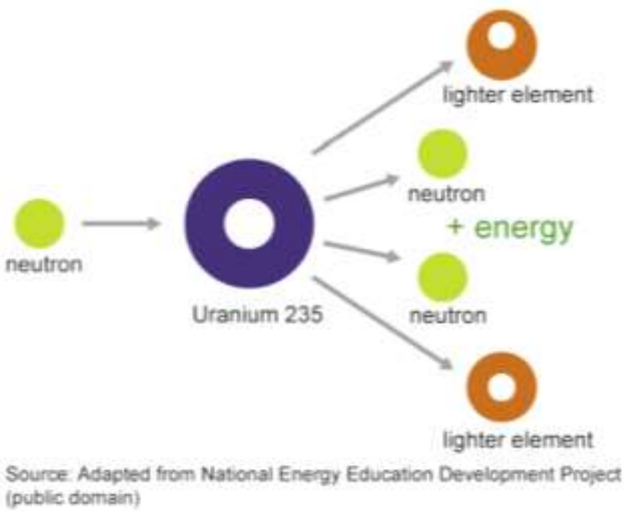

Figure: Splitting of U 235 in fission

Nuclear Fusion:

Nuclear fusion is the process where the nuclei of lighter atoms combine to form heavy nucleus with the release of energy. It produces greater energy than the fission reaction.

Difference between Nuclear Fission & Nuclear Fusion:

Nuclear Fission	Nuclear Fusion
Fission occurs when a neutron bombarded into a larger atom, forcing it to excite and split into two smaller atoms—also known as fission products. Additional neutrons are also released that can initiate a chain reaction.	Fusion occurs when two atoms collide or fuse together to form a heavier atom, like when two hydrogen atoms fuse to form one helium atom.
When each atom split, a tremendous amount of energy is released	The energy released during nuclear fusion is several times greater than the energy released during nuclear fusion.
Fission reactions do not occur in nature naturally	Fusion reactions occur in stars and the sun
Little energy is needed to split an atom in a fission reaction	High energy is needed to bring fuse two or more atoms together in a fusion reaction
The energy released by fission in nuclear power plant heats water into steam. The steam is used to spin a turbine to produce carbon-free electricity.	It is not used in nuclear power plants because tremendous amount of pressure and temperature needed to join the nuclei together.

Components of a Nuclear Power Plant:

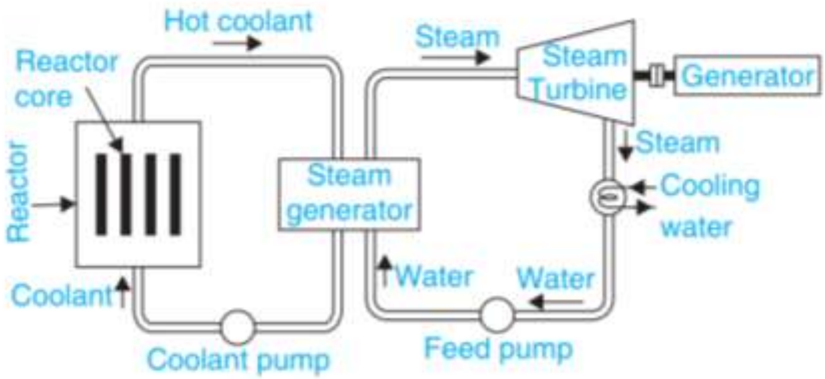

Figure: Components of Nuclear Power Plant

The main components of a nuclear power plant are:

- Nuclear reactor
- Heat exchanger (steam generator)
- Steam turbine
- Condenser
- Electric generator

In a nuclear power plant, the reactor produces heat energy from the nuclear fission of the nuclear fuel. The heat liberated in the reactor is taken up by the coolant circulating through the reactor core. Hot coolant leaves the reactor and then flows through the tubes of steam generator. Hot coolant gives up the heat energy to the feed water flowing through the steam generator. The steam so produced expands in the steam turbine and produce mechanical work. The steam turbine runs an electric generator to produce electricity. The exhaust steam can be condensed for recycling. Pumps are provided to circulate the coolant, condensate and feed water.

Nuclear Reactor:

A nuclear reactor is an apparatus in which heat is produced due to nuclear fission chain reaction.

The reactor generates spontaneous energy from the continuous fission reaction. During fission kinetic energy is converted into thermal energy. The heat produced in the reactor is transferred to a coolant which is either used directly or indirectly by converting into steam. This steam is used to rotate the turbine where the thermal energy is converted into mechanical energy.

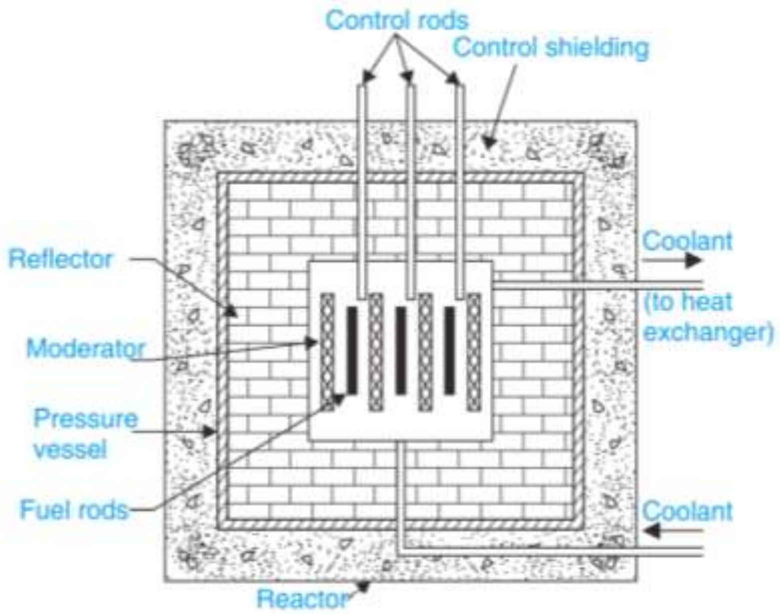

Figure: Nuclear Reactor

Main Components of a Nuclear Reactor are:

Nuclear Fuel: Commonly used nuclear fuels are U233, U235 and Pu239. Among these U235 is most unstable and is capable to sustain chain reaction. This is called as primary fuel. U233 arid Pu239 are artificially produced from Th232 and U238 respectively and are called secondary fuel.

Core: It contains all the fuel and generates the heat required for energy production.

Moderator: Material in the core which slows down the neutrons released from fission so that they cause more fission. H_2O, D_2O (heavy water), He (gas), Be and C (graphite) are the commonly used moderators.

Coolant: It absorbs heat when passes through the core and delivers that heat to the heat exchanger for the formation of the steam. Commonly used coolants are Santiwax R (organic, Hg, He, CO2)

Control rods: These are made with neutrons-absorbing material like cadmium or boron. These are inserted into or withdrawn from the core to control the rate of reaction. By pushing these rods deeper into the central core, any number of excess neutrons can be absorbed.

Shielding: Shielding is necessary in order to protect the walls of the reactor vessel from radiation damage, and to protect operating personnel from exposure to radiation.

Reflector: A reflector is placed round the core to reflect back some of the neutrons that leak out from the surface of the core. It is generally made of the same material as the moderator

Reactors Vessel: It encloses the various parts inside the reactor including the core, shield, reflector etc.

Containment: The enveloping structure that separated the nuclear reactor from the surrounding environment.

Properties of Moderator:

The desirable properties of a moderator in a reactor are:

- High slowing down power.
- Low parasite capture.
- Non-corrosiveness.
- High melting point for solids and low melting point for liquids.
- Chemical and radiation stability.
- High thermal conductivity.

Properties of Coolant:

The desirable characteristics for a reactor coolant are:

- Low parasite capture.
- Low melting point.
- High boiling point.
- Chemical and radiation stability.
- Low viscosity.
- Non-toxicity.
- Non-corrosiveness.
- Minimum induced activity.
- High specific heat.
- High density.

Difference between Nuclear and Thermal Power Plant:

Nuclear Power Plant	Thermal Power Plant
It needs less space.	It needs more space.
Uses nuclear fission of radioactive fuels to produce heat energy. This energy is used to produce steam.	Uses coal, oil or gases to produce heat energy. This energy is used to produce steam.
These plants are located away from populated area to avoid the risk of radioactive pollution.	These plants are installed where there is suitability of supply of fuel, water and transport.
It has high initial cost in comparison to thermal power plants.	It has low initial cost in comparison to nuclear power plants.
It has low operating cost in comparison to thermal power plants.	It has high operating cost in comparison to nuclear power plants.
Coal is the source of power. Fuel source is limited.	Nuclear fuels like Uranium are the sources of power. Fuels are available sufficiently.
Overall efficiency is more.	Overall efficiency is less.
It takes more time for starting the plant.	It starts easily.
Standby losses are less.	Standby losses are more.
Better in environment friendly.	Least environment friendly.

Site Selection for Nuclear Power Plant:

The following factors are considered while selecting the site for a nuclear power plant.

- The site should be nearer to a river, reservoir or sea to fulfill the requirement of water for the plant.
- To minimize the power loss in transmission lines and to reduce the cost of power delivered to the consumer, the plant should be located nearer to the load centre.
- The power plant should be located far away from populated area to avoid the radioactive hazard.
- The power plant should have easy accessibility through rail and road transportation facilities.
- The wastes of a nuclear power plant are radioactive and there should be sufficient space near the plant site for the disposal of wastes.
- There should be considerably no risk of disaster.
- The site should be safe as per geological, hydrological, meteorological and seismological report for the location.

Radioactive waste disposal:

Radioactive waste contains radioactive material. It is usually a byproduct of nuclear power plant. It is hazardous to environment and living organisms, so it is regulated by government agencies in order to protect human health and the environment.

Radioactivity naturally decays over time. So isolated and confined radioactive wastes possess no threat after a sufficient time period. These wastes can be well managed for disposal. It is approached to manage radioactive waste by segregation and storage for short-lived waste, near-surface disposal for low and some intermediate level waste, and deep burial or partitioning / transmutation for the high- level waste.

List of Nuclear Power Stations:

The various nuclear power plants situated in India are as follows:

Name of the Plant	Location	Capacity
Tarapur power plant	Maharashtra	380 MW
Rana-Partap Sagar power plant	Near Kota, Rajasthan	400 MW
Kalpakkam power plant	Near Chennai, Tamil Nadu	470 MW
Narora power plant	Uttar Pradesh	470 MW
Kakrapar power plant	Surat district, Gujarat	470 MW

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DIESEL ELECTRIC POWER STATION

In an engine-generator set, the generator shaft is coupled to the Engine shaft. The engine converts chemical energy in fuel into mechanical energy. The generator converts mechanical energy into electrical energy.

Diesel engine is an excellent prime mover for electric generator capacities of from 100 hp to 5000 hp. The Diesel units used for electric generation are more reliable and long - lived piece of equipment compared with other types of plants.

Diesel engine power plants are installed where:

- Supply of coal and water is not available in desired quantity.
- Power is to be generated in small quantity for emergency services.
- Standby sets are required for continuity of supply such as in hospital, telephone exchange.

Advantages of diesel electric power plants:

The advantages of diesel power plants are listed below.

- Design and installations are very simple.
- Requires less water for cooling purpose.
- Standby losses are less as compared to other Power plants.
- Low fuel cost.
- Quickly started and put on load.
- Smaller storage is needed for the fuel.
- Layout of power plant is quite simple.
- No problem of Ash handling.
- Less supervision required.
- For small capacity, diesel power plant is more efficient as compared to steam power plant.
- Able to respond to varying loads without any difficulty.
- Occupy less space.
- Requires less operating and supervising staff as compared to steam power plant.
- Overall capital cost is lesser than that of steam power plant.

Disadvantages of diesel electric power plants:

The disadvantages of diesel power plants are listed below.

- High operating cost.
- High maintenance and lubrication cost.
- Fuel cost is more, since in India diesel is costly.
- The plant cost per kW is comparatively more.
- The life of diesel power plant is small due to high maintenance.
- Noise is a serious problem in diesel powerplant.
- Diesel power plant cannot be constructed for large scale.
- These can’t be constructed in large size. Its capacity is limited.
- Diesel power plant are not economical.

Applications:

- They are quite suitable for mobile power generation and are widely used in Transportation systems consisting of railroads, ships, automobiles and airplanes.
- They can be used for electrical power generation incapacitiesfrom100 to 5000 H.P.
- They can be used as standby power plants.
- They can be used as peak load plants for some other types of power plants.

Layout of diesel electric power plants:

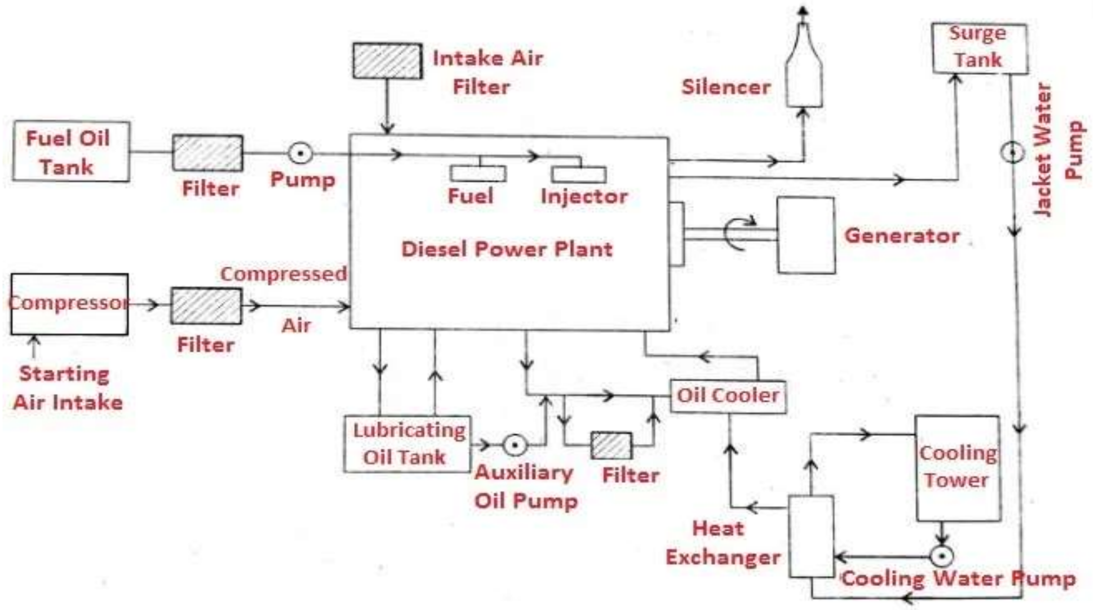

Figure-1: Schematic layout of Diesel Power Plant

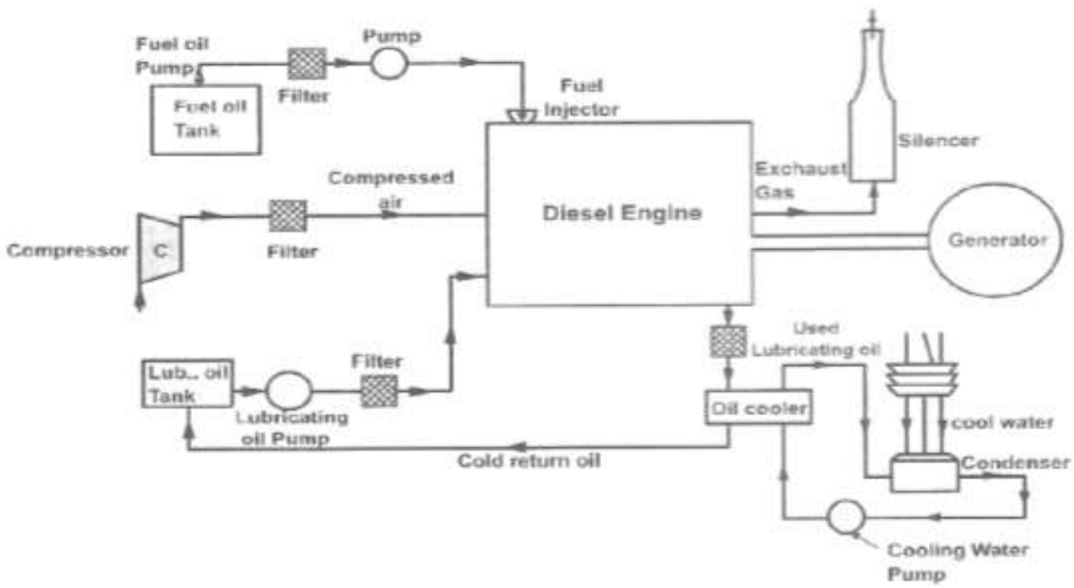

Figure-2: Schematic layout of Diesel Power Plant

Essential Component of Diesel Power Plant

- Engine
- Air intake system
- Exhaust system
- Fuel system
- Starting system
- Governing system
- Cooling system
- Lubrication system

Air Intake System:

The air intake system conveys fresh air through pipes and ducts to

- Air intake manifold of 4s engine
- Scavenging pump inlet of 2s engine
- Supercharger inlet of supercharged engine

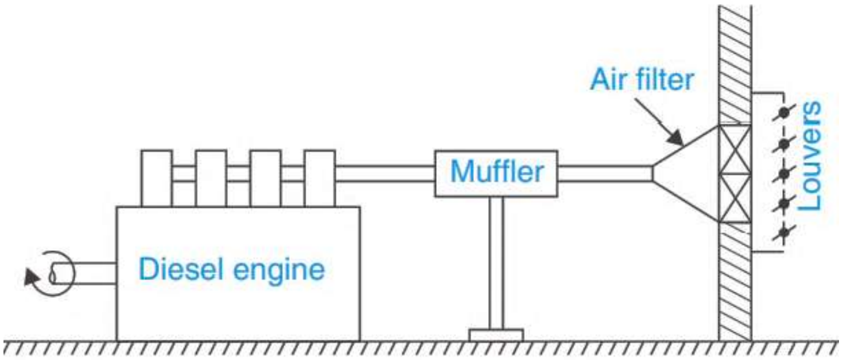

Figure: Air Intake System

The fresh air is first drawn and filtered to catch dirt from outsides air. The filters may be of dry or oil bath. Filtered air is then drawn by the engine during suction.

Exhaust System:

The exhaust system is used to discharge the engine exhaust to the atmosphere outside the plant.

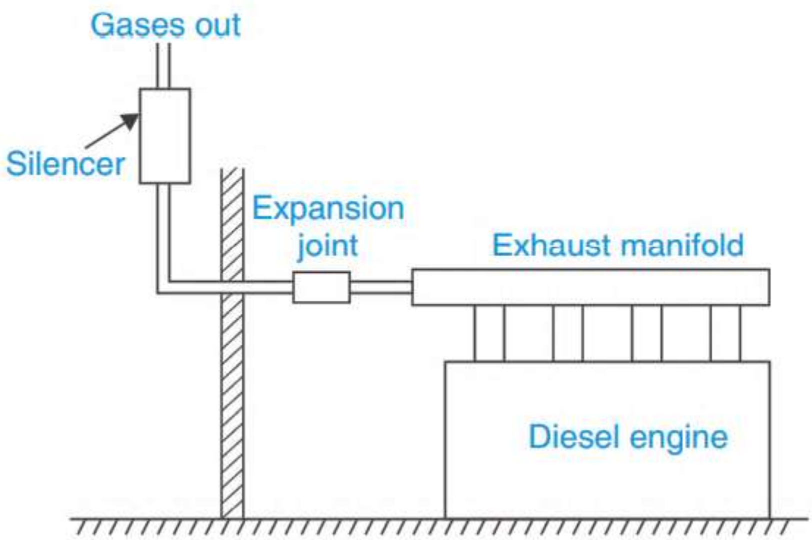

Figure: Exhaust System

The exhaust manifold takes exhaust gases from engine outlet and discharge the gases to the exhaust pipe. The muffler provided with the exhaust pipe reduces pressure in the exhaust line and reduce noise.

Fuel Supply system:

The fuel is delivered to the plant by railroad tank car, by truck or by barge and tanker and stored in the bulk storage situated outdoors for the sake of safety. From this main fuel tank, the fuel oil is transferred to the daily consumption tank by a transfer pump through a filter.

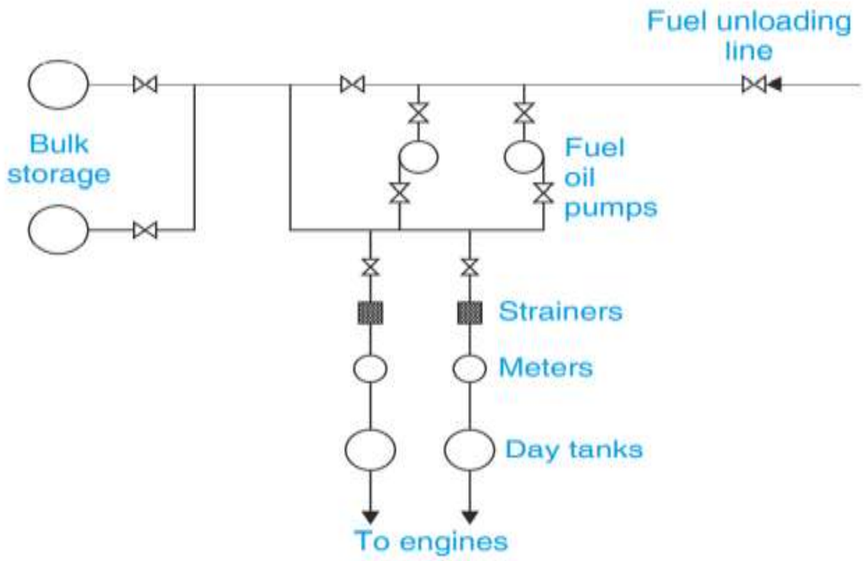

Figure: Fuel Storage & Supply System

The capacity of the daily consumption should be at least the 8-hour requirement of the plant. This tank is located either above the engine level so that the fuel flows by gravity to the injection pump or below the engine level and the fuel oil is delivered to the injection pump by a transfer pump driven from the engine shaft.

Fuel Injection system:

The five essential functions of a fuel injection system are:

- To deliver oil from the storage to the fuel injector.
- To raise the fuel pressure to the level required for atomization.
- To measure and control the amount of fuel admitted in each cycle.
- To control time of injection.
- To spray fuel into the cylinder in atomized form for thorough mixing and burning

Fuel injector is a mechanical device which is responsible for injecting the required amount of fuel into the engine to produce suitable air/fuel mixture for optimal combustion

The types of fuel injection methods are

- Common Rail
- Individual Pump Injection
- Distributor

Common Rail Fuel Injection:

In this type of injection, a pump supplies fuel under high pressure to a fuel header. This forces the fuel to each of the nozzle situated in the cylinders. A mechanically operated mechanism valve allows the fuel to enter in appropriate cylinder. The pressure relief and timing values are used to regulate the injection time and amount. The spring-loaded safety valve used as a check valve. When injection valve lifts to admit high pressure fuel to spray valve, its needle rises against the spring. when the pressure is vented to the atmosphere, the spring shut the valve.

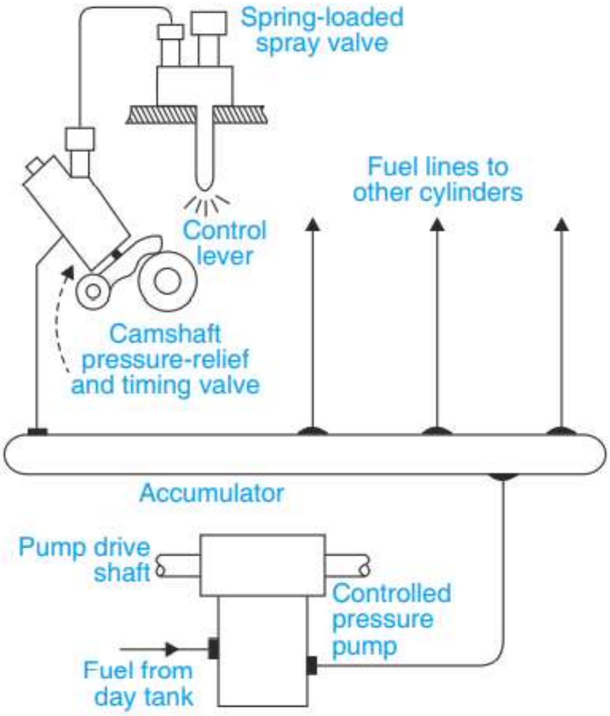

Figure: Common Rail Fuel Injection System

Individual Pump Fuel Injection:

In this type of fuel injection system each fuel nozzle is connected to a separate injection pump. The pump controls the fuel charge and injection timing. Nozzles contain a delivery valve actuated by the fuel-oil pressure.

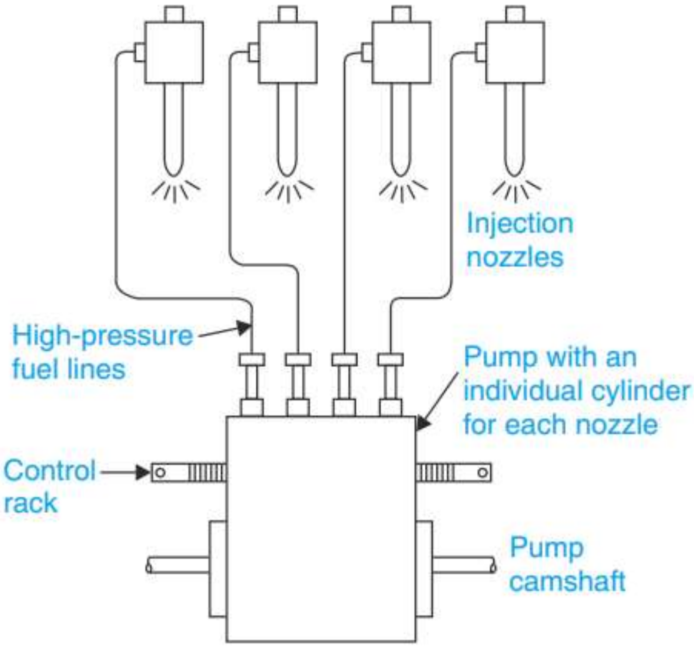

Figure: Individual Pump Fuel Injection System

Distributor System:

In this type of fuel injection system, the fuel is metered at a central point. The pump meters the fuel and time the injection. The pressurized fuel distributes to cylinders in correct firing order by cam operated poppet valves which open to admit fuel to the nozzles.

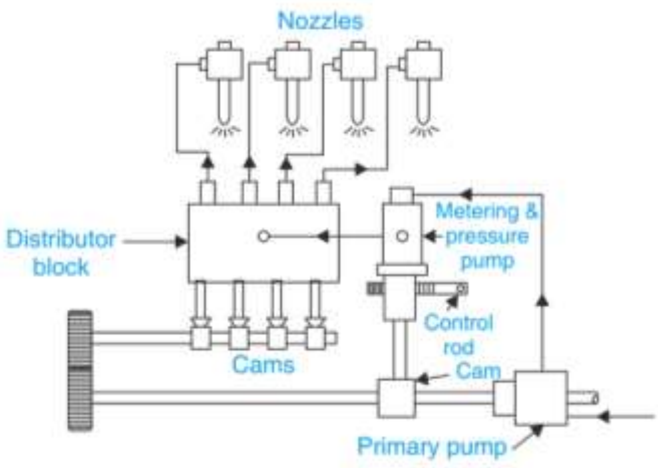

Figure: Distributor Fuel Injection System

Cooling System:

During the combustion process the peak gas temperature in the cylinder of an internal combustion engine is of the order of 2500 K. Metallic components are heated with very high temperature. Thus, cooling for the cylinder head, cylinder and piston is necessary.

Cooling of the engine reduce the possibility of fatigue cracking, knocking and preignition problem and increases the thermal efficiency.

Based on cooling medium two types of cooling system are generally used. These are

- Air as direct cooling system
- Liquid or indirect cooling system

Air cooling is used in small engine and portable engines. Liquid cooling is used in case of big engines.

The cooling system can also be classified into two types:

- *Open Cooling System*: A Plant near the river may utilize the river water for cooling & discharging again the hot water into river. This type of cooling system is known as open cooling system.
- *Closed Cooling System*: The Cooling Water is circulated again & again and only water lost due to leakage, evaporation etc. is made up by taking make up water from supply source.

Liquid cooling system is further classified as:

- Open cooling system
- Natural circulation (Thermo-system)
- Forced circulation system
- Evaporation cooling system

Open Cooling System:

This system is applicable only where plenty of water is available. The water from the storage tank is directly supplied through an inlet valve to the engine cooling water jacket. The hot water coming out of the engine is not cooled for reuse but it is discharged.

Natural circulation (Thermo-system)

The system is closed and designed so that the water may circulate naturally because of the difference in density of water at different temperatures. When the water is heated, its density decreases and it tends to rise, while the colder molecules tend to sink. Circulation of water then is obtained as the water heated to rise and the water-cooled in the radiator with the help of air passing over the radiator either by a fan.

Forced circulation system

Forced circulation cooling system that is closed one. The coolant (water or synthetic coolant) is circulated through the cylinder jacket with the help of a pump and driven by the engine.

Evaporation Cooling System:

In this method, water gets converted into steam after cooling the engine. This steam is cooled by the evaporative colling method.

Lubrication System:

Engine lubrication system provides lubricating oil to moving parts of the engine to reduce the friction between them. It reduces the wear & tear of the engine parts.

This system consists of lubricating oil pump, oil tanks, filters, coolers, purifiers & connecting pipes.

In this system the lubricating oil is stored in main lubricating oil tank. From this tank, oil is drawn by means of oil pump and then passed through the oil filter for removing impurities. Then this clean lubricating oil is delivered to the different points of the engine where lubrication is required. The oil cooler is provided in the system to keep the temperature of the lubricating oil as low as possible. It is then cooled through heat exchanger by means of cold water and then it is fed to the engine.

The main function of the lubricant is:

- To reduce friction and wear between the parts having relative motion.
- To clean the surface by carrying away the carbon and metal particles caused by wear.
- To absorb shock between bearings and other parts and consequently reduce noise.
- To cool the surfaces by carrying away heat generated due to friction.
- To remove the heat generated due to friction and keeps the parts cool.

Engine lubrication system is classified as:

- Wet Sump lubrication system
    - Splash system
    - Semi pressure system
- Dry sump lubrication system
- Mist lubrication system

Starting System:

Initial rotation of the engine shaft is done by the starting system until the firing start and the engine runs with its own power. In case of small diesel generator set, the initial rotation of shaft is done by rotating the handle. But in case of large power plants, it is done by compressed air. This system includes storage compressed air tank, self-starter, auxiliary engines & electrical motors (battery) etc.

Site Selection for Plant

The following factors should be considered while selecting a site for diesel power plant.

- *Foundation subsoil conditions* - Foundation of subsoil condition at a reasonable depth provides a strong support to the engine.
- *Access to the site* - The site should be accessible for rail and road.
- *Distance from the load centre* - The location of the plant should be near to the load centre to reduce the cost of transmissions line, cost of maintenance and power load.
- *Availability of water* - Sufficient water should be available at the site.
- *Fuel transportation* - To minimize the transportation charge, the sites should be near to the source of fuel supply.

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HYDEL POWER STATION

Hydroelectric power is the obtained from the energy of falling water whereas hydroelectric power plant is the power plant utilising this potential energy of water at a high level for the generation of electrical energy. There is a conversion of hydraulic energy into mechanical energy followed by electrical energy.

Advantages of Hydroelectric power plants:

- Water is available throughout the year.
- Operational and maintenance cost is lower.
- The cost of fuel is nil.
- Hydro Plants are made for multiple purposes.
- The requirement of working staff is less.
- The cost of expenses is lower.
- It is a clean and non-polluting source of energy.
- No fuel is required.
- Dams are constructed near rivers. As the water level rises, the kinetic energy of water gets changed to potential energy.

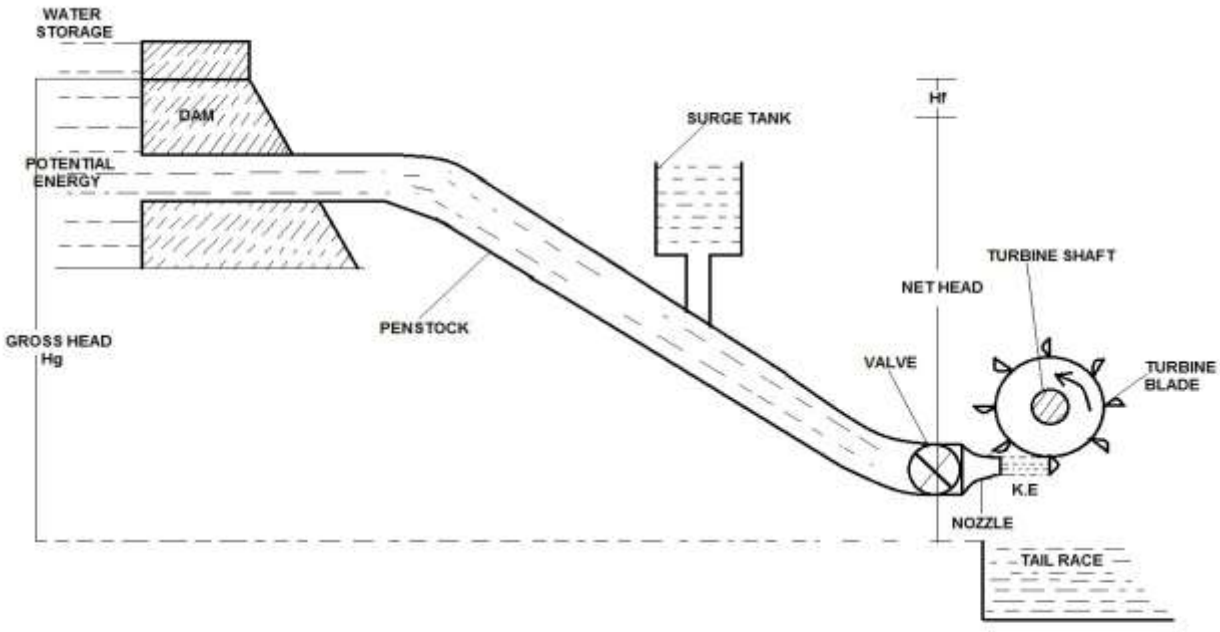
Disadvantages of Hydroelectric power plants:

- Embankment construction cost is high.
- Land space requirement for set up is large.
- Water must be abundant to continue the process.
- Aquatic life is affected.
- Embankment areas need to be evacuated for flood plains.
- Highly expensive.
- Large areas of human habitation and agricultural fields are submerged.
- Dams can be made in limited areas.

General arrangement of storage type hydroelectric project

The major requirement for hydroelectric power plant is explained below.

- There must be availability of water in huge quantity at sufficient head. For this requirement construction of dam across a river or lake is required.
- The dam provides an artificial storage reservoir.
- A pressure tunnel is taken off from the reservoir to the valve house at the start of the penstock.
- The valve house contains main sluice valves for controlling water flow to the power station and automatic isolating valves for cutting off water supply in case the penstock bursts.
- A surge tank is provided just before the valve house for better regulation of water pressure in the system.
- Penstock to carry water.
- Water turbine
- Alternator



Layout of hydroelectric power plant

Working:

From the reservoir the water is carried to valve house through pressure tunnel and from valve house to the water turbine through pipes of large diameter made of steel or reinforced concrete, called the penstock. The water turbine converts hydraulic energy into mechanical energy and the alternator coupled to the water turbine converts mechanical energy into electrical energy. Water after doing useful work is discharged to the tailrace.

Selection of site of hydel power plant.

The following factors should be considered while selecting site for hydroelectric power plants.

- **Availability of Water:** Huge quantity of water is required for hydro-electric power plants because it runs on the energy possessed by flowing water. Availability of water for plant depends on the amount of rainfall, losses of water and storage of water.
- **Water Storage:** Building of dam across the river is essential to store water for plant. Water falling from the top of the dam possesses high energy. Before constructing the dam near the river detail study on the geographical and topographical features of catchment area is required.
- **Water Head:** The available water head depends upon the topography of the area. Availability of head of water has considerable effect on the cost and economy of power generation. In order to determine the most effective and economical head it is necessary to consider all possible factors which affect it.
- **Distance from Load Centre:** Hydroelectric power plant is usually located far away from the load centre.
- **Accessibility of the Site:** Adequate transportation facilities must be available.

- **Water Pollution:** Polluted water may cause excessive corrosion and damage to the metallic structures. Hence availability of good quality water is essential.
- **Large Catchment Area:** The reservoir must have a large catchment area so that level of water in the reservoir may not fall below the minimum required in dry season.
- **Availability of Land:** The land available should be cheap in cost and rocky in order to withstand the weight of the large building and heavy machinery.

List of hydro power stations with their capacities and number of units in the state

Sl. No.	Name of the Power Plant	Place	Capacity	No. of Units
1	Odisha Hydro Power Corporation Limited (OHPCL)	Rengali	250 MW	5 x 50 MW
2		Upper Kolab	320 MW	4 x 80 MW
3		Upper Indravati	600 MW	4 x 150 MW
4		Machkund	60 MW	3 x 23 MW
				3 x 17 MW
5		Burla	287.8 MW	2 x 49.5 MW
				2 x 32 MW
				2 X 43.65 MW
				1 X 37.5 MW
6		Chipilima	72 MW	3 x 24 MW
7		Balimela	510 MW	6 x 60 MW
				2 x 75 MW

Different types of Turbines & Generators used in hydro power plant:

- There are two main types of hydro-power turbines such as: Reaction turbine and Impulse turbine.
- The type of hydropower turbine selected for a project is based on the height of standing water, known as Head and the flow or volume of water over time.
- Other deciding factors include how deep the turbine must be set, turbine efficiency and cost.

The different turbines used in hydro power plants are:

- Pelton turbine
- Francis's turbine
- Kaplan turbine

NOTE: Refer study material of Subject Hydraulic machines for turbines and numerical.

REFERENCE:

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GAS TURBINE POWER STATION

Gas Turbine Power Plant is used to generate electrical energy using air as the medium, which helps to rotate the turbines and connected to generators to develop electricity.

Elements of simple gas turbine power plants:

The gas turbine power plant generally comprises of a compressor which draws air into the engine, pressurise the air and feed the compressed air to the combustion chamber where the gas turbine fuels are burned in presence of compressed air and propelling force is generated from the burnt gases. The elements of gas turbine power plant are:

1. **Compressor:**

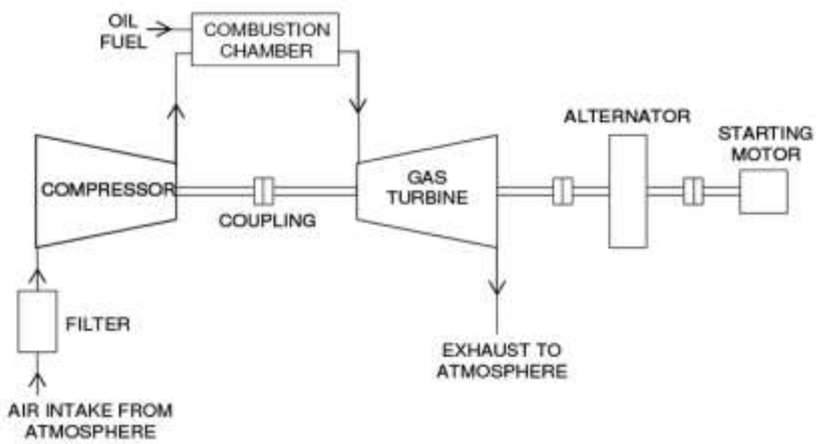
   It draws air into the engine, pressurise the air and feed the compressed air to the combustion chamber at very high speeds.

2. **Combustion system,**

   It is typically made up of a ring of fuel injectors that inject a steady stream of fuel into combustion chambers where it mixes with the air. The mixture is burned at temperatures of more than 2000 ^{0}F. The combustion produces a high temperature, high pressure gas stream that enters and expands through the turbine section.

3. **Turbine:**

   It is an intricate array of alternate stationary and rotating aerofoil-section blades. As hot combustion gas expands through the turbine, it spins the rotating blades. The rotating blades perform a dual function such as: (i) they drive the compressor to draw more pressurized air into the combustion section, and (ii) they spin a generator to produce electricity.



Layout of Gas turbine power plant

4. **Alternator:**

   It is used to produce electricity when it runs by turbine.

Fuels of gas turbine power plants:

Gas turbines are mostly operated on natural gas or liquefied natural gas (LNG) because of its purity and ease of combustion.

Gas turbines uses liquid fuels and gaseous fuels.

Some examples of gas turbine fuels are:

1. *Gaseous fuels:* Natural gas, Blast furnace gas, Producer gas, Coal gas
2. *Solid fuels:* Pulverized coal.
3. *Liquid fuel:* Different types of oils used may distillated oils and residual oils.
4. Gasoline and Kerosene or blend of the two are also used.

Merits of gas turbine power plants:

The merits/advantages of gas turbine plant are:

- High operating speed.
- There is no smoke combustion occurred.
- It required less space.
- The capacity of work produced for 1 kg of air is high.
- The lubrication process is simple.
- Capital cost is less compared to other plants.
- There is no problem with ash content.
- It has higher mechanical efficiency.
- Required maintenance is less than another plants.
- It has high reliability.
- These plants are more flexible during operation.

Demerits of gas turbine power plants:

The demerits/disadvantages of gas turbine plant are:

- There is a need of external energy to start a compressor before the turbine starts.
- This plant has the different type of metals required than other plants.
- It requires a special type of cooling system or methods.
- The life of the plant is less.
- Layout of this plant is complex than diesel plant.
- These plants are more dangerous and has more risk.

Applications of gas turbine power plants:

Some applications of gas turbine plant are:

- To produce electricity.
- Used in turbo pumps, rotary compressors.
- Used in aircraft.
- Used in heavy engines like diesel engines.
- Used in marine engines.

Selection of site for gas turbine power plants:

1. It should be located near the Load centre to reduce transmission costs and the transmission losses.
2. Labour should be easily availability.
3. Site should be away from localities since it is noisy in operation.
4. Transportation facilities should be available easily.
5. Land should be available in cheap
6. Availability of land at cheap cost.
7. Bearing capacity of land should be high.

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GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

STRENGTH-OF-MATERIAL

3RD SEMESTER

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SIMPLE STRESS & STRAIN

STRENGTH OF MATERIAL:

It is the property of the material due to which the material can resist the external load acting upon it.

LOAD:

It is the external force which acts on a body, machine parts or structural members. It is denoted as P or W. Its SI unit is Newton (N).

- **Types of Load:**
  There are various types of load such as dead/steady load, variable load, suddenly applied or shock load, impact load. It may also be classified as tensile loads, compressive loads, shearing load, bending loads, torsional - loads.

STRESS:

It is the internal resistive force offered by the body against the deformation caused by external load acting upon it. It is denoted as σ or *f*.

If an external force P acts on a body, the body offers resistant force R per unit area of resisting section. Mathematically, $Stress\ (\sigma) = \frac{R}{A} = \frac{P}{A}$ where, P = external load acting on the body = Resistive force (R)

- *Stress is defined as the resistance offered by a body per unit area of resisting section, against the loads producing deformation.*

STRAIN:

It is the measure of deformation of a body per its original dimension. It is denoted as 'e or ϵ'.

Mathematically, $Strain\ (e) = \frac{Deformation}{Original\ \ dimension\ \ of\ the\ body}$

TYPES OF STRESS:

There are two kinds of basic stresses which are

- Normal stresses – always act normal to the stressed surface (either tensile or compressive)
- Shearing stresses – always act parallel to the stressed surface

Tensile Stress:

It is the stress offered by the body against the increase in length caused by the tensile load acting on it. If a tensile load or pulling force (P) acts on the area of cross section (A) of the body, the tensile stress may be written as - $Tensile\ Stress\ (\sigma) = \frac{P}{A}$

Compressive stress:

It is the stress offered by the body against the decrease in length caused by the compressive load acting on it. If a compressive load or pushing force (P) acts on the area of cross section(A) of a body, then the compressive stress may be written as – $Compressive\ Stress\ (\sigma) = \frac{P}{A}$

Shear Stress:

It is the stress offered by the body against the two equal and opposite tangential force acting on its area of cross section which causes the sliding of one part of the body over the other. If the tangential force P acts on a body to cause shear, then shear stress may be written as – *Shear Stress* $(\tau) = \frac{P}{A}$

TYPES OF STRAIN:

Tensile strain:

It is the strain produced in the body when tensile stress induced in it due to the external tensile load.

Mathematically, *Tensile strain (e)* $= \frac{\text{deformation of the body due to tensile load}}{\text{original dimension of the body}}$

Compressive strain:

It is the strain produced in the body when compressive stress induces in it due to the external compressive load.

Mathematically, *Compressive strain (e)* $= \frac{\text{deformation of the body due to compressive load}}{\text{original dimension of the body}}$

Shear Strain:

It is the strain produced in the body when shear stress induces in it due to the external tangential load. It is the measure of angle through which the body is deformed by the applied force. Mathematically, *Shear strain* $(ø) = \frac{\text{shear deformation}}{\text{original dimension of the body}}$

Volumetric strain:

It is the ratio of change in volume per original volume of the body.

Mathematically, *Volumetric Strain* $(e_v) = \frac{\text{change in volume of the body}}{\text{original volume of the body}}$

HOOKE'S LAW:

It states that, "*Within elastic limit, stress is directly proportional to strain*".

Mathematically, Stress α Strain $\Rightarrow \sigma \,\alpha\, e \quad \Rightarrow \frac{\sigma}{e} = E$ (where E = Young's modulus)

YOUNG'S MODULUS OF ELASTICITY:

It is the ratio of tensile stress to tensile strain or compressive stress to compressive strain, within elastic limit. It is denoted by E. Mathematically, $\frac{\text{normal stress}}{\text{normal strain}} = \frac{\sigma}{e} = E$

MODULUS OF RIGIDITY:

It is the ratio of shear stress to shear strain, within the elastic limit. It is denoted by C /G/ N.

Mathematically, $\frac{\text{shear stress}}{\text{shear strain}} = \frac{\tau}{ø} = E$

BULK MODULUS:

It is the ratio of normal stress to the volumetric strain, within elastic limit. It is denoted by K.

Mathematically, $\frac{\text{direct stress}}{\text{volumetric strain}} = \frac{\sigma}{e} = K$

LINEAR STRAIN:

It is the strain produced by tensile or compressive forces in longitudinal axis. If a rectangular bar under tension extends along its length, the linear strain or longitudinal strain may be given mathematically, $\textit{Linear strain} = \frac{\textit{Change in length}}{\textit{Original length}} = \frac{\Delta l}{l}$

LATERAL STRAIN:

It is the strain produced by the tensile or compressive force along the other two mutually perpendicular axes other than the longitudinal axis. It is the ratio of change in lateral dimension to the original lateral dimension of the body. It is also known as the transverse strain.

Mathematically, $\textit{Lateral Strain} = \frac{\textit{Change in lateral dimension}}{\textit{Original lateral dimension}}$

NOTES:

- If a cylindrical body of length *l* and diameter *d* is subjected to a tensile pull along its length, its length increases and its diameter decreases. This change in length per original length is known as *linear strain* and the change in diameter per original diameter is known as *lateral strain*.

- If a rectangular body of length *l*, breadth *b* and thickness *t* is subjected to a tensile pull along its length, its length increases and its lateral dimensions such as breadth and thickness decreases. This change in length per original length is known as linear strain and the change in breadth per original breadth or change in thickness per original thickness is known as lateral strain.

POISSON'S RATIO:

It is the ratio of lateral strain to the longitudinal strain. It is denoted by **μ or** $\mathbf{\frac{1}{m}}$

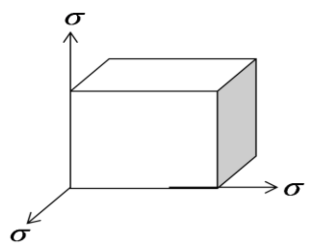
NOTES:

Terms	Symbol	Formula	Units
Stress	σ or *f*	$\frac{P}{A}$	N/m^2, N/mm^2, N/cm^2, KN/m^2, MN/m^2, kgf/cm^2
Strain	E	$\frac{\Delta l}{l}$	Unit less
Young's modulus	E	$\frac{\sigma}{e}$	Same as stress
Rigidity modulus	C / N / G	$\frac{\tau}{\phi}$	Same as stress
Bulk modulus	K	$\frac{\sigma}{dv/v}$	Same as stress
Poisson's ratio	μ or $\frac{1}{m}$	$\frac{\text{Lateral strain}}{\text{Linear strain}}$	Unit less
Change in length	$\boldsymbol{\Delta} l$ or d*l* or δ*l*	$\frac{Pl}{AE}$ **or** $e \times l$	mm , cm
Change in volume	$\boldsymbol{\Delta} V$	$\frac{\Delta l}{l}(1 - \frac{2}{m}) \times V$	mm^3, cm^3

RELATION BETWEEN ELASTIC CONSTANTS:

- **Relation between Bulk modulus (K) and Young's modulus (E):**

Consider a cube subjected to direct tensile stresses along three mutually perpendicular directions shown in figure.



Consider the side AB deforms linearly and the other two perpendicular sides undergoes lateral deformations.
So the net tensile strain in any direction may be written as –

$$e = \frac{\sigma}{E} - (\frac{1}{m} \times \frac{\sigma}{E}) - (\frac{1}{m} \times \frac{\sigma}{E}) = \frac{\sigma}{E}(1 - \frac{2}{m}) \qquad \text{-------- (1)}$$

Volume of the body (V) = l^3

Differentiating both sides with respect to l, we get

$$\frac{dV}{dl} = 3l^2 \Rightarrow dV = 3l^2 \times dl = 3l^3 \times \frac{dl}{l} = 3l^3 \times e \qquad (\because e = \text{strain} = \frac{dl}{l})$$

Substituting the value of 'e' from equation-1, we get

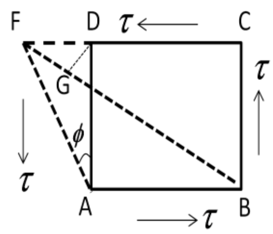
$$dV = 3l^3 \times \frac{\sigma}{E}(1 - \frac{2}{m}) \qquad \Rightarrow \frac{dV}{V} = (\frac{3l^3}{l^3}) \times \frac{\sigma}{E}(1 - \frac{2}{m})$$

We know that, $K = \frac{\sigma}{dV/V} = \frac{\sigma}{(\frac{3l^3}{l^3}) \times \frac{\sigma}{E}(1 - \frac{2}{m})} = \frac{E}{3(1 - \frac{2}{m})}$

$$\Rightarrow E = 3K(1 - \frac{2}{m}) \qquad \text{------------------- (2)}$$

- **Relation between Modulus of rigidity (C) and Young's modulus (E):**

Consider a cube of length l subjected to shear stress (τ) as shown in figure.



Consider that one of its diagonal BD elongates and other diagonal AC reduces due to shear stress.
Let after deformation shear strain 'ø' produces.

From figure we get, $\tan\phi = \frac{DF}{AD} \cong \phi$

Consider BD = BG ; as the angle between BD and BG is very small.
Change in length of the diagonal after deformation
= BF – BD = BF – BG = FG

Consider the deformation is very small and $\angle BFC = \angle BDC = 45^0$

$$FG = DF\cos 45^0 = \frac{DF}{\sqrt{2}}$$

Shear strain for the diagonal BD = $\frac{BF - BD}{BD} = \frac{FG}{BD} = \frac{DF\cos 45^0}{AD \times \sqrt{2}} = \frac{DF}{2 \times AD} = \frac{\phi}{2} = \frac{\tau}{2C}$ ….(3)

The diagonal increases due to the direct stresses and also due to the stresses in lateral direction.

Direct strain = $\frac{\sigma_N}{E}$ Lateral strain = $\frac{\sigma_N}{mE}$

So, the resultant strain = $\frac{\sigma_N}{E} + \frac{\sigma_N}{mE}$ ----------------- (4) Where σ_N = normal stress

From equation -2 we get, $\frac{\sigma_N}{E} + \frac{\sigma_N}{mE} = \frac{\sigma_N}{E}(1+\frac{1}{m})$

From equation 3 and 4 we get, $\frac{\tau}{2C} = \frac{\sigma_N}{E}(1+\frac{1}{m})$

$\Rightarrow E = 2C(1+\frac{1}{m})$ ----------------- (5)

♣ **Relation between E, C and K:**

We know that, $E = 2C(1+\frac{1}{m}) \quad \Rightarrow (1+\frac{1}{m}) = \frac{E}{2C}$ ----------- (6)

We know that, $\Rightarrow E = 3K(1-\frac{2}{m}) \quad \Rightarrow (1-\frac{2}{m}) = \frac{E}{3K}$ ----------- (7)

From equation-6 we get: $\frac{1}{m} = \frac{E}{2C} - 1$

Substituting this value in equation-7 we get: $1 - 2\times(\frac{E}{2C} - 1) = \frac{E}{3K}$

$$\Rightarrow 1 - \frac{E}{C} + 2 = \frac{E}{3K} \quad \Rightarrow \frac{C - E + 2C}{C} = \frac{E}{3K} \quad \Rightarrow \frac{3C - E}{C} = \frac{E}{3K}$$

$$\Rightarrow 9KC - 3EK = EC \quad \Rightarrow EC + 3EK = 9KC$$

$$\Rightarrow E(3K + C) = 9KC \quad \Rightarrow E = \frac{9KC}{3K + C}$$ --------------- (8)

This is the required relation between the three elastic constants.

***** PROBLEMS *****

Q -1) *A metal bar 4 m long and 100 mm × 200 mm in cross section is subjected to a pull of 50 kN. If Young's modulus of the material of the bar is 200 kN/mm², find: (i) stress in the bar ii) Strain produced iii) elongation of the bar.*

Ans) Data Given

Area of cross section (A) = 100 mm × 200 mm = 2×10^4 mm²

E = 200 kN/mm² Length (l) = 4m = 4000 mm Pull/Load (P) = 50 kN

i) stress in the bar (σ)

$\sigma = \frac{P}{A} = \frac{50}{2\times10^4} = 2.5 \times 10^{-3}$ kN/mm²

ii) strain produced (e)

$e = \frac{\sigma}{E} = \frac{2.5 \times 10^{-3}}{200} = 1.25 \times 10^{-5}$

iii) elongation of the bar (δl)

$\delta l = \frac{Pl}{AE} = \frac{50 \times 4000}{2 \times 10^4 \times 200}$ mm = 0.05 mm **(ANS)**

Q -2) *A metal bar 50 mm × 50 mm in section is subjected to an axial compressive load of 500 kN. If the contraction of a 200 mm gauge length is found to be 0.5 mm and the increase in thickness 0.04 mm, find the values of Young's modulus and Poisson's ratio for the bar material.*

Ans) Data Given

Length (l) = 200 mm, width (b) = 50 mm, thickness (t) = 50 mm
Axial compressive load (P) = 500 kN = 500×10^3 N
change in length (δl) = 0.5 mm
change in thickness (δt) = 0.04 mm
Young's modulus**(E)**
We know that, contraction of the bar (δl) = $\frac{Pl}{AE}$

$\therefore$ **E =** $\frac{500 \times 10^3 \times 200}{50 \times 50 \times 0.5} = 80 \times 10^3$ N/mm^2 = 80 GPa

Poisson's ratio ($\frac{1}{m}$)

linear strain (e) = $\frac{\delta l}{l} = \frac{0.5}{200} = 0.0025$

lateral strain = $\frac{1}{m}$ × linear strain = $\frac{1}{m} \times 0.0025$

also increase in thickness (δt) = t × lateral strain

$\Rightarrow \quad 0.04 = 50 \times \frac{1}{m} \times 0.0025$

$\Rightarrow \quad \frac{1}{m} = \frac{0.04}{50 \times 0.0025} = 0.32$ **(ANS)**

Q – 3) *A steel bar 50 mm × 50 mm in cross section is 1.2 m long. It is subjected to an axial pull of 200 kN. What are the changes in length, width and volume of the bar, if the value of Poisson's ratio is 0.3? Take E = 200 GPa.*

Ans) Data Given

Length (l) = 1.2 m = 1200 mm width (b) = 50 mm thickness (t) = 50 mm
Axial pull (P) = 200×10^3 N Poisson's ratio ($\frac{1}{m}$) = 0.3
modulus of elasticity (E) = 200×10^3 N/mm^2

Change in length $\delta l = \frac{Pl}{AE} = \frac{200 \times 10^3 \times 1.2 \times 10^3}{50 \times 50 \times 200 \times 10^3} = 0.48$ mm

Change in width (δb)

linear strain (e) = $\frac{\delta l}{l} = \frac{0.48}{1.2 \times 10^3} = 0.0004$

lateral strain = $\frac{1}{m} \times e = 0.3 \times 0.0004 = 0.00012$

$\therefore$ Change in width (δb) = b × lateral strain = 50 × 0.00012 = 0.006 mm

Change in volume (δv)
original volume of the bar (V) = l × b × t
= 1200 × 50 × 50 = 3×10^6 mm^3

We know that , $\frac{\delta v}{V} = \frac{P}{\text{btE}}\left(1 - \frac{2}{m}\right) = \frac{200 \times 10^3}{50 \times 50 \times 200 \times 10^3}(1 - 2 \times 0.3) = 0.00016$

$\therefore$ Change in volume (dv) = 0.00016 V = 0.00016 × (3×10^6) = 480 mm^3 **(ANS)**

Q- 4) *In an experiment, a bar of 30 mm diameter is subjected to a pull of 60 kN. The measured extension on gauge length of 200 mm is 0.09 mm and the change in diameter is 0.0039mm. Calculate the Poisson's ratio and the values of the three moduli.*

Ans) Data Given

Diameter (d) = 30 mm length (l) = 200 mm extension (δl)= 0.09 mm

Pull (P) = 60×10^3 change in diameter (δd) = 0.0039 mm

Poisson's ratio ($\frac{1}{m}$)

linear strain (e) = $\frac{\delta l}{l} = \frac{0.09}{200} = 0.00045$

lateral strain = $\frac{\delta d}{d} = \frac{0.0039}{30} = 0.00013$

$\therefore$ **Poisson's ratio =** $\frac{0.00013}{0.00045} = 0.289$

Values of three moduli

Area of the bar (A) = $\frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times 30^2 = 706.9\ mm^2$

Extension of the bar (δl) $= \frac{Pl}{AE}$

$$\Rightarrow \quad 0.09 = \frac{60 \times 10^3 \times 200}{706.9\,E} = \frac{17 \times 10^3}{E}$$

$\therefore$ Young's modulus (E) = $\frac{17 \times 10^3}{0.09} = 188.9 \times 10^3\ N/mm^2$

From Poisson's ratio, we get m = $\frac{1}{0.289} = 3.46$

$$\therefore \quad \text{Modulus of rigidity (C)} = \frac{E}{2(1+1/m)} = \frac{188.9 \times 10^3}{2 \times (1+0.289)} = 73.3 \times 10^3\ N/mm^2$$

$$\therefore \quad \text{Bulk modulus (K)} = \frac{E}{3(1-2/m)} = \frac{188.9 \times 10^3}{3 \times (1-0.289)} = 149.2 \times 10^3\ N/mm^2$$ **(ANS)**

***** ASSIGNMENT- 01 *****

GROUP – A (2 marks questions)

1. Define stress, strain and Young's modulus.
2. State Hooke's law of elasticity.
3. Define modulus of rigidity and bulk modulus.
4. Write the relation between three elastic constants.
5. What is Poisson's ratio?
6. State the relation between Young's modulus and modulus of rigidity.
7. State the relation between Young's modulus and Bulk modulus.

GROUP – B (5 marks questions)

1. A square steel rod 20 mm ×20 mm in section to carry an axial compressive load of 100 kN. Calculate the shortening in a length of 50 mm. E = $2.14 \times 10^8\ kN/mm^2$. (**Ans:** *0.0584 mm*)
2. A material has a Young's modulus of $1.25 \times 10^5\ N/mm^2$ and Poisson's ratio of 0.25. Calculate the modulus of rigidity and the Bulk modulus.

3. Find the change in diameter of the rod 2 cm diameter and 2 m long subjected to a pull of 20 N. Take E = 2×10^6 N/cm^2 and Poisson's ratio = 0.25.
4. For a given material the Young's modulus is 110 GN/m^2 and the modulus of rigidity is 42 GN/m^2. Find the bulk modulus and the lateral contraction of a round bar of 37.5 mm diameter and 2.4 m length when stretched by 2.5 mm. (**Ans:** *96.77 GN/m^2, 0.0121 mm*)
5. Under what axial load the diameter of a steel bar will reduce from 8 cm to 7.995 cm? Take E=200 kN/mm^2 and Poisson's ratio as 0.3 for steel.
6. A hollow steel column of external diameter 250 mm has to support an axial load of 2000 kN. If the ultimate stress for the steel column is 480 N/mm^2, find the internal diameter of the column allowing a load factor of 4.
7. A 20 mm diameter brass rod was subjected to a tensile load of 40 kN. The extension of the rod was found to be 254 divisions in the 200 mm extension meter. If each division is equal to 0.001 mm, find the elastic modulus of brass.

GROUP – C (10 mark questions)

1. Derive the relation between three elastic constants.
2. The following observations were made during the tensile test on a mild steel specimen 40 mm in diameter and 200 mm long.

   Elongation under a load of 40 kN = 0.0304 mm

   Load at yield point = 161 kN

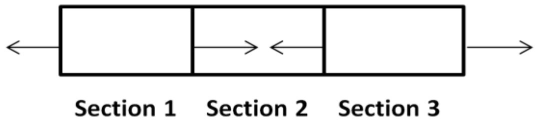
   Maximum load = 242 kN

   Length of specimen at fracture = 249 mm

   Determine the Young's modulus, yield point stress, ultimate stress and percentage elongation.
   *(**Ans:** 2.09×10^8 kN/m^2, 1208×10^4 kN/m^2, 19.2×10^4 kN/m^2, 24.5%)*
3. The following data are related to a bar subjected to a tensile test. Diameter of the bar = 30 mm, tensile load = 54 kN, gauge length = 300 mm, extension of the bar = 0.112 mm, change in diameter = 0.00366 mm. Calculate (i) Poisson's ratio; (ii) the values of three moduli.
   *(**Ans:** 0.327, 2.05×10^5 MN/m^2, 0.77×10^5 MN/m^2, 1.97×10^5 MN/m^2)*

PRINCIPLE OF SUPERPOSITION:

Consider a bar of uniform area A, Young's modulus E and split into three sections 1, 2 and 3 subjected to tensile and compressive forces as shown in figure.

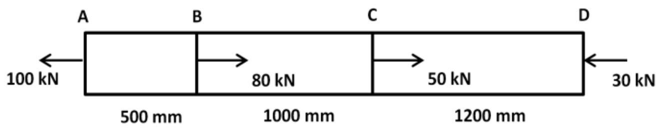


Consider the first section, and determine the tensile/compressive force acting on it. Then find the change in length of the section-1 by using the formula: $\boldsymbol{\Delta l} = \frac{Pl}{AE}$

- ♣ Continue the same step for section-2 and section-3 also.
- ♣ Add all the values of change in length to determine the total change in length of the bar.
- ♣ Consider that the change in length for tensile forces is positive and for compressive forces are negative.
- ♣ If area of the bar is given uniform, then the value of area for all three sections is same.
- ♣ The value of Young's modulus is same for the same materials.
- ♣ If a bar of different section is given then the area of different sections are not same.

***** PROBLEMS *****

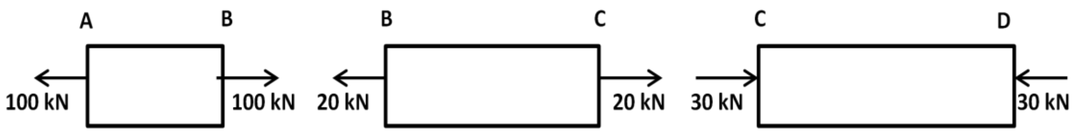
Q-1) *A bar having cross sectional area of 500 mm^2 is subjected to axial forces as shown in figure. Find the total elongation of the bar. Take E = 80 GPa.*



Ans) <u>Data Given</u>

Cross sectional area (A) = 500 mm^2 Young's modulus (E) = 80 kN/mm^2

Consider that AB, BC and CD are three sections. The forces acting on each section are shown individually.



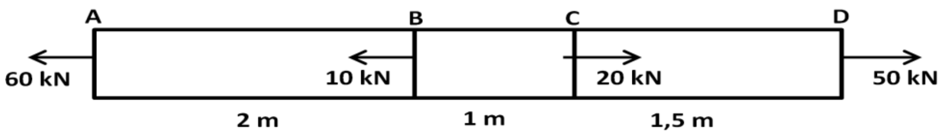
Change in length of section AB = $\delta l_{AB} = \frac{P_{AB}\,L_{AB}}{AE} = \frac{100 \times 500}{500 \times 80}$ = 1.25 mm (tensile)

Change in length of section BC = $\delta l_{BC} = \frac{P_{BC}\,L_{BC}}{AE} = \frac{20 \times 1000}{500 \times 80}$ = 0.5 mm (tensile)

Change in length of section CD = $\delta l_{CD} = \frac{P_{CD}\,L_{CD}}{AE} = \frac{30 \times 1200}{500 \times 80}$ = 0.9 mm (compressive)

Total change in length (δl) = 1 + 0.5 – 0.9 = 0.6 mm   **(ANS)**

Q-2) *A steel rod ABCD 4.5m long and 25mm in diameter is subjected to the forces as shown in figure. If the value of Young's modulus for the steel is 200 GPa, determine its deformation.*

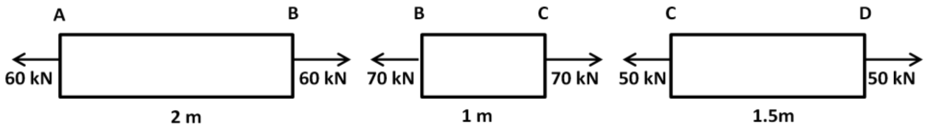


Ans) Data Given

Length of rod (l) = 4.5 m = 4500 mm diameter (d) = 25 mm E = 200 kN/mm^2

area of cross section (A) = $\frac{\pi}{4}$ d^2 = $\frac{\pi}{4}$ × (25)^2 = 491 mm^2

Consider that AB, BC and CD are three sections. The forces acting on each section are shown individually.



Change in length of section AB = $\delta l_{AB} = \frac{P_{AB}\,L_{AB}}{AE} = \frac{60 \times 2000}{491 \times 200}$ = 1.22 mm (tensile)

Change in length of section BC = $\delta l_{BC} = \frac{P_{BC}\,L_{BC}}{AE} = \frac{70 \times 1000}{491 \times 200}$ = 0.71 mm (tensile)

Change in length of section CD = $\delta l_{CD} = \frac{P_{CD}\,L_{CD}}{AE} = \frac{50 \times 1500}{491 \times 200}$ = 0.76 mm (tensile)

Total change in length (δl) = 1.22 + 0.71 + 0.76 = 2.69 mm **(ANS)**

STRESSES IN COMPOSITE SECTION:

- A composite bar is consists of two or more materials.
- The load acting on the composite section is equal to the sum of the loads carried by the sections of different materials.
- The deformation per unit length is constant. i.e. strain = constant
- The extension or contraction of the bar is equal.
- Consider a Composite column of outer tube and inner tube having different materials. For different materials the value of young's modulus is different.

  Let, for outer tube A_1 = area, E_1 = young's modulus

  for inner tube A_2 = area, E_2 = young's modulus

  Let, the length of the column is l and the column is subjected to axial load of P.

  So, we may write,

  Total load on the column = load on outer tube + load on inner tube

  $\therefore \quad P = \sigma_1 A_1 + \sigma_2 A_2$ ------------- (1)

  Where σ_1 and σ_2 are the stresses in the outer and inner tube.

  $\sigma_1 A_1$ and $\sigma_2 A_2$ are the load on outer and inner tube respectively.

  Let dl = decrease in length of the column

  Strain in each tube (e) = $\frac{dl}{l}$

  Strain in outer tube = strain in inner tube $= \frac{\sigma_1}{E_1} = \frac{\sigma_2}{E_2}$ ------------ (2)
- $\frac{E_1}{E_2}$ = Modular ratio of two materials = m

***** PROBLEMS *****

Q-3) *A reinforced concrete circular section of 50 000 mm² cross sectional area carries 6 reinforcing bars whose total area is 500 mm². Find the safe load, the column can carry, if the concrete is not to be stressed more than 3.5 MPa. Take modular ratio for steel and concrete as 18.*

Ans) Data Given

Area of the column (A) = 50 000 mm^2 No. of reinforcing bars = 6
Total area of steel bars (A_s) = 500 mm^2 Max. stress in concrete (σ_c) = 3.5 N/mm^2
Modular ratio = $\frac{E_s}{E_c}$ = 18
Area of concrete (A_c)= 50 000 – 500 = 49500 mm^2
We know that, $\frac{\sigma_s}{\sigma_c} = \frac{E_s}{E_c}$
So the stress in steel (σ_s) $= \frac{E_s}{E_c} \times \sigma_c = 18 \times 3.5 = 63$ N/mm^2
For composite section, we can write
Total safe load (P) = load shared by steel (Ps) + load shared by concrete (Pc)
$\Longrightarrow$ $P = \sigma_s A_s + \sigma_c A_c = (63 \times 500) + (3.5 \times 49500) = 204750$ N = 204.75 KN **(ANS)**

Q-4) *A reinforced concrete column of 400 mm diameter has 4 steel bars of 20 mm diameter embedded in it. Find the maximum load which the column can carry, if the stresses in steel and concrete are not to exceed 120 MPa and 5 MPa respectively. Take modulus of elasticity of steel as 18 times that of concrete.*

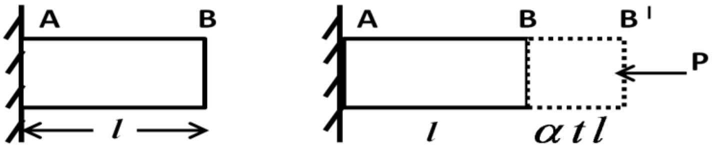
Ans) Data Given

Diameter of concrete column (D) = 400 mm No. of reinforcing bars = 4
diameter of steel bars (d) = 20 mm Max. stress in steel $(\sigma_s)_{max}$ = 120 N/mm^2
Max. stress in concrete $(\sigma_c)_{max}$ = 5 N/mm^2 Modulus of elasticity of steel (E_s) = 18 E_c

Total area of the concrete circular column = $\frac{\pi}{4} D^2 = \frac{\pi}{4} \times (400)^2 = 125660$ mm^2
Area of the steel bars (A_s) = $4 \times \frac{\pi}{4} d^2 = 4 \times \frac{\pi}{4} \times 20^2 = 1257$ mm^2
So, area of the concrete (A_c) = 125660 – 1257 = 124403 mm^2
If the stress in steel is 120 N/mm^2, then
stress in the concrete = $\frac{E_c}{E_s} \times 120 = \frac{1}{18} \times 120 = 6.67$ N/mm^2.
This stress is more than the maximum stress in concrete. So it can't be considered.
If the stress in concrete is 5 N/mm^2, then
stress in steel = $\frac{E_s}{E_c} \times 5 = 18 \times 5 = 90$ N/mm^2
This stress is less than the maximum stress in steel, therefore stresses in steel and concrete may be taken as 90 N/mm^2 & 5 N/mm^2.
∴ Maximum load (P) = load shared by steel (Ps) + load shared by concrete (Pc)
$\Longrightarrow$ $P = \sigma_s A_s + \sigma_c A_c = (90 \times 1297) + (5 \times 124403) = 735\ 150$ N = 735.15 kN **(ANS)**

TEMPERATURE / THERMAL STRESS:

- When the temperature of a body increases or decreases, some stresses develop in the body to resist the deformation of the body due to change in temperature. This stress is known as temperature or thermal stress.
- Consider a bar AB of length 'l ' fixed at one end A, deformed due to change in temperature as shown in figure.



- Let, t = change in temperature
  α = coefficient of linear expansion.
  Let, the body expands due to rise in temperature 't' = $BB^{/} = \alpha t l$
  Let, the load 'P' is applied at the free end to prevent expansion.
  Then compressive stress induce in the body $\{\sigma_c\} = \frac{P}{A}$
- Strain in bar = $\frac{change\ in\ length}{original\ \ length} = \frac{\sigma tl}{l + \sigma tl} = \frac{\sigma tl}{l} = l$ (the value $\alpha t l$ is very small, it is neglected)
  We know that, $\frac{stress}{strain}$ = E ⇒ $\frac{\sigma}{\sigma t}$ = E
  or **σ = αtE = thermal stress**
  e = αt = temperature strain
  P = σA = αTEA = load on the body

***** PROBLEMS *****

Q-5) *Two parallel walls 6 m apart are stayed together by a steel rod 25 mm diameter passing through metal plates and nuts at each end. The nuts are tightened when the rod is at a temperature of 100^0C. Determine the stress in the rod, when the temperature falls down to 60^0 C, if a) the ends don't yield b) The ends yield by 1 mm*
Take E = 200 GPa and α = 12 × 10^{-6} per ^{0}C.

Ans) <u>Data Given</u>

Length of rod (l) = 6m = 6000 mm Diameter of rod (d) = 25 mm
Change in temperature (t) = $100^0 - 60^0 = 40^0$ C Modulus of elasticity (E) = 200 N/mm^2
Coefficient of linear expansion (α) = 12 × 10^{-6} per ^{0}C

a) Stresses in the rod when the ends don't yield –
   σ_1 = α.t.E = $(12 \times 10^{-6}) \times 40 \times (200 \times 10^3) = 96$ N/mm^2 = 96 MPa
b) Stresses in the rod when the ends yield by 1 mm –
   $\sigma_2 = [\ \alpha t - \frac{amount\ \ of\ yield\ \ in\ ends}{l}\ ] \times E$
   $= [(12 \times 10^{-6}) \times 40 - \frac{1}{6 \times 10^3}\ ] \times 200 \times 10^3 =$ 62.6 N/mm^2 = 62.6 MPa **(ANS)**

Q-6) A gun metal rod 20 mm diameter, screwed at the ends, passes through a steel tube 25 mm and 30 mm internal and external diameters respectively. The nuts on the rod are screwed tightly home on the ends of the tube. Find the intensity of stress in each metal, when the common temperature rises by 200^0F. Take Coefficient of expansion for steel = 6×10^{-6} per ^{0}F, Coefficient of expansion for gun metal = 10×10^{-6} per ^{0}F, Modulus of elasticity for steel = 200 GPa, Modulus of elasticity for gun metal = 100 GPa.

Ans) <u>Data Given</u>

Diameter of gun metal rod = 20 mm   Internal diameter of steel tube = 25 mm
External diameter of steel tube = 30 mm   Rise in temperature (t) = 200^0F
Coefficient of expansion for steel (α_s) = 6×10^{-6} per ^{0}F
Coefficient of expansion for gun metal (α_G) = 10×10^{-6} per ^{0}F
Modulus of elasticity for steel (E_S) = 200 GPa = 200×10^3 N/mm^2
Modulus of elasticity for gun metal (E_G) = 100 GPa = 100×10^3 N/mm^2

Let, σ_G = stress in gun metal rod and σ_s = stress in steel tube
area of gun metal rod (A_G) = $\frac{\pi}{4} \times 20^2 = 100 \times \pi$ mm^2
area of steel tube (A_s) = $\frac{\pi}{4}[(30)^2 - (25)^2] = 68.75\ \pi$ mm^2

As α_g is greater than α_s, the expansion of gun metal will be more than steel tube.
Since the gun metal will be subjected to compressive stress and the steel tube will be subjected to tensile stress.
Tensile load in steel tube = Compressive load in Gun metal rod

i.e. $\sigma_s \times A_s = \sigma_G \times A_G$

Stress in steel tube (σ_s) = $\frac{A_g}{A_s} \times \sigma_G = \frac{100\ \pi}{68.75\ \pi} \times \sigma_G = 1.45\ \sigma_G$

Strain in steel tube (e_s) = $\frac{\sigma_s}{E_s} = \frac{\sigma_s}{200 \times 10^3}$

Strain in gun metal (e_G) = $\frac{\sigma_G}{E_G} = \frac{\sigma_G}{100 \times 10^3}$

We know that, Strain in steel = Strain in Gun metal

$\Longrightarrow\quad e_s + \alpha_s t = \alpha_G t - e_G$

$\Longrightarrow\quad e_s + e_G = (\alpha_G - \alpha_s) \times t$

$\Longrightarrow\quad \frac{\sigma_s}{200 \times 10^3} + \frac{\sigma_G}{100 \times 10^3} = [(10 \times 10^{-6}) - (6 \times 10^{-6})] \times 200$

$\Longrightarrow\quad \frac{1.45\ \sigma G}{200 \times 10^3} + \frac{\sigma_G}{100 \times 10^3} = 200 \times (4 \times 10^{-6})$

$\Longrightarrow\quad \frac{3.45\ \sigma G}{200 \times 10^3} = 800 \times 10^{-6}$

$\Longrightarrow\quad 3.45\ \sigma_G = 800 \times 10^{-6} \times 200 \times 10^3 = 160$

$\therefore\quad \sigma_G = \frac{160}{3.45} = 46.4$ N/mm^2 = 46.4 MPa

$\therefore\quad \sigma_s = 1.45\ \sigma_G = 1.45 \times 46.4 = 67.3$ N/mm^2 = 67.3 MPa **(ANS)**

STRAIN ENERGY:

It is the energy stored in a deformed elastic body when external load acts on it. This energy is released when load is removed.

RESILIENCE:

It is the total strain energy stored by the body when external load acts on it within elastic limit. It is measured by the amount of energy absorbed per unit volume of the material within elastic limit.

PROOF RESILIENCE:

It is the maximum strain energy stored by the body per unit volume when the external load acts on it within the elastic limit.

EXPRESSION FOR STRAIN ENERGY:

Consider a bar of area 'A', length l subjected to load W.

Let, the bar extends by dl due to the load and produces maximum stress σ.

Let U = strain energy stored in the bar = work done by the load

so we may write, $U = \frac{1}{2} \times W \times dl$

we know that, $dl = \frac{\sigma\, l}{E}$ substituting the value of dl, we get

$U = \frac{W}{2} \times \frac{\sigma\, l}{E} = \frac{\sigma\, A}{2} \times \frac{\sigma\, l}{E}$ (∵ $W = \sigma \times A$)

$\mathbf{U = \frac{\sigma^2 A\, l}{2E} = \frac{\sigma^2 V}{2E}}$ (∵ $V = A \times l$)

STRESSES DUE TO GRADUALLY APPLIED LOAD:

When a load acts upon a body stepwise starting from zero to its last value, then it is known as gradually applied load.

Let, W = gradually applied load on the body

dl = change in length

σ = maximum stress

Energy due to external load = $\frac{1}{2} \times \sigma \times A \times dl$

Work done on the body = $\frac{1}{2} \times W \times dl$

But strain energy stored = work done on the body

⇒ $\frac{1}{2} \times \sigma \times A \times dl = \frac{1}{2} \times W \times dl$

⇒ $\boldsymbol{\sigma = \frac{W}{A}}$ **------------ (1)**

Stress due to suddenly applied load:

When a load acts suddenly on a body it is known as suddenly applied load.

Let, W = suddenly applied load

σ_s = suddenly applied load

dl = increase in length

Strain energy stored = External load acting on the body

$$W \times dl = \frac{1}{2} \times \sigma_s \times A \times dl$$

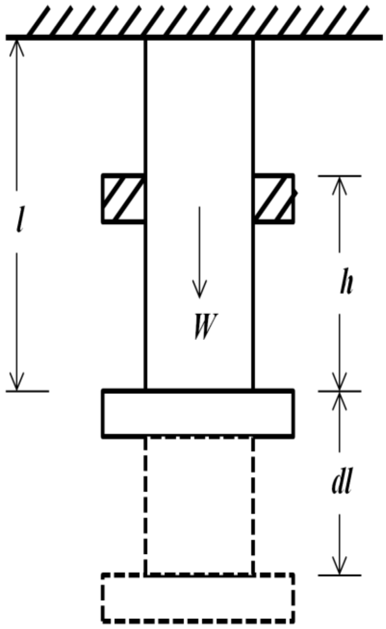
$$\Rightarrow \quad \boldsymbol{\sigma_s = \frac{2W}{A}} \quad \text{-------------- (2)}$$

Thus stress due to suddenly applied load is double than stress due to gradually applied load.

STRESS DUE TO IMPACT LOAD:

When a load falls from a height and strikes the body with some momentum, it is known as impact load. Consider a weight W is falling from height 'h' on the collar fitted on the rod.

Let:



l = length of the rod
A = cross sectional area of rod
dl = change in length
σ = maximum stress
External work done on the load = Energy stored in the rod

$$\Rightarrow \quad W(h + dl) = \frac{1}{2} \times \sigma \times A \times dl$$

$$\Rightarrow \quad W\left[h + \frac{\sigma\, l}{E}\right] = \frac{1}{2} \times \sigma \times A \times \frac{\sigma\, l}{E} \qquad \left(\because \quad dl = \frac{\sigma\, l}{E}\right)$$

$$\Rightarrow \quad W\left[h + \frac{\sigma\, l}{E}\right] = \frac{\sigma^2 A l}{2\,E}$$

$$\Rightarrow \quad \frac{\sigma^2 A l}{2\,E} - \frac{\sigma\, W\, l}{E} - Wh = 0$$

$$\Rightarrow \quad \sigma = \frac{\frac{W\,l}{E} \pm \sqrt{\frac{W^2\, l^2}{E^2} + \frac{2W\,hA\,l}{E}}}{\frac{Al}{E}} = \frac{\frac{W\,l}{E} \pm \frac{W\,l}{E}\sqrt{1 + \frac{2W\,hA\,l}{E} + \frac{E^2}{W^2\,l^2}}}{\frac{Al}{E}}$$

$$\Rightarrow \quad \sigma = \frac{W + W\sqrt{1 + \frac{2hA\,E}{Wl}}}{A}$$

Taking positive sign we get,

$$\boldsymbol{\sigma = \frac{W}{A}\left[1 + \sqrt{1 + \frac{2hA\,E}{Wl}}\right]} \quad \text{------ (3)}$$

***** ASSIGNMENT- 02 *****

GROUP – A (2 mark questions)

1. What do mean by composite section?
2. Define temperature/thermal stress and strain.
3. Define strain energy.
4. Define resilience.

GROUP – B (6 mark questions)

1. Find the expression for temperature stress for a rise in temperature of t^0C when the ends don't yield. Take α as coefficient of expansion and *l* as original length.
2. A reinforces concrete column is 300 mm × 300 mm in section. The column is provided with 8 steel bars of 20 mm diameter. The column carries a load of 360 KN. find the stresses in concrete and steel bars. Take $E_s = 2.1 \times 10^5$ N/mm^2 and $E_b = 0.14 \times 10^5$ N/mm^2.
3. A steel rod of 20 m long at a temperature 20^0C is subjected to rise in temperature to 65^0C. Find the temperature stress produced, i) when the expansion of the rod is prevented; ii) when the rod is permitted to expand by 5.8 mm. Take $\alpha = 12 \times 10^{-6}$ per ^0C and $E = 2 \times 10^5$ N/mm^2.
4. Derive the expressions for stresses due to gradually applied load, suddenly applied load and impact load.

GROUP – C (8 mark questions)

1. A compound tube consists of a steel tube 150 mm internal diameter and 10 mm thickness and an outer brass tube 170 mm internal diameter and 10 mm thickness. The two tubes are of the same length. The compound tubes carries an external load of 1000 KN. Find the stresses and load carried by each tube and the amount it reduced. Length of each tube is 100mm.
   Take $E_s = 2 \times 10^5$ N/mm^2 and $E_b = 1 \times 10^5$ N/mm^2.
2. A 15 mm diameter steel rod passes centrally through a copper tube 50 mm external diameter and 40 mm internal diameter. The tube is closed at each end by rigid plates of negligible thickness. The nuts are tightened lightly on the projecting parts of the rod. If the temperature of the assembly is raised by 60^0C, calculate the stresses developed in copper and steel.
3. A steel bar is placed between two copper bars each having the same area and length as the steel bar at 15^0C. The bars are rigidly connected at both ends when the temperature rises to 315^0C. The length of the bars increases by 1.50 mm. Determine the original length and the final stresses in the bars. Take $E_s = 2.1 \times 10^5$ N/mm^2 $E_c = 1 \times 10^5$ N/mm^2
   $\alpha_s = 0.000012$ per^0C $\alpha_c = 0.0000175$ per^0C
4. A solid steel bar 50 cm long and 7 cm in diameter is placed inside an aluminium tube having 7.5 cm inside diameter and 10 cm outside diameter. The aluminium tube is 0.015 cm longer than the steel bar. An axial load of 600 kN is applied to the bar and tube through rigid cover plates. Find the stresses developed in the steel bar and aluminium tube. E for steel = 220 GPa. E for aluminium = 70 GPa. (**Ans:** $\sigma_s = 106.82\ MN/m^2$, $\sigma_{al} = 54.99\ MN/m^2$)

THIN CYLINDRICAL SHELL

THIN CYLINDER:

If the thickness of the wall of the cylinder is less than 1/20 of its diameter then the cylinder is said to be thin cylinder.

ASSUMPTION FOR THIN SHELLS:

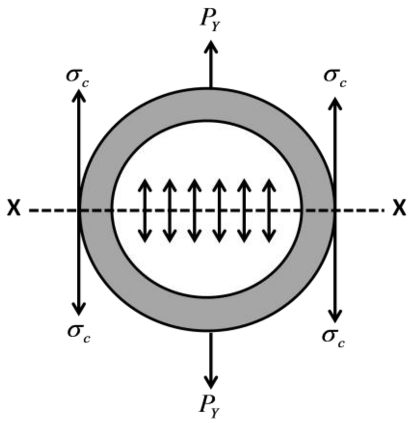
- A thin cylinder may fail along longitudinal seam or across a transverse section.
- Hoop or circumferential stresses acting across longitudinal section.
- Longitudinal or axial stresses acting across at right angles to the longitudinal axis of the cylinder.
- Radial stresses are neglected.

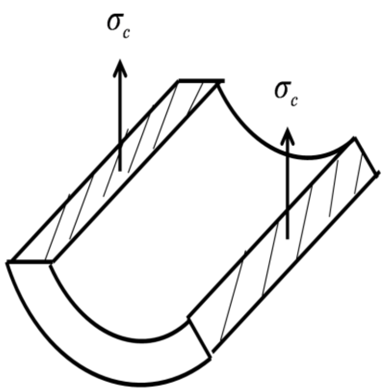
HOOP OR CIRCUMFERENTIAL STRESS:

When a thin cylindrical shell is subjected to an internal pressure, tensile stresses develop in a tangential direction to its circumference, which may split the shell into two troughs, such stresses are known as hoop or circumference stresses.

Determination of hoop stress:

Consider a thin cylinder subjected to an internal pressure (p). Consider any section X-X which divides the cylinder into two parts. Due to internal pressure, force P_Y will act normal to the X-X axis. This force P_Y will develop the tensile stress σ_c which is known as *hoop or circumferential stress*.





Let l = length of the shell d = internal diameter of the shell
t = thickness of the shell p = intensity of internal pressure

Pressure force acting along each side of X-X plane of the shell (P_Y) = internal pressure × area on X-X plane = p × (d × l)

Area resisting the bursting force $P_Y = 2\, t\, l$

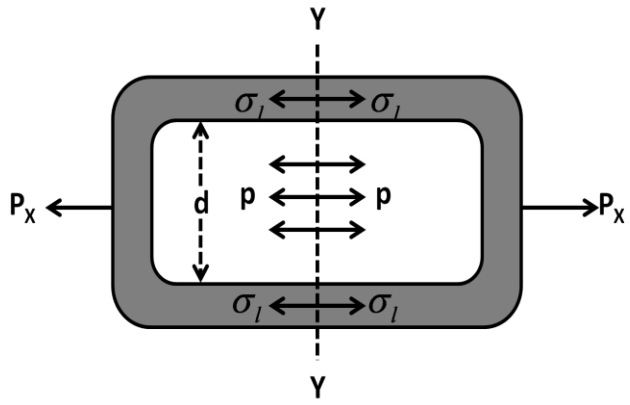
Circumferential stress in the shell = $\sigma_c = \dfrac{\text{Pressure force}}{\text{area resisting the internal pressure}} = \dfrac{\text{pd}\,l}{2tl} = \dfrac{\mathbf{pd}}{\mathbf{2t}}$

∴ $\boxed{\boldsymbol{\sigma c = \frac{pd}{2t}}}$ This tensile stress across X-X axis is also known as Hoop stress.

LONGITUDINAL STRESS:

When a thin cylindrical shell is subjected to an internal pressure, tensile stresses may also develop in longitudinal direction which may split the shell into two halves or into two cylinders, such stresses are known as longitudinal stresses.

Consider a thin cylinder subjected to an internal pressure (p). Consider any section Y-Y at right angles to the length of the cylinder which divides the cylinder into two half cylinders. Due to internal pressure, force P_X will act normal to the Y-Y axis. This force P_Y will develop the tensile stress σ_l parallel to the length of the cylinder. It is known as *longitudinal stress*.



Let l = length of the shell d = diameter of the shell

t = thickness of the shell p = intensity of internal pressure

Total pressure force along longitudinal direction = P_X = internal pressure × area on Y-Y plane

$$= p \times \frac{\pi}{4} d^2$$

Area resisting the bursting force $P_X = \pi dt$

Longitudinal stress in the shell = $\sigma_l = \dfrac{\text{total pressure force}}{\text{area resisting the internal pressure}} = \dfrac{p \times \pi/4\, d^2}{\pi dt} = \dfrac{pd}{4t}$

∴ $\boxed{\sigma_l = \dfrac{\mathbf{pd}}{\mathbf{4t}}}$ This tensile stress across Y-Y axis is known as longitudinal stress.

CIRCUMFERENTIAL STRAIN AND LONGITUDINAL STRAIN:

Let δd = change in diameter of the shell

δl = change in length of the shell

$\frac{1}{m}$ = Poisson's ratio

σ_c = circumferential stress and σ_l = longitudinal stress

Circumferential strain $(e_c) = \dfrac{\delta d}{d} = \dfrac{\sigma_c}{E} - \dfrac{\sigma_l}{mE} = \dfrac{pd}{2tE} - \dfrac{pd}{4tEm} = \boxed{\dfrac{\mathbf{pd}}{\mathbf{2tE}}\left(\mathbf{1} - \dfrac{\mathbf{1}}{\mathbf{2m}}\right)}$

Longitudinal strain $(e_l) = \dfrac{\delta l}{l} = \dfrac{\sigma_l}{E} - \dfrac{\sigma_c}{mE} = \dfrac{pd}{4tE} - \dfrac{pd}{2tEm} = \boxed{\dfrac{\mathbf{pd}}{\mathbf{2tE}}\left(\dfrac{\mathbf{1}}{\mathbf{2}} - \dfrac{\mathbf{1}}{\mathbf{m}}\right)}$

CHANGE IN DIMENSION OF THIN CYLINDRICAL SHELL:

We know that, $e_c = \frac{\delta d}{d} = \frac{pd}{2tE}(1 - \frac{1}{m})$

∴ *Change in diameter* (δd) = $e_c \times d = \frac{pd}{2tE}(1 - \frac{1}{m}) \times d = \mathbf{\frac{pd^2}{2tE}(1 - \frac{1}{2m})}$

We know that, $e_l = \frac{\delta l}{l} = \frac{pd}{2tE}(\frac{1}{2} - \frac{1}{m})$

∴ *Change in length* (δ*l*) = $e_l \times l = \frac{pd}{2tE}(\frac{1}{2} - \frac{1}{m}) \times l = \mathbf{\frac{pDl}{2tE}(\frac{1}{2} - \frac{1}{m})}$

Internal volume of the cylinder (V) = $\frac{\pi}{4} \times d^2 \times l$

Final volume of the cylinder = V + δV = $\frac{\pi}{4} \times (d + \delta d)^2 \times (l + \delta l)$

Change in Volume = δV = final volume – initial volume = $\frac{\pi}{4} \times (d + \delta d)^2 \times (l + \delta l) - \frac{\pi}{4} \times d^2 \times l$

Neglecting the smaller terms we get:

Change in volume (δV) = $\frac{\pi}{4} \times (d^2 . \delta l + 2dl . \delta d)$

∴ *Volumetric strain* (e_v) $= \frac{\delta V}{V} = \frac{\frac{\pi}{4} \times (d^2 . \delta l + 2dl . \delta d)}{\frac{\pi}{4} \times d^2 \times l} = \frac{\delta l}{l} + \frac{2\,\delta d}{d} = e_l + 2 \times e_c$

∴ *Change in volume* (δV) = $\mathbf{V(e_l + 2 \times e_c)}$

THIN SPHERICAL SHELL:

Stress in spherical shell (σ) = $\frac{pD}{4t}$ ----------------- (10)

Strain in any section of spherical section (e) = $\frac{\sigma_c}{E} - \frac{\sigma_l}{mE} = \frac{\sigma_c}{E}(1 - \frac{1}{m}) = \mathbf{\frac{pD}{4t\,E}(1 - \frac{1}{m})}$ --------- (10)

NOTES:

Terms	Symbol	Formula	Units
Hoop stress	σ_c or f_y	$\frac{p \times d}{2 \times t}$	Same as Stress
Longitudinal stress	σ_l or f_x	$\frac{p \times d}{4 \times t}$	Same as Stress
Change in diameter	Δd	$\frac{pd^2}{2tE}(1 - \frac{1}{2m})$	mm or cm
Change in length	Δ*l*	$\frac{pdl}{2tE}(\frac{1}{2} - \frac{1}{m})$	mm or cm
Change in volume	Δv	$V(e_l + 2e_c) = \frac{pD}{2tE}(\frac{5}{2} - \frac{2}{m})$	mm or cm

***** PROBLEM *****

Q-1) *A mild steel cylinder contains some fluid under pressure and its diameter is 1.5 m. If the thickness of the cylinder wall is 4 mm, determine the safe pressure inside the cylinder. Assume the maximum allowable tensile stress in M.S as 80 N/mm^2.*

Ans) Data Given

Diameter (d) = 1.5 m = 1500 mm thickness (t) = 4 mm
Maximum allowable stress (σ) = 80 N/mm^2
Let, p = safe pressure inside the cylinder
Hoop stress is given by -

$$\sigma c = \frac{p\ d}{2t} = \frac{p \times 1500}{2 \times 4} \quad \Rightarrow \quad 80 = \frac{p \times 1500}{2 \times 4} \quad \Rightarrow \quad p = \frac{2 \times 4 \times 80}{1500} = \mathbf{0.4267\ N/mm^2}$$

longitudinal stress is given by -

$$\sigma_l = \frac{p\ d}{4\ t} = \frac{p \times 1500}{4 \times 4} \quad \Rightarrow \quad 80 = \frac{p \times 1500}{4 \times 4} \quad \Rightarrow \quad p = \frac{4 \times 4 \times 80}{1500} = \mathbf{0.8534\ N/mm^2}$$

∴ The required safe pressure inside the cylinder is p = 0.4267 N/mm^2. **(ANS)**

Q-2) *A cylinder is made of a material whose maximum allowable tensile stress is 60 N/mm^2. The diameter of the cylinder is 100 mm. If pressure of a fluid contained in the cylinder is 20 bar, determine the safe thickness of the cylinder wall.*

Ans) Data Given

Maximum tensile stress = 60 N/mm^2 Diameter (d) = 100 mm
Pressure (p) = 20 bar = 2 N/mm^2
Hoop stress is given by –

$$\sigma c = \frac{p\ d}{2t} = \frac{2 \times 100}{2 \times t} \quad \Rightarrow \quad 60 = \frac{2 \times 100}{2 \times t} \quad \Rightarrow \quad t = \frac{2 \times 100}{2 \times 60} \quad \therefore \quad \mathbf{t = 1.667\ mm}$$

longitudinal stress is given by -

$$\sigma_l = \frac{p\ d}{4\ t} = \frac{2 \times 100}{4 \times t} \quad \Rightarrow \quad 60 = \frac{2 \times 100}{4 \times t} \quad \Rightarrow \quad t = \frac{2 \times 100}{4 \times 60} \quad \therefore \quad \mathbf{t = 0.833\ mm}$$

∴ The required safe thickness is 1.667 mm. **(ANS)**

Q-3) *A boiler is 1.5 m in diameter having thickness of plate as 10 mm. The efficiencies of the longitudinal and circumferential joints are respectively 60% and 80%. If the maximum allowable tensile stress in plate be 70 N/mm^2, calculate the safe steam pressure in the boiler.*

Ans) Data Given

Diameter (d) = 1.5 m = 1500 mm thickness (t) = 10 mm
efficiency η_l = 0.60 & η_c = 0.80
Maximum allowable tensile stress = 70 N/mm^2

Hoop stress is given by –

$$\sigma_c = \frac{p\ d}{2t \times \eta_l} \quad \Rightarrow \quad 70 = \frac{p \times 1500}{2 \times 10 \times 0.60} \quad \Rightarrow \quad p = 0.56\ N/mm^2$$

Longitudinal stress is given by –

$\sigma_l = \frac{p\,d}{4\,t \times \eta_l}$ $\Rightarrow$ $70 = \frac{p \times 1500}{4 \times 10 \times 0.80}$ $\Rightarrow$ p = 1.439 N/mm^2

∴ The required safe pressure is 0.56 N/mm^2. **(ANS)**

Q-4) *The internal diameter of a cylindrical shell is 1 m and its length is 3 m, the plates being 1.5 cm thick. Determine the circumferential and longitudinal stresses set up and changes in dimensions of the shell when a fluid is introduced in it at a pressure of 1.5 N/mm^2. Take E = 200 kN/mm^2 and poison's ratio 0.3.*

Ans) Data Given

Diameter (d) = 1 m = 1000 mm
length (l) = 3 m = 3000 m
thickness (t) = 1.5 cm = 15 mm
pressure (p) = 1.5 N/mm^2
E = 200 kN/mm^2
Poisson's ratio ($\frac{1}{m}$) = 0.3

Circumferential/hoop stress (σc) = $\frac{p\,d}{2t} = \frac{1.5 \times 1000}{2 \times 15}$ = 50 N/mm^2

longitudinal stress (σl) = $\frac{p\,d}{4\,t} = \frac{1.5 \times 1000}{4 \times 15}$ = 25 N/mm^2

Change in diameter (δd) = $\frac{pd^2}{2tE}(1 - \frac{1}{2m}) = \frac{1.5 \times 1000^2}{2 \times 15 \times 2 \times 10^5}\ (1 - \frac{1}{2 \times 0.3})$ = 0.2125 mm

change in length (δl) $= \frac{pD\,l}{2tE}(\frac{1}{2} - \frac{1}{m}) = \frac{1.5 \times 1000 \times 3000}{2 \times 15 \times 2 \times 10^5}\ (\frac{1}{2}$ - 0.3) = 0.15 mm **(ANS)**

***** ASSIGNMENT – 03 *****

GROUP - A (2 mark questions)

1. Define thin cylindrical shell.
2. Define hoop and longitudinal stress.
3. State the expression of hoop and longitudinal stress.

GROUP - B (6 mark questions)

1. Write the assumptions for thin cylindrical shell.
2. Derive the expression for hoop and longitudinal stresses for a thin cylindrical shell.
3. A steam boiler of 800 mm diameter is made up of 10 mm thick plates. If the boiler is subjected to an internal pressure of 2.5 MPa, find the circumferential and longitudinal stresses induced in the boiler plates.
4. A cylindrical air receiver for a compressor is 2 m in internal diameter and made of plates 12 mm thick. If the hoop stress is not to exceed 60 N/mm^2, find the maximum safe air pressure.
5. A boiler is subjected to an internal steam pressure of 2 MPa. The thickness of the boiler plate is 2 cm and the permissible tensile stress is 120 MPa. Find the maximum diameter, when the efficiency of longitudinal joint is 90% and that of circumferential joint is 40%.

GROUP - C (8 marks questions)

1. A closed vessel made of steel plates 4 mm thick with plane carries fluid under pressure of 3 N/mm^2. The diameter of the cylinder is 25 cm and length 75 cm. Calculate the longitudinal and hoop stress. Determine the change in diameter, length and volume of cylinder.
   Take $E = 2.1 \times 10^5$ N/mm^2 and $1/m = 0.28$.

2. A thin cylindrical shaft 2 m long, 20 cm diameter and 1 cm thick is subjected to an internal pressure of 200 kg/cm^2. Take Poisson's ratio as 0.25 and $E = 2 \times 10^6$ kg/cm^2.
   Find i) hoop stress ii) longitudinal stress iii) change in its dimensions and volume.

3. A hollow cylindrical drum 600 mm in diameter has a thickness of 10 mm. If the drum is subjected to an internal air pressure of 3 N/mm^2, determine the increase in volume of the drum. Take $E = 2 \times 10^5$ N/mm^2 and $1/m = 0.3$.

4. A cylindrical thin shell, 80 cm in diameter and 3 m long is having 1 cm metal thickness. If the shell is subjected to an internal pressure of 2.5 MPa, determine (i) change in diameter (ii) change in length (iii) change in volume. Take E = 200 GPa and Poisson's ratio = ¼.

TWO DIMENSIONAL STRESS SYSTEM

PRINCIPAL PLANE:

The three mutually perpendicular planes along which the stresses at a certain point in a body can be resolved at right angle to these planes are known as principal planes. These planes carry only normal stresses but no shear stress.

Out of three stresses one is maximum, one is minimum and the third one is lying between these two stresses.

The plane carrying the maximum normal stress is known as Major principal plane and the plane carrying the minimum normal stress is known as the minor principal plane.

PRINCIPAL STRESS:

The normal stresses across the principal planes are known as principal stresses.

The stress across the major principal plane is known as major principal plane and the stress across the minor principal plane is known as minor principal plane.

DETERMINATION OF PRINCIPAL STRESSES:

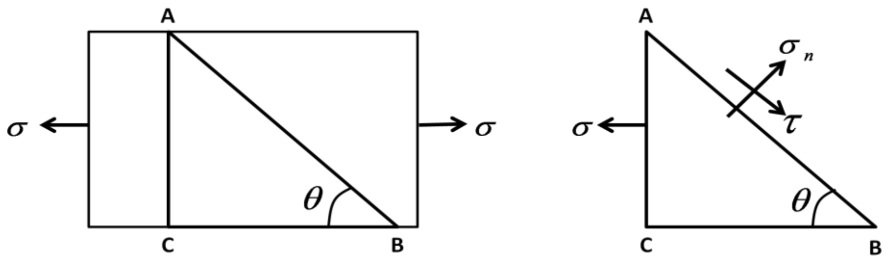
Sign convention

- All tensile stress and strain are positive.
- All compressive stress and strain are negative.
- The shear stress which tends to rotate the body in clockwise direction is positive.
- The shear stress which tends to rotate the body in anti clockwise direction is negative.
- The shear stresses on the vertical faces are positive and the shear stresses on the horizontal faces are negative.

Case-I: **Stresses on an oblique section of a body subjected to direct stress in one plane:**

Consider a rectangular body of unit thickness and uniform area of cross section subjected to direct stress along X-X axis as shown in figure.

Consider an oblique section AB inclined at angle Θ with the X-X axis.



Let σ = tensile stress across the face AC

Θ = Angle between AB and BC.

Consider the equilibrium of ABC.

The horizontal force acting on the face AC = P = $\sigma \times AC$

Resolving the forces normal to the section AB –

$P_n = P \sin\Theta = \sigma \times AC \times \sin\Theta$

Resolving the forces tangentially to the section AB –

$P_t = P \cos \Theta = \sigma \times AC \cos \Theta$

Normal stress across the section AB $= \sigma_n = \frac{P_n}{AB} = \frac{\sigma \times AC \times \sin\Theta}{AB} = \frac{\sigma \times AC \times \sin\Theta}{\frac{AC}{\sin\Theta}}$

$= \sigma \sin^2\Theta = \frac{\sigma}{2} \times (1 - \cos 2\Theta)$

$= \boldsymbol{\frac{\sigma}{2} - \frac{\sigma}{2} \times (1 - \cos 2\Theta)}$ ------- (1)

Shear stress across the section AB $= \tau = \frac{P_t}{AB} = \frac{\sigma \times AC \times \cos\Theta}{AB} = \frac{\sigma \times AC \times \cos\Theta}{\frac{AC}{\sin\Theta}}$

$= \sigma \sin\Theta \cos\Theta$

$= \boldsymbol{\frac{\sigma}{2} \sin 2\Theta}$ ------------------ (2)

Normal stress across the section AB will be maximum, if $\sin^2\Theta = 1$ or $\Theta = 90^0$

Shear stress across the section AB will be maximum, if $\sin 2\Theta = 1$ or $\Theta = 45^0$ or 135^0.

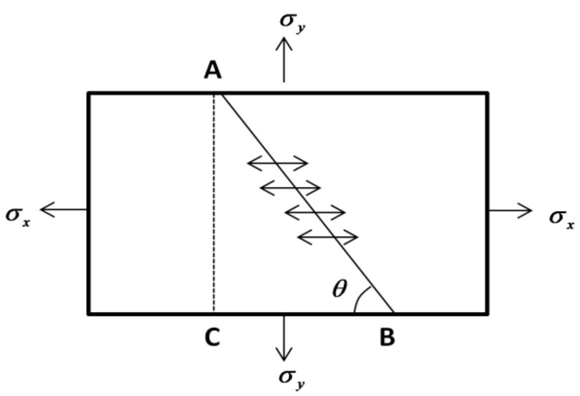
Thus maximum shear stress, when $\Theta = 45^0$ or 135^0 $= \boldsymbol{\tau_{max} = \sigma/2}$

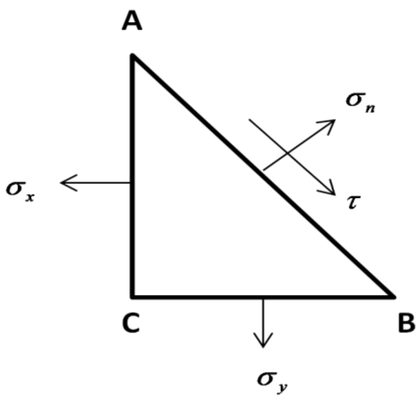
The resultant stress may be obtain from the relation, $\boldsymbol{\sigma_R = \sqrt{\sigma_n^2 + \tau^2}}$ ----- (3)

Case-II: **<u>Stresses on an oblique section of a body subjected to direct stress in two mutually perpendicular stresses</u>:**

Consider a rectangular body of unit thickness and uniform area of cross section subjected to direct tensile stresses along X-X axis and Y-Y axis as shown in figure.

Consider an oblique section AB inclined at angle Θ with the X-X axis.





Let σ_x = tensile stress along X-X axis

σ_y = tensile stress along Y-Y axis

Θ = angle made by section AB with X-X axis

Consider the equilibrium of the section ABC

Horizontal force acting on the face AC $= P_x = \sigma_x \times AC$

Vertical force acting on the face AC $= P_y = \sigma_y \times BC$

Resolving the forces normal to the section AB

$P_n = P_x \sin\Theta + P_y \cos\Theta = (\sigma_x \times AC \times \sin\Theta) + (\sigma_y \times BC \times \cos\Theta)$

Resolving the forces tangentially to the section AB –

$P_t = P_x \cos\Theta - P_y \sin\Theta = (\sigma_x \times AC \times \cos\Theta) - (\sigma_y \times BC \times \sin\Theta)$

Normal stress across the section AB $= \sigma_n$

$= \frac{P_n}{AB} = \frac{(\sigma_x \times AC \times \sin\Theta) + (\sigma_y \times BC \times COS\ \Theta)}{AB}$

$$= \frac{(\sigma_x \times AC \times \sin\Theta)}{AB} + \frac{(\sigma_y \times BC \times COS\ \Theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \sin\Theta)}{\frac{AC}{\sin\Theta}} + \frac{(\sigma_y \times BC \times COS\ \Theta)}{\frac{BC}{\cos\Theta}}$$
$$= \sigma_x \sin^2\Theta + \sigma_y \cos^2\Theta = \frac{\sigma_x}{2}(1 - \cos 2\Theta) + \frac{\sigma_y}{2}(1 + \cos 2\Theta)$$
$$= \frac{\sigma_x}{2} - \frac{\sigma_x}{2}\cos 2\Theta + \frac{\sigma_y}{2} + \frac{\sigma_y}{2}\cos 2\Theta$$
$$\therefore \quad \boldsymbol{\sigma_n = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2}\cos 2\Theta} \quad \text{---------------------------- (1)}$$

Shear stress across the section AB = τ

$$= \frac{P_t}{AB} = \frac{(\sigma_x \times AC \times \cos\ \Theta) - (\sigma_y \times BC \times \sin\ \Theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \cos\ \Theta)}{AB} - \frac{(\sigma_y \times BC \times \sin\ \Theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \cos\ \Theta)}{\frac{AC}{\sin\Theta}} - \frac{(\sigma_y \times BC \times \sin\ \Theta)}{\frac{BC}{\cos\Theta}}$$
$$= \sigma_x \sin\Theta\cos\Theta + \sigma_y \sin\Theta\cos\Theta$$
$$= (\sigma_x - \sigma_y)\sin\Theta\cos\Theta$$
$$\therefore \quad \boldsymbol{\tau = \frac{\sigma_x - \sigma_y}{2}\sin 2\Theta} \quad \text{-------------------------------------- (2)}$$

Shear stress across the section AB wil be maximum, if $\Theta = 45^0$

Thus maximum shear stress, $\boldsymbol{\tau_{max} = \frac{\sigma_x - \sigma_y}{2}}$

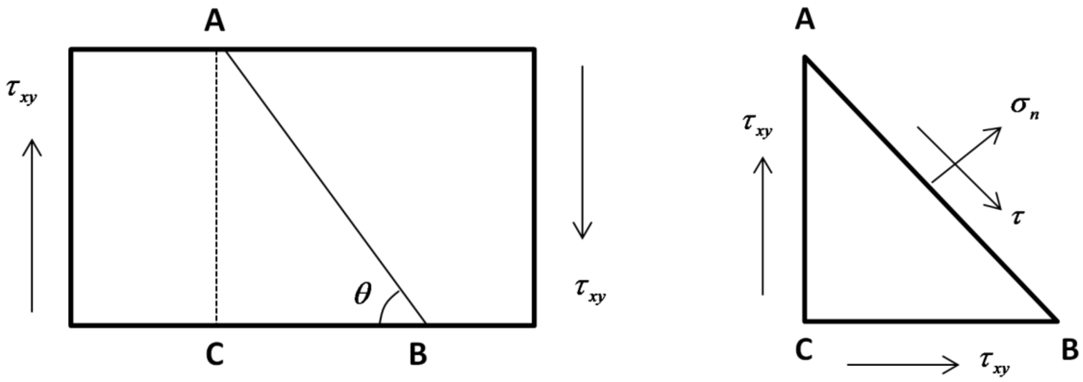
Resultant stress may be obtain from the relation, $\boldsymbol{\sigma_R = \sqrt{\sigma_n^2 + \tau^2}}$ ----- (3)

Case-III: **<u>Stresses on an oblique section of a body subjected to shear stress</u>:**

Consider a rectangular body of unit thickness and uniform area of cross section subjected to a shear stress along X-X axis.

Consider an oblique section AB at an angle Θ with the axis X-X as shown in figure.

Let τ_x = shear stress along X-X axis



Consider the equilibrium of the section ABC

The vertical force acting on the face BC = $P_1 = \tau_x \times AC$

The horizontal force acting on the face BC = $P_2 = \tau_x \times BC$

Resolving the forces normal to the section AB

$P_n = P_1 \cos \Theta + P_2 \sin \Theta = \tau_x \,.\, AC \cos \Theta + \tau_x \,.\, BC \sin \Theta$

Resolving the forces tangential to the section AB

$P_t = P_2 \sin \Theta - P_1 \cos \Theta = \tau_x \,.\, BC \sin \Theta - \tau_x \,.\, AC \cos \Theta$

Normal stress across the section AB = σ_n

$$= \frac{P_n}{AB} = \frac{(\tau_x \times AC \times \cos\ \Theta) + (\tau_x \times BC \times \sin\ \Theta)}{AB}$$
$$= \frac{(\tau_x \times AC \times \cos\ \Theta)}{AB} + \frac{(\tau_x \times BC \times \sin\ \Theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \cos\ \Theta)}{\frac{AC}{sin\Theta}} + \frac{(\tau_x \times BC \times \sin\ \Theta)}{\frac{AC}{sin\Theta}}$$
$$= \tau_x \sin\ \Theta.\cos \Theta + \tau_x \sin \Theta.\cos \Theta$$
$$= 2 \times \tau_x \sin \Theta.\cos \Theta$$
$$= \boldsymbol{\tau_x \sin 2\Theta} \qquad \text{--------------------} \ (1)$$

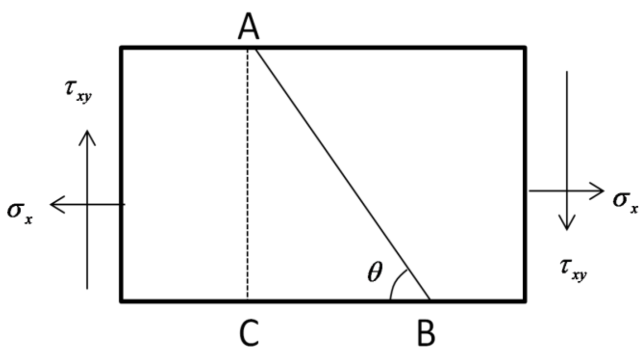
Shear stress across the section AB = τ

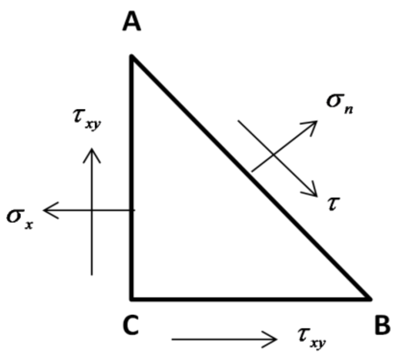
$$= \frac{P_t}{AB} = \frac{(\tau_x \times BC \times \sin\ \Theta) - (\tau_x \times AC \times \mathrm{COS}\ \Theta)}{AB}$$
$$= \frac{(\tau_x \times BC \times \sin\ \Theta)}{AB} - \frac{(\tau_x \times AC \times \cos\ \Theta)}{AB}$$
$$= \frac{(\sigma_x \times BC \times \sin\ \Theta)}{\frac{BC}{sin\Theta}} - \frac{(\tau_x \times AC \times \cos\ \Theta)}{\frac{AC}{sin\Theta}}$$
$$= \tau_x \sin^2\Theta - \tau_x \cos^2 \Theta$$
$$= \frac{\tau_x}{2}(1 - \cos 2\ \Theta) - \frac{\tau_x}{2}(1 + \cos 2\Theta)$$
$$= \frac{\tau_x}{2} - \frac{\tau_x}{2}\cos 2\Theta - \frac{\tau_x}{2} - \frac{\tau_x}{2}\cos 2\Theta$$
$$= -\ \boldsymbol{\tau_x \cos 2\Theta} \qquad \text{----------------------} \ (2)$$

Maximum or minimum shear stress may be obtain by equating $-\ \tau_x \cos 2\Theta = 0$
when $\Theta = 45^0$ or 135^0.

Case-IV: <u>Stresses on an oblique section of a body subjected to normal stress in one plane and shear stress</u>

Consider a rectangular body of unit thickness and uniform area of cross section subjected to direct tensile stress along X-X axis and followed by a shear stress along X-X axis as shown in figure.
Consider an oblique section AB at an angle Θ with the X-X axis.





Let σ_x = tensile stress along X-X axis

τ_x = shear stress along X-X axis

Consider the equilibrium of the section ABC

Horizontal force acting on the face AC = $P_x = \sigma_x \times AC$

The vertical force acting on the face AC = $P_y = \tau_x \times AC$

The horizontal force acting on the face BC = $P = \tau_x \times BC$

Resolving the forces normal to the section AB

$$P_n = P_x \sin\Theta - P_y \cos\Theta - P\sin\Theta$$
$$= \sigma_x \times AC\sin\Theta - \tau_x . AC\cos\Theta - \tau_x . BC\sin\Theta$$

Resolving the forces tangential to the section AB

$$P_t = P_x \cos\Theta + P_y \sin\Theta - P\cos\Theta$$
$$= \sigma_x \times AC\cos\Theta + \tau_x . AC\sin\Theta - \tau_x . BC\cos\Theta$$

Normal stress across the section AB = σ_n

$$= \frac{P_n}{AB} = \frac{(\sigma_x \times AC \times \sin\ \theta) - (\tau_x \times AC \times \cos\ \theta) - (\tau_x \times BC \times \sin\ \theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \sin\theta)}{AB} - \frac{(\tau_x \times AC \times \cos\ \theta)}{AB} - \frac{(\tau_x \times BC \times \sin\ \theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \sin\theta)}{\frac{AC}{\sin\theta}} - \frac{(\tau_x \times AC \times \cos\ \theta)}{\frac{AC}{\sin\theta}} - \frac{(\tau_x \times BC \times \sin\ \theta)}{\frac{BC}{\cos\theta}}$$
$$= \sigma_x \sin^2\Theta - \tau_x \sin\Theta.\cos\Theta - \tau_x \sin\Theta.\cos\Theta$$
$$= \frac{\sigma_x}{2}(1-\cos 2\Theta) - 2\tau_x \sin\Theta.\cos\Theta$$
$$= \boldsymbol{\frac{\sigma_x}{2} - \frac{\sigma_x}{2}\cos 2\Theta - \tau_x \sin 2\Theta} \quad \text{-------------------------- (1)}$$

Shear stress across the section AB

$$= \frac{P_t}{AB} = \frac{(\sigma_x \times AC \times \cos\ \theta) + (\tau_x \times AC \times \sin\ \theta) - (\tau_x \times BC \times \cos\ \theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \cos\theta)}{AB} + \frac{(\tau_x \times AC \times \sin\ \theta)}{AB} - \frac{(\tau_x \times BC \times \cos\ \theta)}{AB}$$
$$= \frac{(\sigma_x \times AC \times \cos\ \theta)}{\frac{AC}{\sin\theta}} + \frac{(\tau_x \times AC \times \sin\ \theta)}{\frac{AC}{\sin\theta}} - \frac{(\tau_x \times BC \times \cos\ \theta)}{\frac{BC}{\cos\theta}}$$
$$= \sigma_x \sin\Theta\cos\Theta + \tau_x \sin^2\Theta - \tau_x \cos^2\Theta$$
$$= \frac{\sigma_x}{2}\sin 2\Theta + \frac{\tau_x}{2}(1-\cos 2\Theta) - \frac{\tau_x}{2}(1+\cos 2\Theta)$$
$$= \frac{\sigma_x}{2}\sin 2\Theta + \frac{\tau_x}{2} - \frac{\tau_x}{2}\cos 2\Theta - \frac{\tau_x}{2} - \frac{\tau_x}{2}\cos 2\Theta$$
$$= \boldsymbol{\frac{\sigma_x}{2}\sin 2\Theta - \tau_x \cos 2\Theta} \quad \text{------------------------ (2)}$$

The maximum and minimum normal stress may be obtained by equating the Shear stress to zero.

Maximum principal stress (σ_{p1}) = $\boldsymbol{\frac{\sigma_x}{2} + \sqrt{\frac{\sigma_x}{2}^2 + \tau_x^2}}$ ------------ **(3)**

Minimum principal stress (σ_{p2}) = $\boldsymbol{\frac{\sigma_x}{2} - \sqrt{(\frac{\sigma_x}{2})^2 + \tau_x^2}}$ ------------ **(4)**

Case-V: **Stresses on an oblique section subjected to normal stress along two mutually perpendicular directions and followed by shear stress**

Normal stress (σ_n) = $\frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2}\cos 2\Theta - \tau_x \sin 2\Theta$ --------- (1)

Shear stress (τ) = $\frac{\sigma_x - \sigma_y}{2}\sin 2\Theta - \tau_x \cos 2\Theta$ ----------------------------- (2)

Maximum principal stress (σ_{p1}) = $\frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_x^2}$ ------------- **(3)**

Minimum principal stress (σ_{p2}) = $\frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_x^2}$ -------------- **(4)**

***** PROBLEM *****

Q-1) ***A rectangular block 10 cm × 5 cm in section is subjected to a tensile load of 500 kN. Determine the normal stress and shear stress on an oblique plane making an angle of 30^0 with the length of the block.***

Ans) Data Given

Tensile load (P) = 500 kN
angle made by the oblique plane (Θ) = 30^0
area of block (A) = 10 cm × 5 cm = 50 cm^2 = 5000 mm^2
Tensile stress (σ) = P/A = (500/5000) kN/mm^2 = 0.1 kN/mm^2 = 100 N/mm^2
Normal stress across the section (σ_n) = $\frac{\sigma}{2} - \frac{\sigma}{2} \times (1 - \cos 2\Theta)$
= $\frac{100}{2} - \frac{100}{2} \times (1 - \cos 2\times30)$ = 25 N/mm^2
Shear stress across the section (τ) = $\frac{\sigma}{2}\sin 2\Theta = \frac{100}{2} \times \sin 2\times30$ = 43.3 N/mm^2 (**ANS)**

Q-2) ***A rectangular block of 1000 mm^2 cross sectional area is subjected to a longitudinal compressive load of 1000 kN. Determine the normal stress across the cross section of the block. If the block is cut by an oblique plane making an angle of 40^0 with normal section of the block, determine i) normal and tangential stress on the oblique plane ii) resultant stress on the oblique plane.***

Ans) Data Given

Compressive load (P) = 1000 kN
area of cross section of block (A) = 1000 mm^2
angle made by the oblique plane (Θ) = 40^0
compressive stress (σ) = P/A = (1000/1000) kN/mm^2 = 1 kN/mm^2
Normal stress across the section (σ_n) = $\frac{\sigma}{2} - \frac{\sigma}{2} \times (1 - \cos 2\Theta)$
= $\frac{1}{2} - \frac{1}{2} \times (1 - \cos 2\times40)$ = 0.58 kN/mm^2
Shear stress across the section (τ) = $\frac{\sigma}{2}\sin 2\Theta = \frac{1}{2} \times \sin 2\times40$ = 0.49 N/mm^2
Resultant stress (σ_R) = $\sqrt{\sigma_n{}^2 + \tau^2}$ = $\sqrt{(0.58)^2 + (0.49)^2}$ = 0.76 kN/mm^2
Let α = angle made by the resultant stress with the oblique plane

then tan α = $\frac{\sigma_n}{\tau} = \frac{0.58}{0.49}$ = 1.19

∴ α = $\tan^{-1}$ (1.19) = 49.99^0 **(ANS)**

Q-3) ***An element in a strained body is subjected to two mutually perpendicular tensile stresses of 300 N/mm^2 and 200 N/mm^2. Determine on a plane inclined at 30^0 to the direction of smaller stress, i) normal stress ii) shear stress iii) resultant stress.***

Ans) <u>Data Given</u>

σ_x = tensile stress along X-X axis = 300 N/mm^2

σ_y = tensile stress along Y-Y axis = 200 N/mm^2

angle made by the oblique plane (Θ) = 30^0

Normal stress on the inclined plane (σ_n) = $\frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2} \cos 2\Theta$

$= \frac{300+200}{2} - \frac{300-200}{2} \cos 2\times 30^0$

= 250 – 25 = 225 N/mm^2

Shear stress on the inclined plane (τ) $= \frac{\sigma_x - \sigma_y}{2} \sin 2\Theta$

$= \frac{300-200}{2} \sin 2\times 30^0$ = 43.3 N/mm^2

Resultant stress (σ_R) = $\sqrt{\sigma_n{}^2 + \tau^2} = \sqrt{(225)^2 + (43.3)^2}$ = 303.10 N/mm^2

Let α = angle made by the resultant stress with the oblique plane

then tan α = $\frac{\sigma_n}{\tau} = \frac{225}{43.3}$ = 5.19 ∴

α = $\tan^{-1}$ (5.19) = 81.79^0 **(ANS)**

Q-4) ***The stresses at a point in a component are 100 MPa (tensile) ans 50 MPa (compressive). Determine the magnitude of the normal and shear stresses on a plane inclined at an angle of 25^0 with tensile stress. Also determine the direction of the resultant stress and the magnitude of the maximum intensity of shear stress.***

Ans) <u>Data Given</u>

Tensile stress along X-X axis (σ_x) = 100 MPa

Compressive stress along Y-Y axis (σ_y) = 50 Mpa

Angle made by the plane with tensile stress (Θ) = 25^0

Normal stress on the inclined plane (σ_n) = $\frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2} \cos 2\Theta$

$= \frac{100+(-50)}{2} - \frac{100-(-50)}{2} \cos 2\times 25^0$

= - 23.21 MPa

Shear stress on the inclined plane (τ) $= \frac{\sigma_x - \sigma_y}{2} \sin 2\Theta$

$= \frac{100-(-50)}{2} \sin 2\times 25^0$ = 57.45 MPa

Let α = angle made by the resultant stress with the oblique plane

then tan α = $\frac{\sigma_n}{\tau} = \frac{57.45}{-23.21}$ = - 2.4752

∴ α = $\tan^{-1}$ (- 2.4752) = - 68^0

Maximum shear stress (τ_{max}) = $\pm \frac{\sigma_x + \sigma_y}{2} = \pm \frac{100-(-50)}{2} = \pm$ 75 MPa **(ANS)**

Q –5) ***A plane element in a body is subjected to a tensile stress of 100 MPa accompanied by a shear stress of 25 MPa. Find i) the normal and shear stress on a plane inclined at an angle of 20^0 with the tensile stress and ii) the maximum shear stress on the plane.***

Ans) <u>Data Given</u>

Tensile stress along X-X axis (σ_x) = 100 MPa
Shear stress (τ_{xy}) = 25 MPa
angle made by the plane with tensile stress (Θ) = 20^0

Normal stress on the inclined plane (σ_n) = $\frac{\sigma_x}{2} - \frac{\sigma_x}{2}\cos 2\Theta - \tau_{xy}\sin 2\Theta$

$= \frac{100}{2} - \frac{100}{2}\cos(2\times 20^0) - 25 \times \sin(2\times 20^0)$

$= -4.37$ MPa

Shear stress on the inclined plane (τ) $= \frac{\sigma_x}{2}\sin 2\Theta - \tau_{xy}\cos 2\Theta$

$= \frac{100}{2}\sin(2\times 20^0) - 25 \times \cos(2\times 20^0)$

$= 12.99$ MPa

Maximum shear stress on the plane (τ_{max}) = $\sqrt{(\frac{\sigma_x}{2})^2 + (\tau_{xy})^2}$ = $\sqrt{(\frac{100}{2})^2 + (25)^2}$

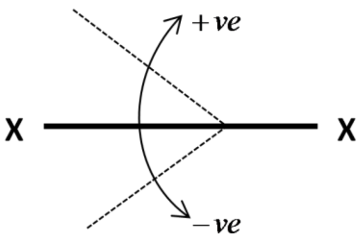
= 55.9 MPa **(ANS)**

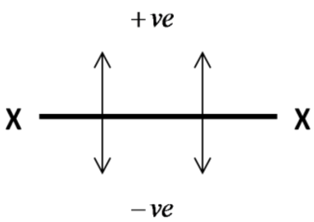
MOHR'S CIRCLE:

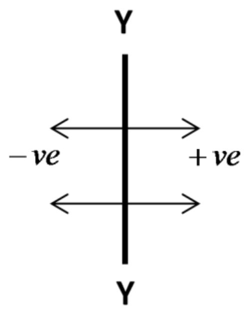
Mohr's circle is a graphical method which is used to determine the normal, shear and resultant stresses.

Sign Convention:

- The angle is taken with respect to X-X axis. All the angles shown in anticlockwise direction to X-X axis are negative and all the angles shown in clockwise direction to X-X axis are positive.







- The measurements above X-X axis are positive and below X-X axis are negative. The measurements to the right of Y-Y axis are positive and to the left of Y-Y axis are negative.

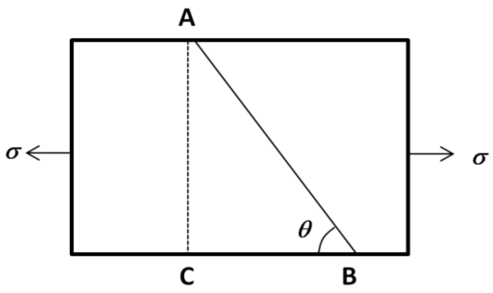
CONSTRUCTION OF MOHR'S CIRCLE

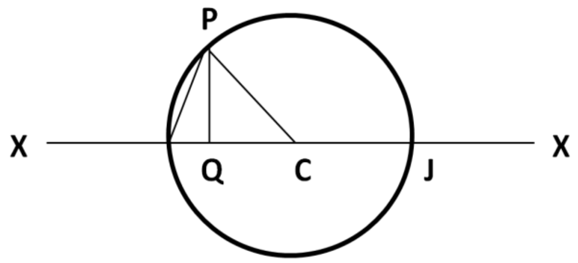
1. **Stresses on an oblique section of a body subjected to a direct stress in one plane:**

   - Draw a horizontal line XOX
   - Cut OJ equal to tensile stress (σ) to some suitable scale. Divide OJ into two equal parts as OC and CJ. The point O represents the stress system on plane BC and the plane J represents stress system on plane AC.
   - Take C as the centre and OC as the radius and draw the circle. This is known as Mohr's circle for stresses.

- Through C draw a line CP at an angle of 2ϴ with CO in clockwise direction meeting the circle at P. The point P represents the section AB.
- Through P, draw PQ perpendicular to OX. Join OP.
- In figure OQ, QP and OP gives the value of normal stress, shear stress and resultant stress.
- The angle POJ is called the angle of obliquity (ϴ).
- When 2ϴ is equal to 90^0 or 270^0 then maximum shear stress will obtain. $\angle \boldsymbol{PCQ} = \mathbf{2\Theta}$

MOHR'S CIRCLE

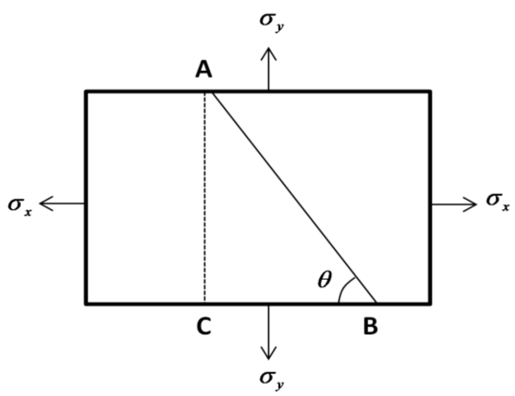


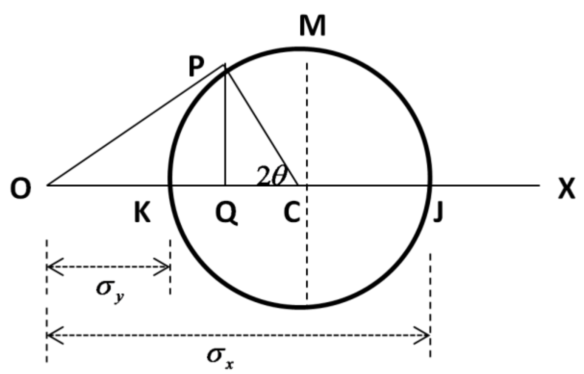


2. **Stresses on an oblique section of a body subjected to direct stresses in two mutually perpendicular directions:**

- Draw a horizontal line OX. Cut off OJ and OK equal to the tensile stresses σx and σy to some suitable scale towards right of O.
- The point J represents the stress system on the plane AC and point K represents the stress system on the plane BC. Bisect JK at C.
- Take C as the centre and CJ as the radius and draw a circle. It is known as Mohr's circle of stresses.
- Draw a line CP through C making an angle 2ϴ with CK in clockwise direction. CP line meets the circle at P. The point P represents the stress systems on the section AB.
- Draw perpendicular PQ from point P to the axis OX. Join OP.
- In figure OQ, QP and OP gives the value of normal stress, shear stress and resultant stress.
- CM and CN give the maximum shear stress to the scale. The angle POC is called as the angle of obliquity.

MOHR'S CIRCLE

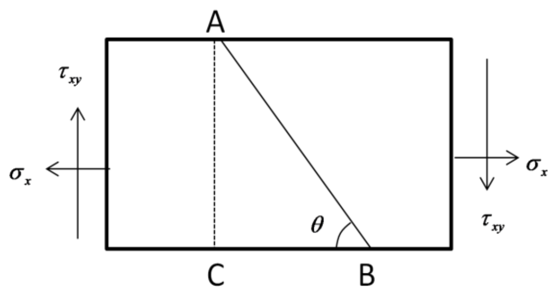


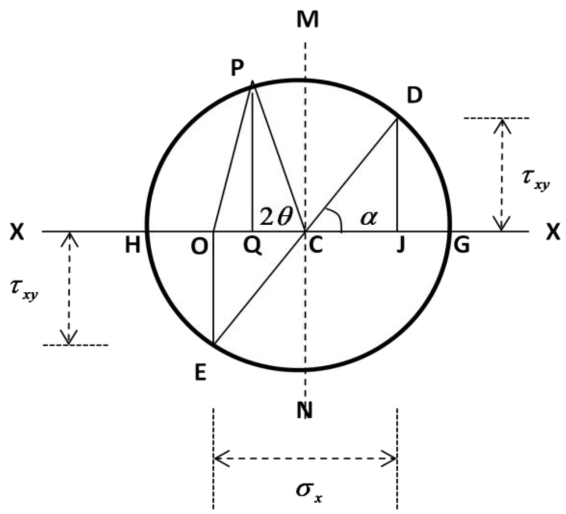


3. **Stresses on an oblique section of a body subjected to a direct stresses in one plane with a shear stress:**

- Draw a horizontal line XOX.
- Cut off OJ equal to the tensile stress σ_x to some suitable scale towards right.
- Draw a perpendicular from J vertically upward and cut JD equal to τ_{xy} to scale. The point D represents the stress system on plane AC.
- Draw a perpendicular from O vertically downward and cut OE equal to τ_{xy} to scale. The point E represents the stress system on plane BC.
- Join DE and bisect it at C.
- Take C as the centre and CD as the radius and draw a circle. It is known as the Mohr's circle of stresses.
- Draw a line CP through C making an angle 2Θ with CE in clockwise direction. The point P will lie on the circle which represents the stress system on plane AB.
- Draw a perpendicular PQ through P to meet the line XOX at Q. Join OP.
- In figure OQ, QP and OP give the normal, shear and resultant stresses to scale. The angle POC is called the angle of obliquity.

MOHR'S CIRCLE

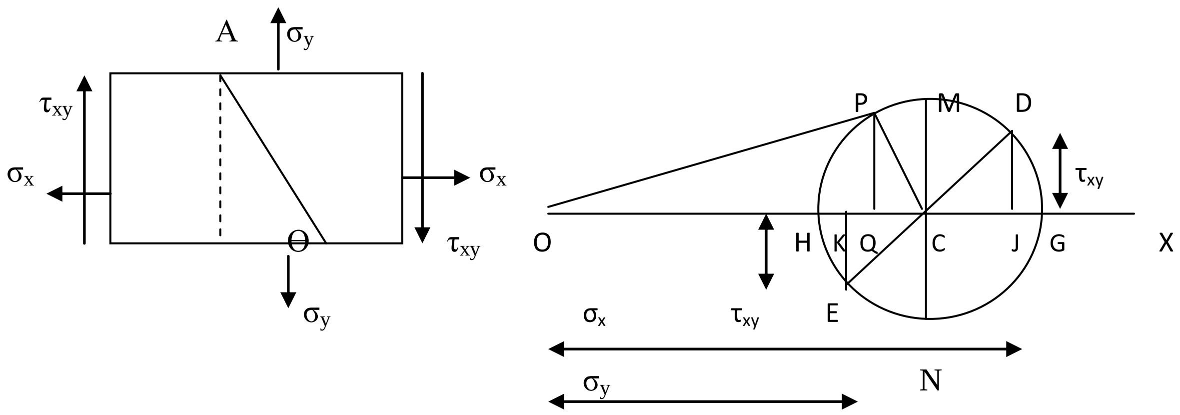




4. **Stresses on an oblique section of a body subjected to direct stresses in two mutually perpendicular directions with a shear stress:**

- Draw a horizontal line OX.
- Cut off OJ and OK equal to tensile stresses σ_x and σ_y respectively to some suitable scale towards right.
- Draw a perpendicular through J vertically upward and cut off JD equal to the shear stress τ_{xy} to scale. The point D represents the stress system on plane AC.
- Draw a perpendicular through K vertically downward and cut KE equal to the shear stress τ_{xy} to scale. The point E represents the stress system on plane BC.
- Join DE and bisect it at C.
- Take C as the centre and radius equal to CD and draw a circle. It is known as Mohr's circle of stresses.

- Draw a line CP through C making an angle 2ϴ with CE in clockwise direction meeting the circle at P. The point P represents the stress system on section AB.
- Draw a perpendicular PQ to the line OX through P. Join OP.
- In figure OQ, QP and OP give the normal, shear and resultant stress respectively to scale.
- OG and OH give the maximum and minimum principal stresses to scale. The angle POC is called as the angle of obliquity.



MOHR'S CIRCLE

***** ASSIGNMENT – 04 *****

Q-1) The stresses at a point of a machine component are 150 MPa and 50 MPa both tensile. Find the intensities of normal, shear and resultant stresses on a plane inclined at an angle of 55^0 with the axis of major tensile stress. Also find the magnitude of the maximum shear stresses in the component.

Q- 2) The stresses at a point in a component are 100 MPa (tensile) and 50 MPa (compressive). Determine the magnitude of the normal and shear stresses on a plane inclined at an angle of 25^0 with tensile stresses. Also determine the direction of the resultant stresses and the magnitude of the maximum intensity of shear stress.

Q-3) A plane element in a rigid body is subjected to a tensile stress of 100 MPa accompanied by a clockwise shear stress of 25 MPa. Find (i) the normal and shear stress on a plane inclined at an angle of 20^0 with the tensile stress; and (ii) the maximum shear stress on the plane.

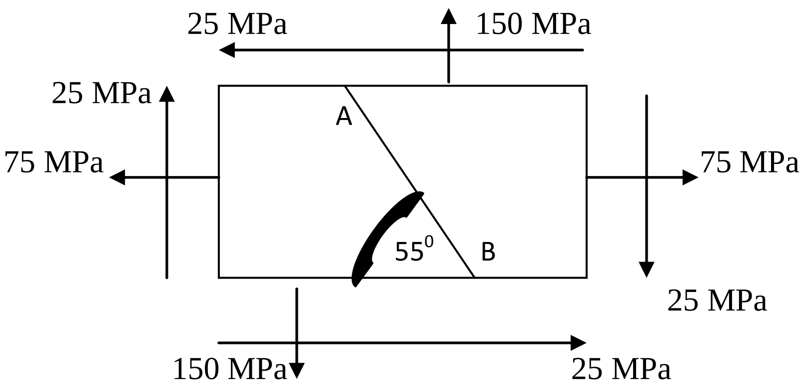
Q-4) An element in a strained body is subjected to a tensile stress of 150 MPa and a shear stress of 50 MPa tending to rotate the element in an anticlockwise direction. Find (i) the magnitude of the normal and shear stresses on a section inclined at 40^0 with the tensile stress; and (ii) the magnitude and direction of maximum shear stress that can exist on the element.

Q-5) An element in a strained body is subjected to a compressive stress of 200 MPa and a clockwise shear stress of 50 MPa on the same plane. Calculate the values of normal and shear stresses on a plane inclined at 35^0 with the compressive stress. Also calculate the value of maximum shear stress in the element.

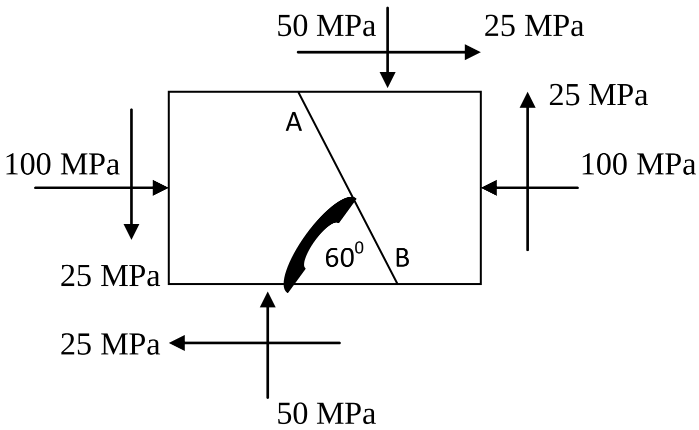
Q-6) A point is subjected to a tensile stress of 250 MPa in the horizontal direction and another tensile stress of 100 MPa in the vertical direction. The point is also subjected to a simple shear stress of 25 MPa, such that when it is associated with the major tensile stress, it tends to rotate the element in the clockwise direction. What is the magnitude of the normal and shear stresses inclined on a section at an angle of 20^0 with the major tensile stress?

Q-7) A plane element in a boiler is subjected to tensile stresses of 400 MPa on one plane and 150 MPa on the other at right angle to the former. Each of the above stresses is accompanied by shear stress of 100 MPa such that when associated with the major tensile stress tends to rotate the element in an anticlockwise direction. Find (i) principal stresses and their directions and (ii) maximum shearing stresses and directions of the plane on which they act.

Q-8) A point in a strained material is subjected to the stresses as shown in figure. Find the normal and shear stresses on the section AB.



Q-9) A machine component is subjected to the stresses as shown in figure. Find the normal and shearing stresses on the section AB inclined at an angle of 600 with X-X axis. Also find the resultant stress on the section.



(Refer R.S Khurmi – Strength of Material book)

SHEAR FORCE & BENDING MOMENT

BEAM:

It is a member of a structure which can carry forces or couple acting on it.

TYPES OF BEAM:

- **Cantilever beam**: It is a beam whose one end is fixed and other end is free.
- **Simply supported beam**: It is a beam whose both ends are freely supported.
- **Overhanging beam**: It is a beam which is freely supported at any two points and having one or both ends projected beyond these two supports.
- **Continuous beam**: It is a beam which is supported at more than two supports.
- **Fixed beam**: It is a beam whose both ends are fixed or built into its supports.

STATICALLY DETERMINATE BEAMS:

If the reactions of the supports of the beams can be determine by the equations of static equilibrium, such beams are known as statically determinate beams. The value of the support reactions is independent of deformation.

STATICALLY INDETERMINATE BEAMS:

If the reactions of the supports of the beams can't be determine by the equations of static equilibrium, such beams are known as statically indeterminate beams. The value of the support reactions are based on deformation.

TYPES OF LOADING:

- **Concentrated or point load**: It is a load which acts at a point on the beam.
- **Uniformly distributed load**: It is a load which spreads over the entire length or part of the length of the beam at a uniform rate.
- **Non uniformly distributed or uniformly varying load**: It is a load which spreads over the entire length or part of the length of the beam at a non uniform rate.

SHEAR FORCE:

Shear force at any cross section of the beam is the algebraic sum of the vertical components of the forces acting on the beam.

BENDING MOMENT:

The bending moment at any point on a loaded beam is the algebraic sum of the moments of all the forces acting on one side of the point about the point.

SHEAR FORCE DIAGRAM:

It is the diagram which represents the variation/distribution of shear force along the length of the beam.

BENDING MOMENT DIAGRAM:

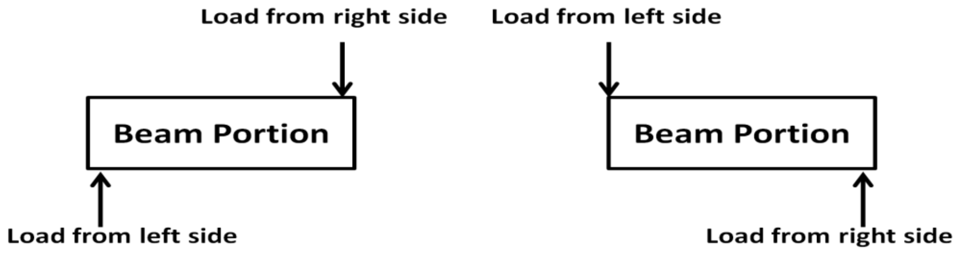
It is the diagram which represents the variation/distribution of bending moment along the length of the beam.

SIGN CONVENTION:

Sign convention is always selected according to the selection of the beam either from the left or right side of the beam.

<u>Sign convention of shear force:</u>

- ♣ Shear force is taken as positive, if the left hand portion of the beam tends to slide upwards and right hand side of the beam tends to slide downward. (figure - 1)
- ♣ Shear force is taken as negative, if the left hand portion tends to slide downwards and the right hand side tends to slide upwards. (figure - 2)



(Positive shear force) *(Negative shear force)*

FIG-1 FIG-2

<u>Sign convention of bending moment:</u>

- ♣ Moment due to all downward forces is taken as negative (hogging moment) and the moment due to all upward forces (sagging moment) are taken as positive.
- ♣ BM is taken as positive, if it is acting in clockwise direction to the left or in anticlockwise direction to the right.
- ♣ BM is taken as negative, if it is acting in anticlockwise direction to the left or in clockwise direction to the right.

Sagging bending moment (positive) **Hogging bending moment (Negative)**

SAGGING BENDING MOMENT:

It represents the positive bending moment. If the bending moment tends to bend the beam to produce concavity at the point of curvature, the bending moment is known as sagging bending moment.

HOGGING BENDING MOMENT:

It represents the negative bending moment. If the bending moment tends to bend the beam to produce convexity at the point of curvature, the bending moment is known as hogging bending moment.

RELATION BETWEEN LOADING, SHEAR FORCE AND BENDING MOMENT:

- ♣ If there is a point load at any section of a beam, then the SF suddenly changes but the BM does not change. The SF line is vertical.
- ♣ If there is no load between any two points of a beam section SF does not change but the BM changes linearly. The SF line is horizontal but BM line is an inclined straight line.
- ♣ If there is a U.D.L between two points, then the SF changes linearly and BM changes according to parabolic law. The SF line is an inclined straight line but the BM line is a parabola.

Determination of Shear force and Bending Moment and Shear force and Bending moment diagram for the following cases:

1. **Cantilever beam with point load (**concentrated loads**)**

   - ➢ *Determine the reaction force at the fixed end.*
   - ➢ *Determine the SF at the required points (including the free and fixed end).*
   - ➢ *Determine the BM at the required points (including the free and fixed end).*
   - ➢ *Draw the SFD*
   - ➢ *Draw the BMD*

2. **Cantilever beam with Uniformly distributed load (**U.D.L**)**

   - ➢ *Determine the reaction force at the fixed end.*
   - ➢ *Determine the SF at the required points (including the free and fixed end).*
   - ➢ *Determine the BM at the required points (including the free and fixed end).*
   - ➢ *Draw the SFD.*
   - ➢ *Draw the BMD.*

3. **Cantilever beam with U.D.L and point load**

   - ➢ *Determine the reaction force at the fixed end.*
   - ➢ *Determine the SF at the required points (including the free and fixed end).*
   - ➢ *Determine the BM at the required points (including the free and fixed end).*
   - ➢ *Draw the SFD.*
   - ➢ *Draw the BMD.*

4. **Simply supported beam with point load**

   - ➢ *Determine the reaction force at the simply supported ends.*

- *Determine the SF at the required points (including end points and the point where SF changes its sign).*
- *Determine the BM at the required points (including the end points where BM is zero and the point where there is maximum BM).*
- *Draw the SFD.*
- *Draw the BMD.*

5. Simply supported beam with U.D.L

- *Determine the reaction force at the simply supported ends.*
- *Determine the SF at the required points (including end points and the point where SF changes its sign).*
- *Determine the BM at the required points (including the end points where BM is zero and the point where there is maximum BM).*
- *Draw the SFD.*
- *Draw the BMD.*

6. Simply supported beam with U.D.L and point load

- *Determine the reaction force at the simply supported ends.*
- *Determine the SF at the required points (including end points and the point where SF changes its sign).*
- *Determine the BM at the required points (including the end points where BM is zero and the point where there is maximum BM).*
- *Draw the SFD.*
- *Draw the BMD.*

***** ASSIGNMENT – 05 *****

GROUP – A (2 mark questions)

1. Define cantilever beam.
2. Name the various types of beams.
3. Define Shear force and bending moment diagram.
4. Define point of contraflexure.
5. What is the maximum bending moment for a simply supported beam with UDL over the entire span?
6. What is the maximum bending moment for a simply supported beam carrying a point load at its middle?

GROUP – B (5 mark questions)

1. State the relationship between loading, shear force and bending moment.
2. Draw the shear force and bending moment diagram for a cantilever beam carrying UDL of w/unit metre over its whole span of *l*.
3. A cantilever beam of 8 m length is loaded with a point load of 50 kg at its free end and UDL of 10 kg/m over 4 m from its fixed end. Sketch the SF and BM diagram.

4. A cantilever beam AB, 2 m long carries a uniformly distributed load of 1.5 kN/m over a length of 1.6 m from the free end. Draw the SF and BM diagram for the beam.
5. A cantilever beam of length 2 m is subjected to load 500 N at its free end 800 N at a distance 0.5 m from its free end, Determine the SF and BM diagram for the beam.
6. Draw the SFD and BMD for a simply supported beam carrying a point load at its middle.
7. Draw the SFD and BMD for a simply supported beam carrying a UDL of w/unit meter length over its whole span.

GROUP – C (10 mark questions)

1. Draw the shear force and bending moment diagram for a cantilever beam of span 2 m subjected to load 500 N at the free end and loads 800 N, 300 N, 400 N at distance 0.5 m, 1 m, and 1.5 m from its free end.
2. A beam AB 10 m long is simply supported at its ends A and B. It carries a UDL of 20 kN/m for a distance of 5 m from the left end A and a concentrated load of 40 kN at a distance of 2 m from the right end B. Draw the S.F and B.M diagrams for the beam.
3. A beam AB 10 m long has supports at its ends A and B. It carries a point load of 5 kN at 3 m from A and a point load of 5 kN at 7 m from A and a UDL of 1 kN per metre between the point loads. Draw the S.F and B.M diagrams for the beam.

THEORY OF SIMPLE BENDING

SIMPLE BENDING:

When a straight beam is subjected to a couple at its ends, constant bending moment will produce at every cross section of the beam with no shear stress. This condition the beam is called as pure torsion or simple bending.

ASSUMPTION IN PURE BENDING:

- The material of the beam is same throughout (homogeneous) and possesses same elastic properties (isotropic) in all direction.
- The transverse section of the beam which is plane before bending remains same after bending.
- Young's modulus for the material is same in tension and compression.
- Each layer of the beam is free to expand or contract independently.
- The radius of curvature of the beam after bending is large as compared to its cross sectional dimensions.
- Loads act perpendicular to the axis of the beam.
- The beam is in equilibrium i.e. the resultant pull or thrust on the transverse section of the beam is zero.

VARIOUS TYPES OF SECTIONS:

Various types of engineering sections may be classified as symmetrical, unsymmetrical and built-up sections.

- Symmetrical sections: In this type of sections the centre of gravity lies at the geometrical centre of the sections. The neutral axis passes through the geometrical centre of the section. Ex – circular/ square/ rectangular sections.
- Unsymmetrical sections: In this type of sections the centre of gravity does not lies at the geometrical centre of the sections. Neutral axis passes through the centre of gravity.
  Ex – T, L, I sections.

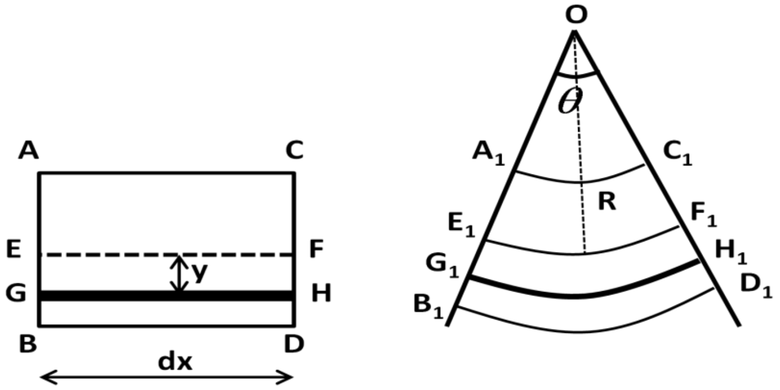
THEORY OF SIMPLE BENDING:

A small portion of a beam ABCD is shown in figure-1.
AB and CD are the two planes.
Let this portion is subjected to simple bending.
Let EF is the length of neutral layer.
Consider another layer GH at a distance 'y' from the neutral axis.
Consider all the layers bend as shown in figure – 2.
The layers AB, CD, EF and GH deformed to A_1B_1, C_1D_1, E_1F_1 and G_1H_1 respectively.
All the layers above EF get compressed and the layers below EF get elongated.

As EF is the neutral layer, its length will remain unchanged.
So $EF = E_1F_1$
Let all the layers bend into arcs with centre 'O' of radius of curvature
'R' and angle between the planes is 'θ'.
Before bending lengths of all layers is same i.e. $GH = EF = E_1F_1$
After deformation $G_1H_1 = (R+ y)\,\theta$
$EF = E_1F_1 = R\,\theta$

Change in length of the layer GH = $(R+y)\,\theta - R\,\theta = y\,\theta$

Strain in the layer GH = e = $\frac{change\ \ in\ lengt\,h}{original\ \ lengt\,h}$ $= \frac{y\,\theta}{R\,\theta} = \frac{y}{R}$



Let, σ = intensity of stress of the layer

E = Young's modulus

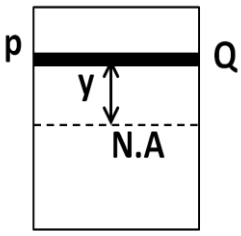
$\therefore\ e = \frac{y}{R} = \frac{\sigma}{E}$ or $\frac{\boldsymbol{\sigma}}{\boldsymbol{y}} = \frac{\mathbf{E}}{\mathbf{R}}$ ---------- **(1)**

or $\sigma = \frac{E}{R} \times y$

MOMENT OF RESISTANCE:

It is the algebraic sum of the moment about neutral axis of the internal forces developed in a beam due to bending.

Consider a beam section as shown in figure.
Consider a small layer PQ at a distance 'y' from the neutral axis.



Let, dA = elementary area of PQ

Intensity of shear stress in the layer PQ = $\sigma = \frac{E}{R} \times y$

Total stress/thrust in the layer PQ = $\frac{E}{R} \times y \times dA$

Moment of resistance offered by the elementary area = Moment of the-
thrust about the neutral axis = total stress × distance = $\frac{E}{R} \times y^2 \times dA$

Total moment of resistance offered by the beam section = $\frac{E}{R} \sum y^2\ dA$

$\sum y^2\ dA$= moment of inertia of the beam section about the neutral axis

Thus $M = \frac{E}{R} \times I$

$\Rightarrow$ $\frac{\mathbf{M}}{\mathbf{I}} = \frac{\mathbf{E}}{\mathbf{R}}$ --------------- (2)

We know that, $\frac{\mathbf{E}}{\mathbf{R}} = \frac{\boldsymbol{\sigma}}{\boldsymbol{y}}$

So we may write $\frac{\mathbf{M}}{\mathbf{I}} = \frac{\mathbf{E}}{\mathbf{R}} = \frac{\boldsymbol{\sigma}}{\boldsymbol{y}}$ ___________ **(3)**

This is known as Bending equation.

SECTION MODULUS:

It is the ratio between moment of inertia of the section of the beam and the maximum distance of layer from the neutral axis.

Mathematically, *section modulus* (Z) = $\frac{\mathbf{I}}{\mathbf{Y}}$

So we may write, $\mathbf{M = \sigma \times Z}$ ________ **(4)**

POLAR MODULUS:

It is the measure of the strength of the shaft in torsion. It is the ratio between the polar moment of inertia of the beam section and the radius of curvature. It is denoted by Z_P. Mathematically, $\mathbf{Z_P = \frac{I_p}{R}}$

***** PROBLEM *****

Q – 1) *A steel plate is bent into a circular arc of radius 10 m. If the plate section be 120 mm wide and 20 mm thick, find the maximum stress induced and the bending moment which can produce this stress. Take E = 2 × 10^5 N/mm^2.*

Ans) Data Given

Radius of curvature (R) = 10 m width = 120 mm
thickness = 20 mm E = 2×10^5 N/mm^2

Moment of inertia of the section about the neutral axis = I = $\frac{120 \times 20^3}{12}$ = **80000 mm^4**

we know that, $\frac{M}{I} = \frac{E}{R} = \frac{\sigma}{y}$ $\Longrightarrow$ $\sigma = \frac{E}{R} \times y$

$\therefore$ $\sigma_{max} = \frac{2 \times 10^5}{10 \times 10^3} \times \left(\frac{20}{2}\right) = \mathbf{200\ N/mm^2}$

Bending moment (M) = $\frac{E}{R} \times l = \frac{2 \times 10^5}{10 \times 10^3} \times \mathbf{8 \times 10^4} = 16 \times 10^5$ N-mm **(ANS)**

Q – 2) *A cast iron test beam 20 mm × 20 mm in section and 1 m long and supported at the ends fails when a central load of 640 N is applied. What uniformly distributed load will break a cantilever of same material 50 mm wide, 100 mm deep and 2 m long?*

Ans) Data Given

Cast iron test beam : Cross section of = 20 mm × 20 mm
length = 1 m = 1000 mm
load (W) = 640 N

C**antilever :** width = 50 mm depth = 100 mm length = 2 m = 2000 mm

for the test beam, maximum bending moment = M = $\frac{WL}{4} = \frac{640 \times 1000}{4} = 16 \times 10^4$ N-mm

moment of resistance = $\frac{1}{6} \sigma b d^2 = \frac{1}{6} \sigma \times 20 \times 20^2 = \frac{4000}{3} \times \sigma$ N-mm

Equating these two we get, $\frac{4000}{3} \times \sigma = 16 \times 10^4$

$\therefore$ $\sigma = 120$ N/mm^2

for the cantilever consider the UDL required is w/metre run

so, maximum bending moment = M = $\frac{Wl^2}{2} = \frac{W \times 2000^2}{2}$ = 2000 w N-mm

moment of resistance of the section = $\frac{1}{6} \sigma b d^2 = \frac{1}{6} \times 120 \times 50 \times 100^2 = 10 \times 10^6$ N-mm

Equating these two we get, 2000 w = 10×10^6

$\therefore$ w = 5000 N/m **(ANS)**

***** ASSIGNMENT – 7 *****

GROUP - A (2 mark questions)

4. Define section modulus of a beam.
5. What do you mean by symmetrical section? Give some example.
6. State bending equation for a beam section.
7. Define flexural rigidity.
8. Write the relation between bending moment and bending stress.
9. Write the expression of section modulus of a rectangular section of dimension (b × d).
10. Write the expression of section modulus of a circular section of diameter d.

GROUP – B (6 mark questions)

1. Explain the theory of simple bending.
2. State the assumption of pure bending.
3. A cast iron cantilever at length 1.5 m fails when a load of 1920 N is applied at the free end. Determine the stress at failure if the section of the cantilever is 40 mm × 60 mm.
4. A cast iron pipe of external diameter 60 mm, 10 mm thickness and 5 m long is supported at its ends. The pipe carries a point load of 100 N at its centre. Calculate the maximum flexural stress induced due to point load.
5. Find the maximum UDL that a beam can support over a span of 10 m if the maximum stress is limited to 500 kg/cm^2 and section modulus of the beam is 128 cm^3.

COMBINED DIRECT & BENDING STRESS

Column: It is a vertical bar or member of a structure, which always subjected to axial compressive forces.

Short column: It is a column whose length is less than 8 times the diameter and slenderness ratio less than 32. This type of column may fail due to direct stress.

Medium column: It is a column whose length varies from 8 to 30 times their diameter and slenderness ratio varies from 32 to 120.

Long column: It is a column whose length is more than 30 times the diameter and slenderness ratio more than 120. This type of column may fail due to bending stress.

Slenderness ratio: It is the ratio of the length of the column to the minimum radius of gyration of the cross sectional area of the column.

Buckling Load: It is the minimum limiting load acting axially on a column due to which the lateral displacement or buckling may appear on a column. It is also known as crippling or critical load.

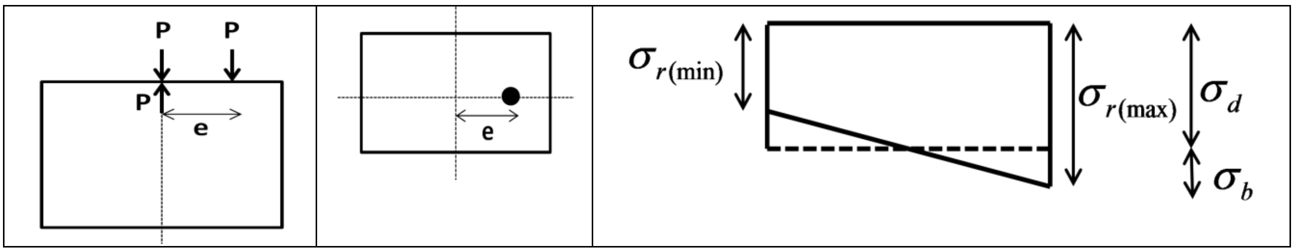
Eccentric load: If the line of action of a load does not coincide with the line passing through the body subjected to load, such a load is called eccentric load.

Eccentricity: It is the distance between the line of action of eccentric load from the centroid of the body.

Stress in short column under eccentric loading:

1. Load acting eccentrically to one axis:

   Consider a short column subjected to an eccentric load ‘P’ at a distance ‘e’ from its axis as shown in figure. From figure; at point ‘O’, there is two equal and opposite loads ‘P’.
   The downward load ‘P’ acting at ‘O’ causes a direct stress.
   The upward force acting at ‘O’ and the eccentric load causes a clockwise couple.



Let A = area of cross section of the column
σ_d = direct stress due to load ‘P’ applied axially
σ_b = bending stress at a distance ‘y’ from the neutral axis.
σ_r = resultant of direct and bending stress

Thus Direct stress = $\sigma_d = \frac{P}{A}$ ----------------------- (1)

Bending stress = $\sigma_b = \frac{M.y}{I} = \frac{P.\ e.y}{I}$ ---------------------- (2)

Resultant stress = $\sigma_r = \sigma_d \pm \sigma_b = \frac{P}{A} \pm \frac{P.\ e.y}{I}$ -------- (3)

Maximum resultant stress = $\sigma_d + \sigma_b$, when σ_b is tensile
Minimum resultant stress = $\sigma_d - \sigma_b$, when σ_b is compressive

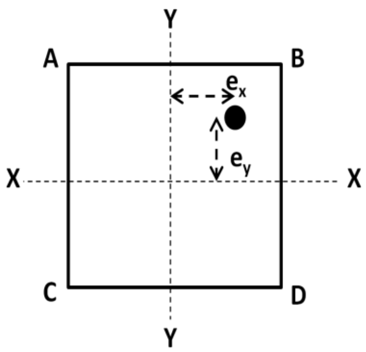
Conditions:

- When $\sigma_d > \sigma_b$; $\sigma_{r\,(max)}$ and $\sigma_{r\,(min)}$ both are positive. Compressive stresses act anywhere of the section.
- When $\sigma_d = \sigma_b$; $\sigma_{r\,(max)} = 2\ \sigma_d = 2\ \sigma_b$ and $\sigma_{r\,(min)} = 0$. Compressive stresses act anywhere of the section and varies from zero at one edge to maximum at other.
- When $\sigma_d < \sigma_b$; $\sigma_{r\,(max)} = \sigma_d + \sigma_d$, which is positive and $\sigma_{r\,(min)} = \sigma_d - \sigma_b$, which is negative. $\sigma_{r\,(max)}$ is compressive and $\sigma_{r\,(min)}$ is tensile.

2. Load acting eccentrically to both axis:

Consider a short column subjected to an eccentric load 'P' with eccentricity about both axes as shown in figure.

Let A = area of cross section of the column
P = load acting on the column
e_x = eccentricity of the load about Y-Y axis
e_y = eccentricity of the load about X-X axis



Moment of the load about X-X axis = $M_x = P \times e_y$
Moment of the load about Y-Y axis = $M_y = P \times e_x$
Direct stress due to load P = $\sigma_d = \frac{P}{A}$
Bending stress due to eccentricity $e_x = \sigma_{by} = \frac{P\ .\ e_x\ .\ x}{I_{yy}} = \frac{M_y\ .x}{I_{yy}}$
Bending stress due to eccentricity $e_y = \sigma_{bx} = \frac{P\ .\ e_y\ .\ y}{I_{xx}} = \frac{M_x\ .\ y}{I_{xx}}$

Resultant stress = $\sigma_r = \frac{P}{A} \pm \frac{M_x\ .\ y}{I_{xx}} \pm \frac{M_y\ .x}{I_{yy}}$

Maximum stress at B = $\sigma_{B\,(max)} = \frac{P}{A} + \frac{M_x\ .\ y}{I_{xx}} + \frac{M_y\ .x}{I_{yy}}$ -------------- (1)

Minimum stress at C = $\sigma_{C\,(min)} = \frac{P}{A} - \frac{M_x\ .\ y}{I_{xx}} - \frac{M_y\ .x}{I_{yy}}$ -------------- (2)

Stress at A = $\sigma_A = \frac{P}{A} + \frac{M_x\ .\ y}{I_{xx}} - \frac{M_y\ .x}{I_{yy}}$ ------------------------ (3)

Stress at D = $\sigma_D = \frac{P}{A} - \frac{M_x\ .\ y}{I_{xx}} + \frac{M_y\ .x}{I_{yy}}$ ----------------------- (4)

Limit of eccentricity:

Consider the stresses are compressive and no tensile stress in a column.

For this case $\sigma_b \leq \sigma_d$ $\Rightarrow$ $\frac{P.e}{Z} \leq \frac{P}{A}$

$\therefore$ $\mathbf{e} \leq \frac{\mathbf{Z}}{\mathbf{A}}$ --------------------------- (5)

For rectangular section, $\mathbf{e} \leq \frac{\mathbf{b}}{\mathbf{6}}$

For circular section, $e \leq \frac{\mathbf{d}}{\mathbf{8}}$

Euler's formula for various end conditions of the column:

Conditions	Formula for Cripping load	
When both ends hinged	$P = \frac{\pi^2 E I}{L^2} = \frac{\pi^2 E I}{l_e^{\,2}}$	P = least buckling load
When both ends fixed	$P = \frac{4\pi^2 E I}{L^2} = \frac{4\pi^2 E I}{(2l_e)^2}$	E = Young's modulus
When one end fixed and other end hinged	$P = \frac{2\pi^2 E I}{L^2} = \frac{2\pi^2 E I}{(\sqrt{2}\, l_e)^2}$	I = moment of inertia
When one end fixed and other end free	$P = \frac{\pi^2 E I}{4L^2} = \frac{4\pi^2 E I}{4\left(\frac{l_e}{2}\right)^2}$	L = total length of column l_e = equivalent length

***** PROBLEM *****

Q-1) A rectangular strut is 150 mm wide and 120 mm thick. It carries a load of 180 kN at an eccentricity of 10 mm in a plane bisecting the thickness. Find the maximum and minimum intensities of stress in the section.

Ans) <u>Data Given</u>

Width (b) = 150 mm thickness (t) = 120 mm

load (P) = 180 kN = 180×10^3 N eccentricity (e) = 10 mm

area of the strut = 150 × 120 = 18 000 mm^2

maximum intensities of stress in the section (σ_{max}) = $\frac{P}{A}\left(1 + \frac{6\,e}{b}\right)$

$= \frac{180 \times 10^3}{18000}\left(1 + \frac{6 \times 10}{150}\right) = 10\,(1 + 0.4) = 14\ N/mm^2 = 14\ MPa$

minimum intensities of stress in the section (σ_{min}) = $\frac{P}{A}\left(1 - \frac{6\,e}{b}\right)$

$= \frac{180 \times 10^3}{18000}\left(1 - \frac{6 \times 10}{150}\right) = 10\,(1 - 0.4) = 6\ N/mm^2 = 6\ MPa$

Q-2) A hollow circular column having external and internal diameters of 300 mm and 250 mm respectively carries a vertical load of 100 kN at the outer edge of the column. Calculate the maximum and minimum intensities of stress in the section.

Ans) Data Given

External diameter (D) = 300 mm internal diameter (d) = 250 mm

load (P) = 100 kN = 100×10^3 N

area of the circular column (A) = $\frac{\pi}{4}(D^2 - d^2) = \frac{\pi}{4}[(300)^2 - (250)^2] = 21.6 \times 10^3$ mm^2

section modulus (z) = $\frac{\pi}{32} \times [\frac{D^4 - d^4}{D}] = \frac{\pi}{32} \times [\frac{300^4 - 250^4}{300}] = 1372 \times 10^3$ mm^3

as the column carries the vertical load at its outer edge, so we can write e = 150 mm

Moment due to eccentricity of load = M = P . e = $(100 \times 10^3) \times 150 = 15 \times 10^6$ N-mm

Maximum intensities of stress in the section (σ_{max}) = $\frac{P}{A} + \frac{M}{Z} = \frac{100 \times 10^3}{21.6 \times 10^3} + \frac{15 \times 10^6}{1372 \times 10^3}$

= 4.63 + 10.93 = 15.56 N/mm^2 = 15.5 MPa

Minimum intensities of stress in the section (σ_{min}) = $\frac{P}{A} - \frac{M}{Z} = \frac{100 \times 10^3}{21.6 \times 10^3} - \frac{15 \times 10^6}{1372 \times 10^3}$ N/mm^2

= 4.63 - 10.93 = - 6.3 N/mm^2 = 6.3 MPa (tension)

***** ASSIGNMENT – 6 *****

GROUP – A (2 mark questions)

1. What is a column?
2. Differentiate between long and short column.
3. Define crippling load.
4. Write the expressions for crippling load for columns for various end conditions.
5. What is eccentric loading?

GROUP – B (5 mark questions)

1. Write short notes on crippling load.
2. Define a column. State the expression for crippling load under various end conditions.
3. A rectangular column 200 mm wide and 150 mm thick is carrying a vertical load of 120 kN at an eccentricity of 50 mm in a plane bisecting the thickness. Determine the maximum and minimum intensities of stress in the section.

GROUP – C (10 mark questions)

1. A rectangular column of 240 mm × 150 mm is subjected to a vertical load of 10 kN placed at an eccentricity of 60 mm in a plane bisecting 150 mm side. Determine stress intensities in the section. **(*Ans*: 695 kN/m^2, -139 kN/m^2)**
2. The line thrust in a compression testing specimen of 2 cm diameter is parallel to the axis of the specimen but is displaced from it. Calculate the distance of the line of thrust from the axis when the maximum stress is 20% greater than the mean stress on a normal section. **(*Ans*: 0.05cm)**
3. A hollow rectangular masonry pier is 1.2 m × 0.8 m wide and 150 mm thickness. A vertical load of 2 MN is transmitted in the vertical plane bisecting 1.2 m side and at an eccentricity of 100 mm from the geometric axis of the section. Calculate the maximum and minimum stress intensities in the section.

TORSION

TORSION:

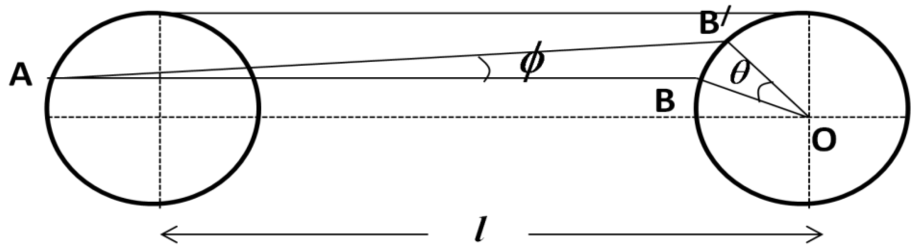
When two equal and opposite torques acts at the two ends of the shaft to produce the possibility of shearing of shaft perpendicular to its longitudinal axis, the shaft is said to be in torsion. Due to torsion or twisting moment every section of shaft subjected to some shear stress.

ASSUMPTION OF PURE TORSION:

- The material of the shaft is uniform throughout.
- The twist along the length of the shaft is uniform throughout.
- The shaft circular in section remains circular after twisting.
- All diameters which are straight before twist remains straight after twist.
- The plane of the shaft normal to its axis before twist remains plane after twist.
- Maximum shear stress induced in the shaft does not exceed its elastic limit.

THEORY OF PURE TORSION:

Consider a circular shaft of radius R and length *l* fixed at one end and its other end is subjected to twisting moment as shown in figure.



Let, the line AB on the surface of the shaft is deformed to AB' and OB to OB'.

Let, $\angle BAB' = \phi$ = shear strain and $\angle BOB' = \Theta$ = angle of twist

$\therefore$ shear strain $= \phi = \frac{BB'}{L} = \frac{R\Theta}{L}$

Let, τ = shear stress on the surface of the shaft, C = modulus of rigidity

we know that, $\frac{\tau}{\phi} = C$ or $\frac{\tau}{C} = \phi = \frac{R\Theta}{L}$ $\Rightarrow$ $\mathbf{\frac{\tau}{R} = \frac{C\,\Theta}{L}}$ **= constant** ------------- (1)

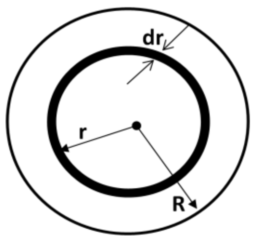
For a shaft the value of C,Θ and L are constants.

Shear stress is maximum at the outer surface and zero at the centre.

TORSIONAL MOMENT OF RESISTANCE:

Consider an elementary ring of the shaft of thickness 'dr' at a radius 'r' from the centre of the shaft as shown in figure.

Let, τ_1 = shear stress at this radius dA = elementary area of the of the ring



Total force acting on the ring = area of the ring × stress on the ring

$= 2\,\pi\, r \times dr \times \tau_1$

Moment of the force about axis of the shaft $= 2\,\pi\, r \times dr \times \tau_1 \times r$

$= 2\,\pi\, r^2 \times dr \times \tau_1$

$= 2\,\pi\, r^2 \times dr \times \frac{\tau_1}{R} \times r$

$= 2\,\pi\, r^3 \times dr \times \frac{\tau}{R}$

As $\frac{\tau}{R} = \frac{\tau_1}{r} = \frac{C\,\theta}{L}$ = constant, we may write $\boldsymbol{\tau_1 = \frac{\tau}{R} \times r}$

Total moment of resistance of the shaft section = $\int_0^R 2\,\pi\, r^3 \times dr \times \frac{\tau}{R}$

Total resisting moment = Applied torque

So, we may write

$$T = \int_0^R 2\,\pi\, r^3 \times dr \times \frac{\tau}{R} = 2\,\pi \frac{\tau}{R} \int_0^R r^3 \times dr$$

$$= 2\,\pi \times \frac{\tau}{R} \times \left[\frac{R^4}{4}\right]_0^R = 2\,\pi \times \frac{\tau}{R} \times \frac{R^3}{4}$$

$$= \frac{2\,\pi\,\tau\,(D/2)^2}{4} = \frac{\pi}{16} \times D^3 \times \tau$$

$\therefore$ $\boldsymbol{T = \frac{\pi}{16} \times \tau \times D^3}$

Relation:

$$T = \frac{\pi}{16} \times \tau \times D^3 \times \frac{D}{2} \times \frac{2}{D} = \frac{\pi}{32} \times \tau \times D^4 \times \frac{2}{2R}$$

$$= I_P \times \frac{\tau}{R}$$

Where $I_p = \frac{\pi}{32} \times D^4$ = **polar moment of inertia** of the section of the shaft.

$\Rightarrow$ $\frac{T}{I_P} = \frac{\tau}{R}$ We know that, $\boldsymbol{\frac{\tau}{R} = \frac{C\,\theta}{L}}$

Comparing the two equation we get

$$\boldsymbol{\frac{T}{I_P} = \frac{\tau}{R} = \frac{C\,\theta}{L}} \quad \text{-------------------- (2)}$$

This is known as the **torsion equation.**

POLAR MOMENT OF INERTIA:

The moment of inertia of a plane area about an axis perpendicular to the plane of the area is called polar moment of inertia of the area with respect to the point at which the axis intersects the plane.

For solid shafts it is given by $I_P = \frac{\pi}{32} \times D^4$

For hollow shafts it is given by $I_P = \frac{\pi}{32} \times (D^4 - d^4)$

POLAR MODULUS:

It is the ratio of polar moment of inertia to the radius of the shaft.

We know that, $\boldsymbol{\frac{T}{I_P} = \frac{\tau}{R}}$

$\Rightarrow$ $\boldsymbol{T = \tau \times \frac{I_P}{R} = \tau \times Z_P}$ where, Z_P = polar modulus of the shaft section

STRENGTH OF A SOLID SHAFT:

Consider an elementary ring of the shaft of thickness 'dr' at a radius 'r' from the centre of the shaft as shown in figure.

Let, τ_1 = shear stress at this radius

dA = elementary area of the of the ring

Total force acting on the ring = area of the ring × stress on the ring
$= 2\,\pi\, r \times dr \times \tau_1$

Moment of the force about axis of the shaft $= 2\,\pi\, r \times dr \times \tau_1 \times r$
$= 2\,\pi\, r^2 \times dr \times \tau_1$
$= 2\,\pi\, r^2 \times dr \times \frac{\tau_1}{R} \times r$
$= 2\,\pi\, r^3 \times dr \times \frac{\tau}{R}$

As $\frac{\tau}{R} = \frac{\tau_1}{r} = \frac{C\,\theta}{L}$ = constant, we may write $\boldsymbol{\tau_1 = \frac{\tau}{R} \times r}$

Total moment of resistance of the shaft section = $\int_0^R 2\,\pi\, r^3 \times dr \times \frac{\tau}{R}$

Total resisting moment = Applied torque

So, we may write

$T = \int_0^R 2\,\pi\, r^3 \times dr \times \frac{\tau}{R} = 2\,\pi \frac{\tau}{R} \int_0^R r^3 \times dr$

$= 2\,\pi \times \frac{\tau}{R} \times [\frac{R^4}{4}]_0^R = 2\,\pi \times \frac{\tau}{R} \times \frac{R^3}{4}$

$= \frac{2\,\pi\,\tau\,(D/2)^2}{4} = \frac{\pi}{16} \times D^3 \times \tau$

$\therefore\quad \mathbf{T = \frac{\pi}{16} \times \tau \times D^3}$

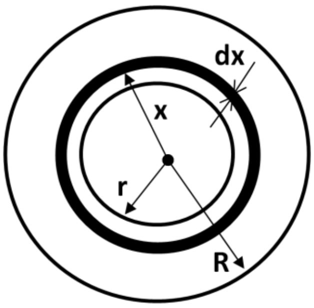
STRENGTH OF A HOLLOW SHAFT:

Consider a hollow shaft subjected to torque T.

Let, R = outer radius of shaft; r = inner radius of the hollow shaft

D = outer diameter of the hollow shaft; d = inner diameter of the hollow shaft

τ = maximum shear stress



Consider a small circular ring of thickness 'dx' at a radius x form the centre of the shaft.

τ_1 = shear stress at this radius

Total force acting on the ring = area of the ring × stress on the ring
$= 2\,\pi\, x \times dx \times \tau_1$

Moment of resistance of force on the ring $= 2\,\pi\, x \times dx \times \tau_1 \times x$
$= 2\,\pi\, x^2 \times dr \times \tau_1$
$= 2\,\pi\, x^2 \times dx \times \frac{\tau_1}{R} \times x$
$= 2\,\pi\, x^3 \times dx \times \frac{\tau}{R}$

As $\frac{\tau}{R} = \frac{\tau_1}{x} = \frac{C\,\theta}{L}$ = constant, we may write $\boldsymbol{\tau_1 = \frac{\tau}{R} \times x}$

Total moment of resistance of the shaft section = $\int_r^R 2\,\pi\, x^3 \times dx \times \frac{\tau}{R}$

Total resisting moment = Applied torque

So, we may write $T = \int_r^R 2\,\pi\, x^3 \times dx \times \frac{\tau}{R} = 2\,\pi \frac{\tau}{R} \int_0^R x^3 \times dx$

$= 2\,\pi \times \frac{\tau}{R} \times [\frac{x^4}{4}]_r^R = 2\,\pi \times \frac{\tau}{R} \times [\frac{R^4}{4} - \frac{r^4}{4}]$

$$= \quad 2\pi \times \frac{\tau}{4R} \times (R^4 - r^4) = \frac{\tau}{R} \times \frac{\pi}{2} \times (R^4 - r^4)$$

$$= \quad \frac{\tau}{\frac{D}{2}} \times \frac{\pi}{32} \times (D^4 - d^4) = \frac{\pi}{16}\ \tau \times \left[\frac{D^4 - d^4}{D}\right]$$

This is the required equation of the hollow shaft.

POWER TRANSMITTED BY A SHAFT:

Work done by the shaft per minute = Torque × angle turned in one minute

$= T_{mean} \times 2\pi N$ N-m

Power transmitted by the shaft (P) $= \frac{\text{Work done per minute}}{60000}$ KW

$$\Rightarrow \quad \mathbf{P} = \frac{T_{mean} \times 2\pi N}{60000}\ \text{kW}$$

TORSIONAL RIGIDITY:

It is the torque which produces the twist of one radian in a shaft of unit length. It is denoted by **C.I$_P$**. Mathematically, $\frac{T}{I_P} = \frac{C\,\theta}{L}$ or $C\theta = \frac{T}{I_P} \times L$

COMPARISON BETWEEN STRENGTH OF SOLID AND HOLLOW SHAFT:

We know that, Strength of solid shaft $= T_s = \frac{\pi}{16} \times \tau \times D_s^3$

Strength of hollow shaft $= T_H = \frac{\pi}{16}\ \tau \times \left[\frac{D^4 - d^4}{D}\right]$

$$\therefore \quad \frac{T_H}{T_S} = \frac{\frac{\pi}{16}\ \tau \times \left[\frac{D^4 - d^4}{D}\right]}{\frac{\pi}{16} \times \tau \times (D_S)^3} = \frac{D^4 - d^4}{D\,(D_S)^3} \quad \text{----------- (1)}$$

Let, $\frac{D}{d} = n$ or $D = nd$, substituting this value in equation-1 we get,

$$\frac{T_H}{T_S} = \frac{n^4 d^4 - d^4}{n\,d\,(D_S)^3} = \frac{(n^4 - 1)d^4}{n\,d\,(D_S)^3} = \frac{(n^4 - 1)d^3}{n\,(D_S)^3} \quad \text{----------------- (2)}$$

(T_H/T_S) ratio value is 1.44.

So we consider that, torque transmitted to the hollow shaft is greater than the solid shaft. Thus the hollow shaft is stronger than solid shaft.

COMBINED BENDING AND TORSION:

In general shafts are subjected to both bending and torsion.

From torsion equation, $\frac{T}{I_P} = \frac{\tau}{R}$

we know that, $T = \frac{\pi}{16} \times \tau \times D^3$

From bending equation, $\frac{M}{I} = = \frac{\sigma_b}{y}$

we know that, $M = \frac{\sigma_b . \pi\, D^3}{32}$

If a material is loaded and direct stress and shear stress induce in it, then according to principal stress and maximum shear stress theory we may write –

$$\sigma_{max} = \frac{\sigma_d}{2} + \sqrt{\left(\frac{\sigma_d}{2}\right)^2 + \tau^3} \quad \text{----------------- (1)}$$

$$\tau_{max} = \sqrt{\left(\frac{\sigma_d}{2}\right)^2 + \tau^3} \quad \text{----------------- (2)}$$

Multiplying both side of equation-1 with $\frac{\pi\, D^3}{32}$, we get

$$\sigma_{max} \times \frac{\pi\, D^3}{32} = \frac{\sigma_d}{2} \times \frac{\pi\, D^3}{32} + \sqrt{\left(\frac{\sigma_d}{2} \times \frac{\pi\, D^3}{32}\right)^2 + \left(\tau \times \frac{\pi\, D^3}{32}\right)^2}$$

$$\Rightarrow \quad M_e = \frac{\mathbf{M}}{\mathbf{2}} + \sqrt{(\frac{\mathbf{M}}{\mathbf{2}})^2 + (\frac{\mathbf{T}}{\mathbf{2}})^2}$$

$$\therefore \quad \mathbf{Me} = \frac{\mathbf{M} + \sqrt{\boldsymbol{M^2} + \boldsymbol{T^2}}}{\mathbf{2}} \quad \text{-------------------} \ (3)$$

where $\mathbf{M_e}$ is known as equivalent bending moment.

Multiplying both side of equation-2 with $\frac{\pi D^3}{16}$, we get

$$\tau_{max} \times \frac{\pi D^3}{16} = \sqrt{(\frac{\boldsymbol{\sigma_d}}{2} \times \frac{\pi D^3}{16})^2 + (\tau \times \frac{\pi D^3}{16})^2}$$

$$\Rightarrow \quad \mathbf{T_e} = \sqrt{(\mathbf{M})^2 + (\mathbf{T})^2} \quad \text{-------------} \ (4)$$

where $\mathbf{T_e}$ is known as equivalent twisting moment.

NOTES:

Shear stress is maximum at the outer surface of shaft and zero at its axis.
The shaft which can resist greatest twisting moment possesses greatest polar modulus.
Strength of hollow shaft is higher than solid shaft.
When a solid shaft is replaced by hollow shaft or hollow shaft by solid shaft, the torque transmitted remains same for both shafts.

Terms	**Symbol**	**Formula**	**Units**
Torsion equation	--	$\frac{\mathbf{T}}{\mathbf{I_P}} = \frac{\boldsymbol{\tau}}{\boldsymbol{R}} = \frac{\mathbf{C\,\Theta}}{\mathbf{L}}$	------
Polar moment of inertia	Ip	$Ip = \frac{\pi}{32} \times D^4$ for solid shaft and $Ip = \frac{\pi}{32} \times (D^4 - d^4)$ for hollow shaft	m^4 mm^4 cm^4
Torque transmitted	T	$\frac{\pi}{16} \times \tau \times D^3$ for solid shaft $\frac{\pi}{16}\ \tau \times [\frac{D^4 - d^4}{D}]$ for hollow shaft	N-m KN-m ----- N-mm KN-mm -----
Power transmitted	P	$\frac{Tmean \times 2\pi N}{60000}$	KW
Mean or Average torque	T or T_{mean} or $T_{average}$	$\frac{60\,P}{2\pi N}$	Watt
Polar modulus	Z_p	$\frac{I_P}{R}$	m^3 mm^3 cm^3
Torsional rigidity	k or μ	CI_p per unit length	$N\text{-}m^2$ $N\text{-}mm^2$
Equivalent twisting moment	T_e	$\sqrt{(\mathbf{M})^2 + (\mathbf{T})^2}$	Same as twisting moment
Equivalent bending moment	M_e	$\frac{\mathbf{M} + \sqrt{\boldsymbol{M^2} + \boldsymbol{T^2}}}{\mathbf{2}}$	Same as bending moment

***** PROBLEM *****

Q -1) *The average torque transmitted by a shaft is 2255 Nm. The maximum torque is 40% of the average torque. If the allowable shear stress in the shaft material is 45 N/mm^2*, *determine available diameter of the shaft.*

Ans) Data Given

Average torque **(**T_{av}**)** = 2255 Nm = 2255 × 10^3 N-mm
allowable shear stress (τ) = 45 N/mm^2
Maximum torque (T) = 1.40 T_{av} = 1.40 × 2255 × 10^3 N-mm = 3157 × 10^3 N-mm
we know that $T = \frac{\pi}{16} \times \tau \times D^3$

$\Longrightarrow \quad 3157 \times 10^3 = \frac{\pi}{16} \times 45 \times D^3$

$\Longrightarrow \quad D^3 = \frac{16 \times 3157 \times 10^3}{\pi \times 45} = 357299.31$

$\therefore \quad D = 70.96$ mm

Q-2) *A circular shaft of 60 mm, diameter is running at 150 r.p.m. If the shear stress is not to exceed 50 MPa, find the power which can be transmitted by the shaft.*

Ans) Data Given

Diameter (D) = 60 mm   speed (N) = 150 r.p.m
maximum shear stress (τ) = 50 MPa = 50 N/mm^2
Torque transmitted by the shaft (T) = $\frac{\pi}{16} \times \tau \times D^3 = \frac{\pi}{16} \times 50 \times 60^3 = 2.12 \times 10^6$ N-mm = 2.12 kN-m
power transmitted by the shaft (P) = $\frac{2\,\pi\,N\,T}{60} = \frac{2\,\pi \times 150 \times 2.12}{60}$ = 33.3 kW

Q-3) *A hollow shaft is to transmit 200 kW at 80 r.p.m. If the shear stress is not to exceed 60 MPa and internal diameter is 0.6 of the external diameter, find the diameters of the shaft.*

Ans) Data Given

Power (P) = 200 kW   Speed (N) = 80 r.p.m
Maximum shear stress (τ) = 60 MPa = 60 N/mm^2
internal diameter of the shaft (d) = 0.6 × external diameter = 0.6 × D
Torque transmitted by shaft (T) $= \frac{\pi}{16}\ \tau \times \left[\frac{D^4 - d^4}{D}\right] = \frac{\pi}{16} \times 60 \times \left[\frac{D^4 - (0.6\,D)^4}{D}\right]$
$= 10.3\, D^3$ N-mm
Power transmitted by the shaft (P) = $\frac{2\,\pi\,N\,T}{60}$

$\Longrightarrow \quad 200 \times 10^3 = \frac{2\,\pi \times 80 \times (10.3 \times D^3)}{60} = 86.3 \times 10^{-3}\, D^3$

$\Longrightarrow \quad D^3 = \frac{200 \times 10^3}{86.3 \times 10^{-3}} = 2.32 \times 10^6$ mm^3

$\therefore \quad D = 1.32 \times 10^2 = 132$ mm
and $\quad d = 0.6 \times 132 = 79.2$ mm

Q-4) *A solid shaft of 120 mm diameter is required to transmit 200 kW at 100 r.p.m. If the angle of twist not to exceed 2^0, find the length of the shaft. Take modulus of rigidity for the shaft material as 90 GPa.*

Ans) Data Given

Diameter (D) = 120 mm Power (P) = 200 kW speed (N) = 100 r.p.m

angle of twist (Θ) = 2^0 = $\frac{2\,\pi}{180}$ = rad modulus of rigidity (C) = 90 GPa = 90 × 10^3

power transmitted by shaft (P) = $\frac{2\,\pi\,N\,T}{60}$

$$\Rightarrow 200 = \frac{2\,\pi \times 100 \times T}{60} = 10.5\ T$$

$$\Rightarrow T = 200/10.5 = 19\ \text{kN-m} = 19 \times 10^6\ \text{kN-mm}$$

polar moment of inertia of a solid shaft (I_p) = $\frac{\pi}{32} \times D^4 = \frac{\pi}{32} \times (120)^4 = 0.4 \times 10^6\ \text{mm}^4$

we know that, $\frac{\mathbf{T}}{\mathbf{I_P}} = \frac{\mathbf{C\,\Theta}}{\mathbf{L}}$

$$\Rightarrow \frac{19 \times 10^6}{20.4 \times 10^5} = \frac{90 \times 10^3 \times (2\,\pi/180)}{l}$$

$$\Rightarrow 0.931 = \frac{3.14 \times 10^3}{l}$$

$$\Rightarrow l = \frac{3.14 \times 10^3}{0.931} = 3.37 \times 10^3 = 3.37\ \text{m}$$

Q – 5) *Prove that a hollow shaft is always stronger than a solid shaft of the same material, weight and length subjected to same torque.*

Ans) Data Given

Let d = internal diameter of hollow shaft

nd = external diameter of hollow shaft ; n greater than 1

D = diameter of solid shaft

As the two shafts having equal length and weight, their area of cross section will be same.

i.e. $\frac{\pi}{4} \times D^2 = \frac{\pi}{4}\,(n^2d^2 - d^2)$

$\Rightarrow$ $D^2 = d^2\,(n^2 - 1)$ $\Rightarrow$ $D = d\,\sqrt{(n^2 - 1)}$

Torque transmitted by hollow shaft $= \frac{\pi}{16}\ \tau \times \left[\frac{n^4d^4 - d^4}{nd}\right] = \frac{\pi}{16}\ \tau \times \left[\frac{n^4 - 1}{n}\right] \times d^3$ ------- (1)

Torque transmitted by solid shaft = $\frac{\pi}{16}\ \tau \times D^3 = \frac{\pi}{16}\ \tau \times (n^2 - 1)^{3/2}$ ----------------- (2)

If the expression 1 will be greater than 2, then hollow shaft will be stronger than solid shaft.

$$\Rightarrow \frac{n^4 - 1}{n} > (n^2 - 1)^{3/2}$$

$$\Rightarrow \frac{n^2 + 1}{n} > (n^2 - 1)^{1/2}$$

$$\Rightarrow (n^2 + 1)^2 > n^2\,(n^2 - 1)$$

$$\Rightarrow n^4 + 2\,n^2 + 1 > n^4 - n^2$$

$$\Rightarrow 3\,n^2 + 1 > 0, \quad \text{which is true}$$

$\therefore$ Hollow shaft is stronger than solid shaft.

***** ASSIGNMENT – 8 *****

GROUP – A (2 mark questions)

1. Write the equation of torsion.
2. What do you mean by torsion?
3. What is polar moment of inertia?
4. Define torsional rigidity.
5. Write the equation for equivalent bending and twisting moment.
6. State the assumptions of pure torsion.

GROUP – B (6 mark questions)

1. Derive the torsion equation.
2. State the assumptions for pure torsion.
3. A solid shaft of 100 mm diameter is transmitting 120 kW at 150 r.p.m. Find the intensity of shear stress in the shaft.
4. Calculate the maximum torque that a shaft of 125 mm diameter can transmit, if the maximum angle of twist is 1^0 in a length of 1.5 m. Take C = 70 GPa.
5. Find the angle of twist per metre length of a hollow shaft of 100 mm external and 60 mm internal diameter, if the shear stress is not to exceed 35 MPa. Take C = 85 GPa.
6. A solid shaft is subjected to a torque of 1.6 kN-m. Find the necessary diameter of the shaft, if the allowable shear stress is 60 MPa. The allowable twist is is 1^0 for every 20 diameters of the shaft. Take C = 80 GPa.

GROUP – C (8 mark questions)

1. A solid shaft of 200 mm diameter has the same cross-sectional area as that of a hollow shaft of the same material with inside diameter 150 mm. Find the ratio of power transmitted by the two shafts at the same speed.
2. A solid shaft transmits 75 kW at 200 r.p.m. Calculate the shaft diameter if the twist in the shaft is not to exceed 1^0 in 2 m of shaft and the shearing stress is limited to 50 N/mm^2. Take C = 1×10^5 N/mm^2.
3. A solid steel shaft has to transmit 100 kW at 160 r.p.m. Taking allowable shear stress as 70 MPa, find the suitable diameter of the shaft. The maximum torque transmitted in each revolution exceeds the mean by 20%.
4. Determine the diameter of a solid shaft which will transmit 90 KW at 160 r.p.m, if the shear stress in the shaft is limited to 60 N/mm^2. Find also the length of the shaft, if the twist must not exceed 1^0 over the entire length. Take C = 8×10^4 N/mm^2.

The End

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

MANUFACTURING-TECHNOLOGY

4TH SEMESTER

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MANUFACTURING TECHNOLOGY

4th SEMESTER – MECHANICAL

CONTENT

1. TOOL MATERIALS
2. CUTTING TOOL
3. LATHE MACHINE
4. SHAPER
5. PLANNING MACHINE
6. MILLING MACHINE
7. SLOTTER
8. GRINDING MACHINE
9. INTERNAL MACHINING OPERATIONS
10. SURFACE FINISH, LAPPING

TOOL MATERIALS

- Cutting tool must possess a variety of different properties in order to cut many different metals under various conditions.
- To meet these demands tool have been produced from a variety of materials.

Characteristics of tool materials:

- Hot hardness.
- Wear resistance.
- Toughness
- Strength.
- Impact resistance.
- Heat conductivity.
- Ductility
- Brittleness
- Elasticity
- Plasticity
- Hardness

Cutting tool materials:

- Cutting tool materials implies the material from which various cutting tools are made.
- The best material to use for a certain job is the one that will produce the machined part at lower cost.

Desirable properties of cutting tool:

- Tool should be harder than the material being cut (Hot hardness).
- To resist disintegration of fine cutting edge and also to with stand the stresses developed during cutting in the weakest part of the tool, the tool should have sufficient strength.
- Sufficient toughness to resist fracture.
- Resistance to impact that is ability to absorb shock without permanent deformation.
- A low co-efficient of friction between the tool material chip materials.
- Ability to dissipate rapidly the heat developed at the tool tip while cutting the work piece.

Types of cutting tool materials:

- High carbon steel
- High carbon medium alloy steel
- High speed steel

- Cast nonferrous alloys or satellite.
- Carbide
- Ceramic
- Diamond

High carbon steel:

- It is the oldest known tool material. It is used as cutting tool materials before the development of high speed steel. Carbon steel with carbon content ranging from 0.8 to 1.2%.
- Carbon steel having good hardening ability and with proper heat treatment, attains as great hardness as any of the high speed steel alloys.
- These are not use for production work, because these can't withstand high temperature.
- These are used for hand tools.
- These are less costly and easy to heat treat.
- The uses of carbon steel tools are limited to cutting of wood and other soft materials.

High carbon medium alloy steel:

- These are carbon contained less than high carbon steel.
- These have greater hot hardness, higher impact resistance and higher wear resistance.
- These properties are acquired by having small amount of tungsten, chromium and molybdenum.
- These can be successfully operated to a temperature of 350°C.

High speed steel:

- High speed steel is a high alloy steel and is marked by superior to high carbon steel in that it retains cutting ability at operating temperature to 594°C,exhibiting so called red hardness.
- This extended operating range compared to carbon steel permitted a nearly 100% increase in cutting speed for equal tool life and give rise to the name high speed steel.
- It contains the alloying element like tungsten, chromium, vanadium, cobalt, molybdenum.
- These alloying elements increase strength, toughness, wear resistance, cutting ability.
- These can be used safely 2 to 3 times higher cutting speeds.
- Although several formulations are in use for making cutting tools, atypical composition is that of 18-4-1 HSS type, which is considered to be one of the best all-purpose steel.
- High speed steel is used in the manufacturing of complicated shaped cutting tools, e.g. reamers, drills, taps, dies and various milling cutters etc.

Various compositions of HSS:

TYPE	TUNGSTEN(W)	CHROMIUM(Cr)	VANDIUM(V)	MOLYBDENUM(Mo)	COBALT(CO)	REMARKS
18-4-1 HSS	18	4	1	-	-	ALL PURPOSE HSS.
Mo-HSS	6	4	2	6	-	EXCELLENT TOUGHNESS AND CUTTING ABILITY
SUPER HSS	20	4	2	-	12	FOR HEAVY DUTY CUTTING OPERATION

Tungsten and chromium increases hardness.

Molybdenum increases red hardness.

Vanadium increases wear resistance.

Cobalt extends red hardness but increases brittleness, cobalt retains hardness up to 650°C increases the cutting efficiency.

Cast nonferrous alloys:

- It is nonferrous alloy consisting mainly cobalt, tungsten, chromium and alloying elements are tantalum, molybdenum, boron.
- They possess high red hardness and can maintain good cutting edges on tools at temp. Up to 925°C.
- It possesses good resistance to shock loads.
- Cast nonferrous alloys contain
  - i) Carbon=1-4%
  - ii) Tungsten=12-25%
  - iii) Cobalt=40-50%
  - iv) Chromium=15-35%
- It does not respond to usual heat treatment process.
- It can be used for machining materials like hard bronzes, cast and malleable iron.
- It can't be machined by grinding only.

Cemented carbide:-

- Carbide cutting tools are made only by powder metallurgy technique.
- Cemented carbides are usually made by binding tungsten powder and carbon at high temp ^{r} in the ratio of 94%and 6%respectively. This compound is then combine with cobalt and the resulting mixture is compacted and sintered in a furnace at about 1400^{o}c thus tungsten carbon cobalt material can maintain high hardness value at temp. Up to 1200^{o}c and therefore be used as much higher cutting speed that HSS.
- Cemented carbides cannot be shaped after sintering.
- Tungsten carbides are tough, strong and wear resistance when machining steels. To overcome this limitation tantalum carbide or titanium carbide are added to basic consumption.

- Superior grades of cemented titanium carbide allow cutting speed approaching these of ceramics and they can be used in the semi-rough cutting of steel and certain cast iron.

Ceramics:-

- Ceramics are made from sintered Al_20 and boron nitride powders. These powders are mixed together and sintered at about 1700^0c.
- Ceramics are usually in the form of disposable tips. They can be operated at 2 to 3 times the cutting speed of carbide.
- These are capable of withstanding high temp.
- Ceramics are very hard and low thermal conductivity.
- Ceramics are extremely brittle & can only be used where shock and vibration do not occur. In order to take full advantages of ceramics tools special or more rigid machine tools are required.

Diamond:-

- Diamond is the hardest material known.
- Diamond used as single point tool for light cuts and high speed and must be rigidly supported because of their high hardness and brittleness.
- It is brittle occurs low resistance to shock and highly wear resistance.
- These are used in the form of bits, inserted or held in a suitable designed wheel or bar.
- Industrial diamond either nature or artificial are commonly used in the machining of hard rubber, plastic, glass, Bakelite, etc.

CUTTING TOOL

Cutting Tool:-

- In machining a cutting tool or cutter is any tool which is used to remove the material from the W/P by means of shear difference.
- Cutting tool must be made of a material harder than the material which is to be cut and the tool must be to withstand the heat generated in the metal cutting process.
- The angle of cutting facer is also important, also the tool must have a specific geometry and clearance angles designed so that the cutting edge can contact the W/P surface.

Single point cutting tool

- This type of cutting tools has only one cutting edge. These used for wide application of lathe, shaper planner, slitter, boring M/C Multi point cutting tools

❖ This type cutting tools have more than cutting edge. These are employed for wide application in twist drills, Reamers, tapes, milling, cutters etc.

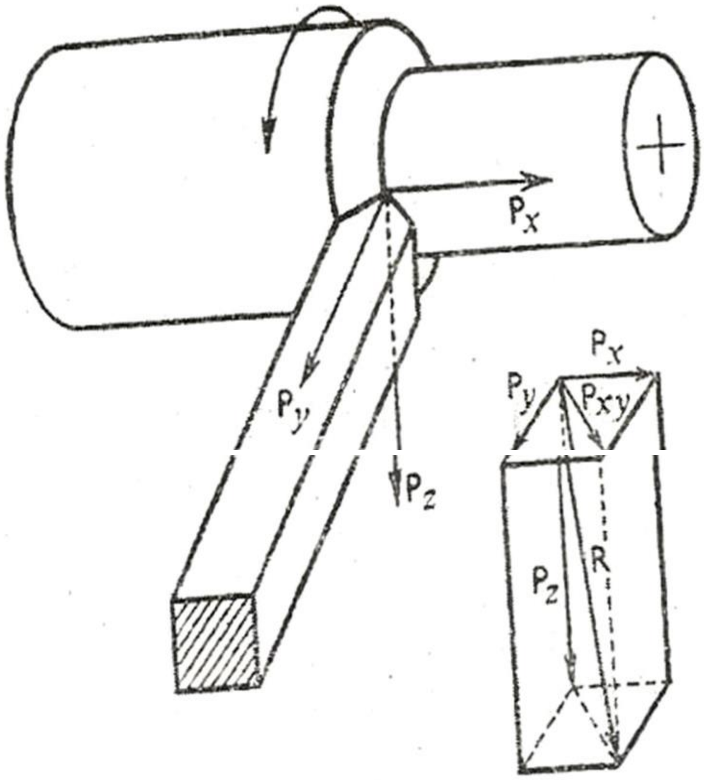
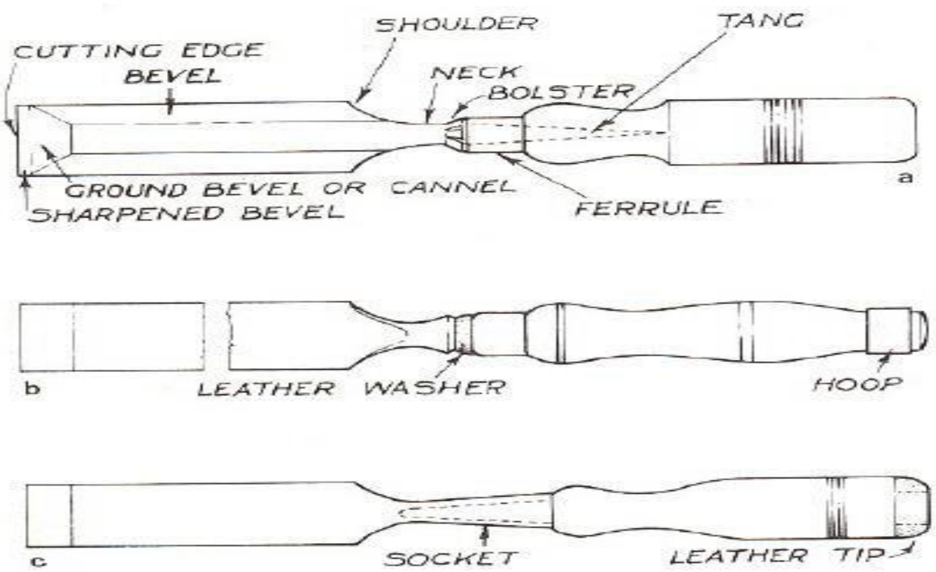


Figure Cutting forces in conventional turning process

Cutting action of hand tools:

Chisel:



❖ A chisel is a hand cutting tools which is shaped cutting edge of blade on its end, for carving, cutting a hard material such as wood, stone, metal by hand with the help of mechanical power.

❖ In used the chisels are forced in to the material to linear relative motion.

❖ The driving forced into the material may be manually applied by using a hammer. In industrial use, a hydraulic ram or falling weight drives the chisel into the material to be cut.

❖ Chisel is employed to use in wood work, metal working etc. In wood & stone working used for carving, cutting, shaving, shaping, trimming.

❖ In metal working process chisel use divided into two categories:

1. **Hot chisel**
2. **Cold chisel**

Die:

❖ Die cutting is the posses of using die to shear weds of low strength material such as rudder, tidier, cloth, plastic, sheet metal etc.

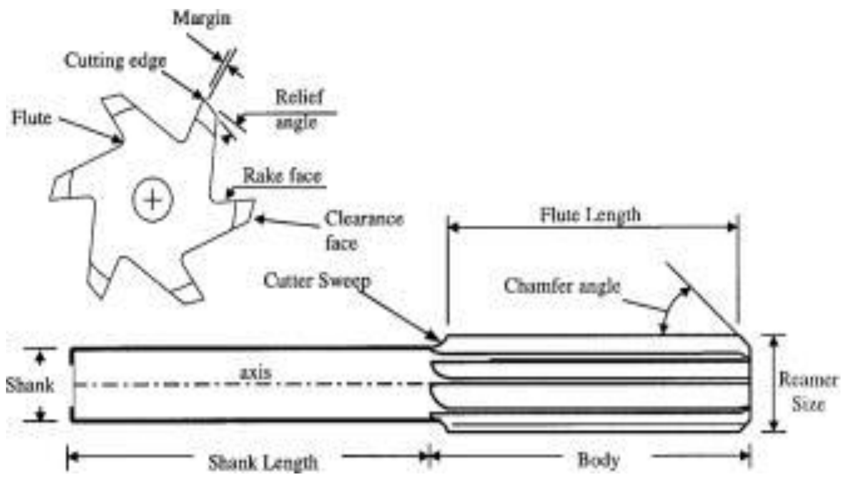
❖ Die cutting can be done on either flat bed or by rotary process. Rotary dry cutting is die cutting using a cylindrical die or rotary processes.

❖ Dies are used to cut the external thread or the rod or pipe end. Dies are made of high carbon steel or HSS.

  ❖ The process of cutting external thread by dies is called dieing. Sharing is also known as die cutting, is a prosses which cuts stock without formation of chips or the off during or melting.

  ❖ The die cutting action can be controlled by electric, hydraulic, pressurized or manual surfaces.

Reamer:



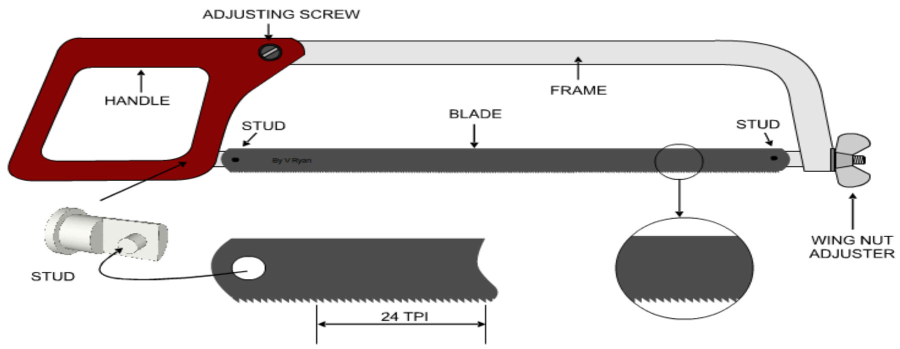
  ❖ It is a multiple edge cutting tools. The process of enlarging the hole is called reaming.

  ❖ There are many different types reamer and there may be designed for used as a hand tool or in a M/C tool such as milling M/C or drill press.

- A typical reamer consists of a set of parallel straight or helical cutting edge along the length of a cylindrical body.
- Each cutting edge is grounded at a slight angle and with slight undercut below the cutting edge.
- This may be used to remove small amount of material.
- Reamers are made of high Carbon or Plain Carbon Steel.
- Reamers are of two types
  1. Hard Reamers
  2. Machine Reamers

Hacksaw blade:

- Hacksaw bled is a fine toothed saw, originally principally for cutting metal. They can also cut various other materials such as plastic & wood.



- On hack-saw the blade can be mounted with the teeth facing toward or away from the handle. Resulting and cutting action on either pushes or pull stroke.
- In normal use, cutting vertically downwards with work held in a bench, vice, the saw blade should be set to be face forward.

Machining Process Parameters:

Factors affecting tool life:

- The life of a tool is affected by many factors such as: cutting speed, feed, depth of cut, chip thickness tool geometry, material of cutting fluid and rigidity of the machine.

Cutting Speed:

- The cutting speed can be defined as the relative surface speed between the tool and the job or the amount of length that will pass the cutting edge of the tool per unit of time.
- It may be defined as the speed which the cutting edge passes over the material. It is expressed in meters per min (mpm).

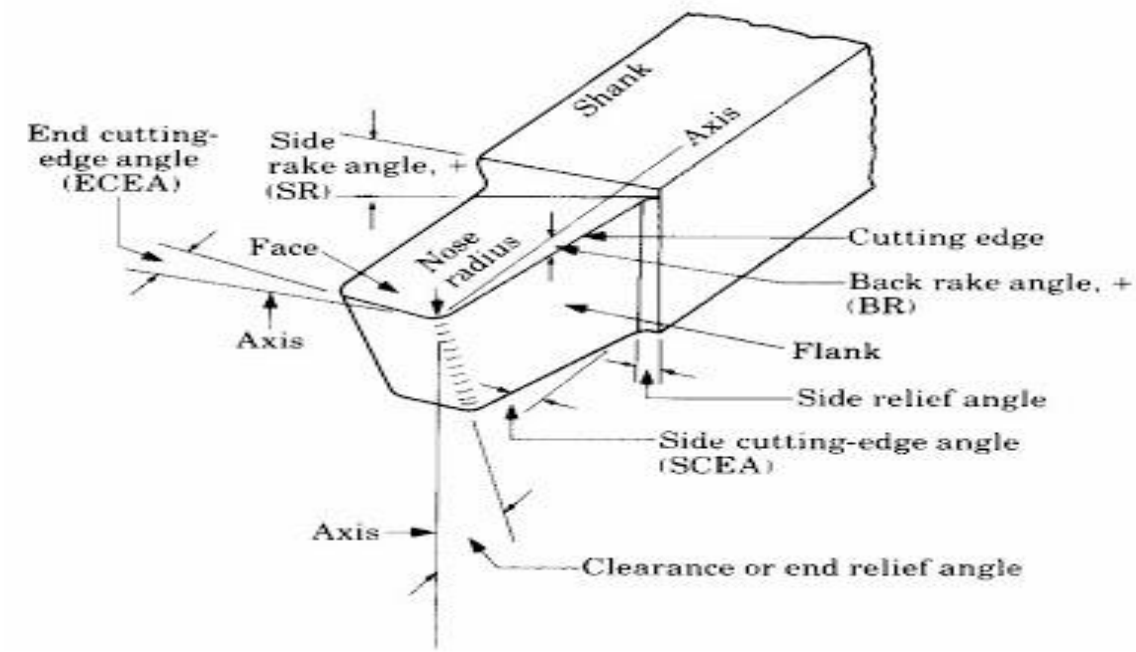
Feed:

- It is defined as the relation by small movement per cycle of the cutting tool, relative to the work piece in a direction which is usually to the cutting speed direction.

Depth of cut:

- The depth of cut is the thickness of the layer of metal removed in one cut or pass, measured in one direction to the machined surface. It is the vertical distance the tool advance.

Cutting tool nomenclature:



Shank:

It is the main body of the tool.

Flank:

The surface or surfaces below and adjacent to the cutting edge is called flank of the tool.

Heel:

It is the intersection of the flank and the base of the tool.

Nose:

It is the point where the side cutting edge and end cutting edge intersection.

Cutting edge:

It is the edge on the face of the tool which removes the material from the work piece. The total cutting edge cutting edge (major), end cutting edge (minor) and the nose.

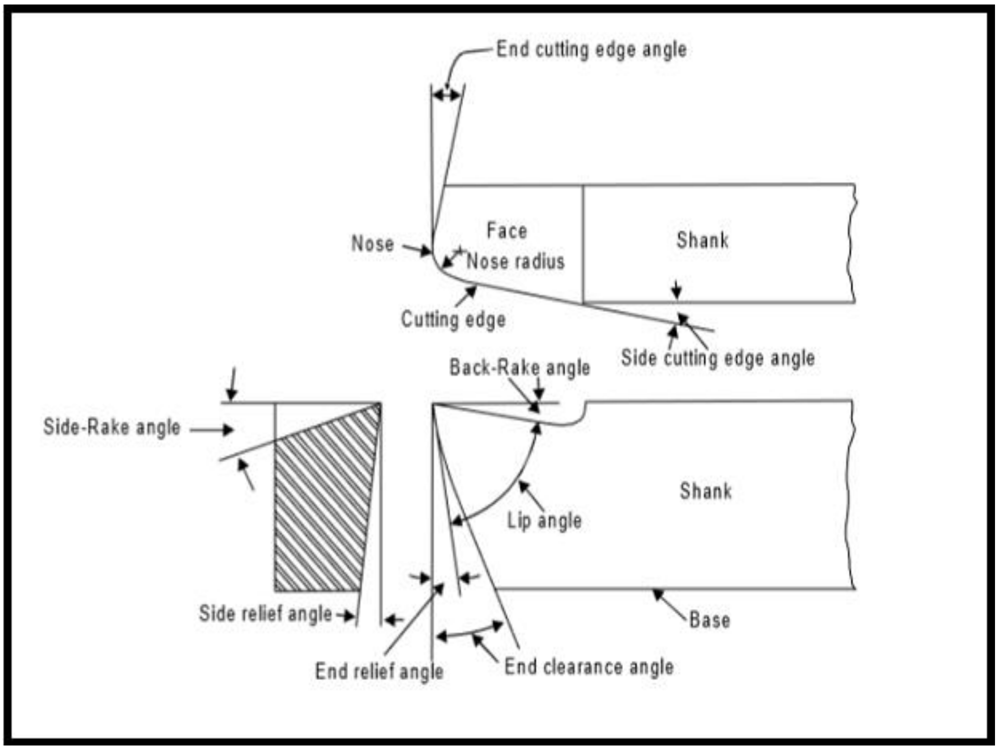
Face:

Base:

It is the underside of the shank.

Rake:

It is the slope of the tap away from the cutting edge. Larger the rake angle, the cutting force and power reduce.



LATHE MACHINE

- Lathe was the first machine tool which came into being as a useful machine for metal cutting. Thus it formed the basis of production of all the other machine tool which is the results of later development.
- Lathe is known as the mother machine tool and can be defined as a machine tool in which the job to be machined is held and rotated in the lathe chuck, a single point cutting tool is advanced radically into the job/work piece at a specified depth and moved longitudinally along the axis of the work piece, removing metal in the form of chips.
- An engine lathe is the most basic and simplest form of lathe which is used for producing cylindrical jobs.
- Except turning operation engine lathe can be used to carry out other operations such as taper turning, thread cutting, boring, drilling, knurling, grooving, chamfering, grinding, parting off etc.

TYPES OF LATHE

- Bench lathe
- Speed lathe

- Engine lathe
- Tool room lathe
- Capstan and turret lathe
- Automatic lathe
- Special purpose lathe.

SPECIFICATION OF LATHE MACHINE

Specification means the important parameters required to completely describing the size of lathe machine and maximum size of work piece lathe can handle.

The major parameters are to specify lathe machines are:

- Distance between centers (live and dead centre): This would specify the maximum length of the work piece that can be turned on a lathe.
- Swing over the bed: It specifies the largest diameter of work piece that can be rotated on the lathe machine without striking the guide ways.
- Swing over the carriage: It specifies the largest diameter of work piece that can be turned on the lathe machine without striking the top of carriage.
- Maximum diameter of work piece through spindle: The maximum diameter of hole through the hollow spindle is specified to mention the maximum diameter of work piece, lathe can handle, when the work piece is fed through the spindle hole.
- Height of centers over bed.

The following specifications should also be provided to completely specify a lathe machine.

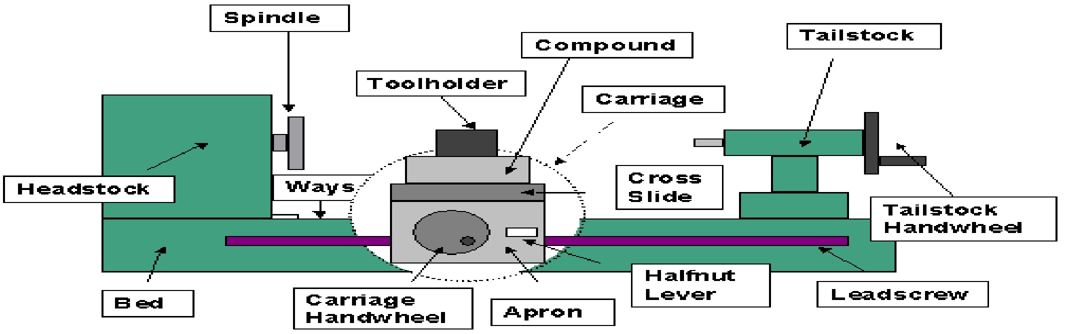
- Length of bed
- Width of bed
- Face plate diameter
- Size of tool post
- No. of spindle speeds
- Range of spindle speeds
- Power rating of electric motor
- Lead screw diameter and no. of threads per cm.

PARTS OF LATHE

Basic parts of lathe are

I) Bed
II) Headstock
III) Tailstock
IV) Carriage – (below parts consists by carriage)

- Saddle
- Cross slide
- Compound rest
- Tool post
- Apron
- Feed mechanism
- Legs

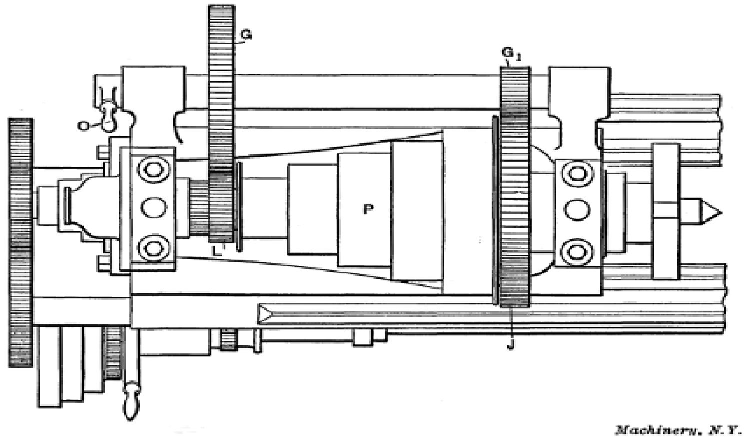


<u>Bed</u>:-

- Bed is the base of lathe machine on which different parts of lathe like headstock, tailstock, and carriage assembly are mounted.
- Bed must be rigid as it has to withstand various cutting force transmitted to it during the operation of lathe.
- It is usually made of single piece casting of grey cast iron or semi steel (toughened cast iron), with the addition of steel scrap to the cast iron during machining – the material cast iron facilitating an easy sliding action.

<u>Headstock</u>:-

- The headstock is a box like casting mounted permanently on the bed of the engine lathe at the left hand end of the machine.
- The headstock supports the spindle and contains a gearbox by which the spindle and hence the work piece may rotated at various speeds.
- The spindle is hollow to accept the bar stock and is built into the headstock with the spindle nose projecting from the housing of the headstock. The spindle nose is threaded so that a faceplate or a chuck can be turned on it to hold and rotate the work piece.
- For machining different materials, with different cutting tools to obtain rough or finish, different work speeds are necessary. The different work speeds are provided generally by two different types of headstock:
    i) Belt driven headstock
    ii) All-geared headstock



Belt driven headstock:

- A Belt driven head stock consists of
  - a) Step cone pulley
  - b) Back gear arrangement
- The cone pulleys (p) are mainly responsible for obtaining different spindle speeds by means of belt.
- When spindle speeds slower than those obtainable by the direct belt drive are require, especially in case of thread cutting, the back gear should be used.
- To operate the back gear, first the lock pin (A) should be removed this leaves the permanently joined pulleys and gear wheel E to revolve freely on lathe spindle. Gear wheel is permanently fixed to the spindle. Then the lever B should be turned to bring the back gears C and D those are connected as one unit and rotate freely, mesh with gears E and F.
- The fig.-3 shows the back gear in the disengaged position, the larger gear and the cone pulley being locked together. This provides four higher speeds and the spindle rotates at the same speed as the pulley. The drive from the cone pulley goes straight to lathe spindle or chuck.
- The fig.-4 shows the back gear in the engaged position, the large gear and the cone pulley rotate independent of each other that is they are not locked together.

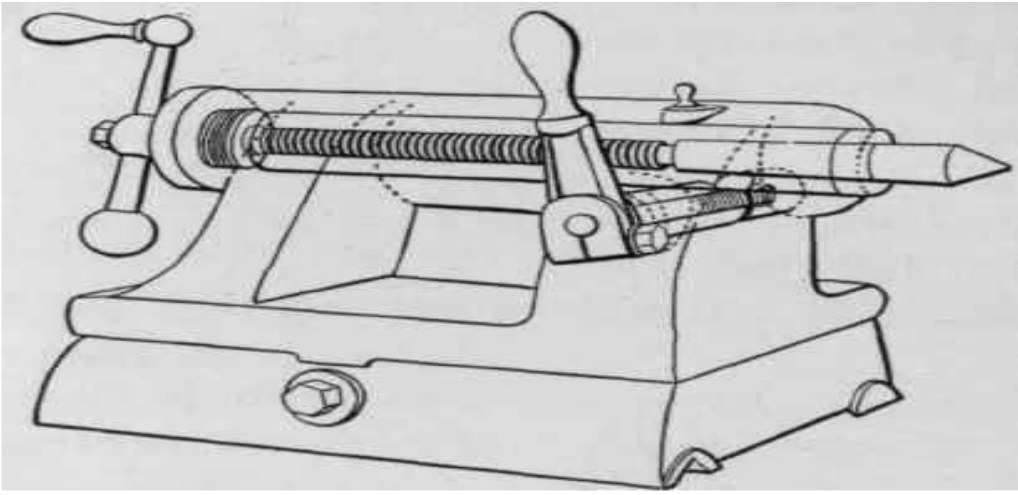
All geared headstock:

- Modern and generally larger heavy duty lathes are consists of all gear headstocks, enabling the spindle speeds to be readily changed by the operation of external handles or levers.
- Not only does this enable rapid changes to be made but a larger and more evenly graduated range of spindle speeds is available.

- The gear wheels are located on spines on the spindle and lay shafts and are brought into mesh by the appropriate levers. They are so arranged that it is impossible to engage more than is necessary for any one spindle speeds.
- To shift gears while the machine is in running could cause serious damage to the speed. So speed changes on most all geared lathe may be made only while the machine is stopped.

Tailstock:

- Tailstock is located at the right hand end of lathe bed. The tailstock also known as loose head can be securely clamped in any convenient position.
- It can also be offset 25mm for cutting small angle plates.
- For machining, long jobs are held between the headstock and the tailstock so that they do not bend while machined.
- The tailstock barrel is given longitudinal movement within the tailstock body by means of a screw and hand wheel.
- Tailstock used for providing a support to the end of the work piece, usually a shaft.
- It also used for supporting the end of the long work piece in dead centre, when the work piece is held between live centre and dead centre.



Carriage:

- The lathe carriage serves the purpose of supporting, guiding and feeding the tool against the job during the operation on the lathe.
- The carriage carries the cutting tool and controls its movements either parallel to the ways, called straight turning or at right angles to the ways called facing.
- It can be moved left or right between the head stock and the tailstock by hand wheel.
- The carriage consists of

    a) Saddle

    b) Cross slide

    c) Compound rest

d) Tool post

e) Apron

Saddle:

- It is that part of the carriage which slides along the bed ways and supports the cross slide, compound rest and tool post.
- The saddle is an H-shaped casting that is machined to fit the outer ways of the lathe bed. The saddle can be moved along the ways either manually or by power through the gear mechanism in the apron box.

Cross slide:

- The cross slide is mounted on the carriage and has two purpose, it supports the compound rest and also allow the movement of cutting tool at right angle to the lathe centre line.
- Both the cross slide and the compound slide are fitted with indexing dials.
- The cross slide can be moved by hand wheel or by power feed.

Compound rest:

- A compound rest is mounted on the cross-slide and it carries a graduated circular base, called swivel plate used for swivel the tool post to any angle in a horizontal plane.
- A compound rest has two function:-
  - i) It supports the tool post.
  - ii) It allows movement of the tool along a path not parallel to the lathe centre line. This permits the turning of conical or tapered surfaces.

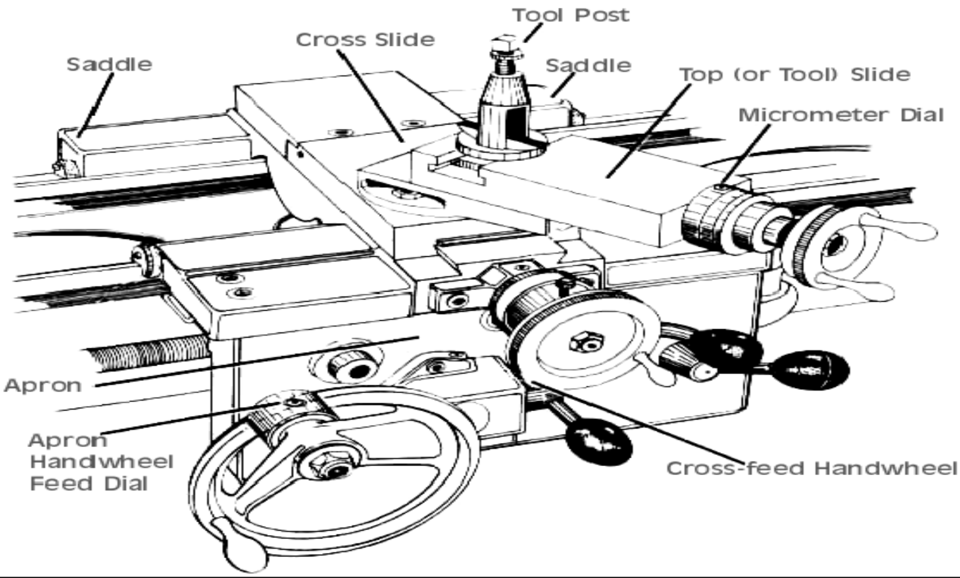
Tool post:

- It is an essential condition of turning that the cutting tool be rigidly and securely held and the device used for the purpose is known as tool post.
- It is the important part of the carriage and is used for holding the tool or tool holder in position.
- The tool post is mounted on the compound slide.
- The tool post can be moved left or right with the help of compound slide and it can be clamped in place also. The tool post can be rotated at whatever angle is best for the job.

Apron:

- The Apron is bolted to the front of the saddle. The apron houses the gears and controls for the carriage and the feed mechanism.

- The control levers held in the apron are – levers which engage and reverse the feed lengthwise or crosswise and the lever which engages the threading gears. The start – stop clutch lever is usually close besides the apron.
- Manual movement of the carriage along the bed is effected by turning a hand wheel on the front of the apron, which is geared to a pinion on the backside. This pinion engages a rack that is attached beneath the upper front edge of the bed in an inverted position.
- It carries the clutch mechanism and the slip half nut. Out of these two, the clutch mechanisms used to transmit motion from the feed rod where as the latter, in conjunction with the lead screw, moves the whole carriage in thread cutting.



Feed Mechanism:

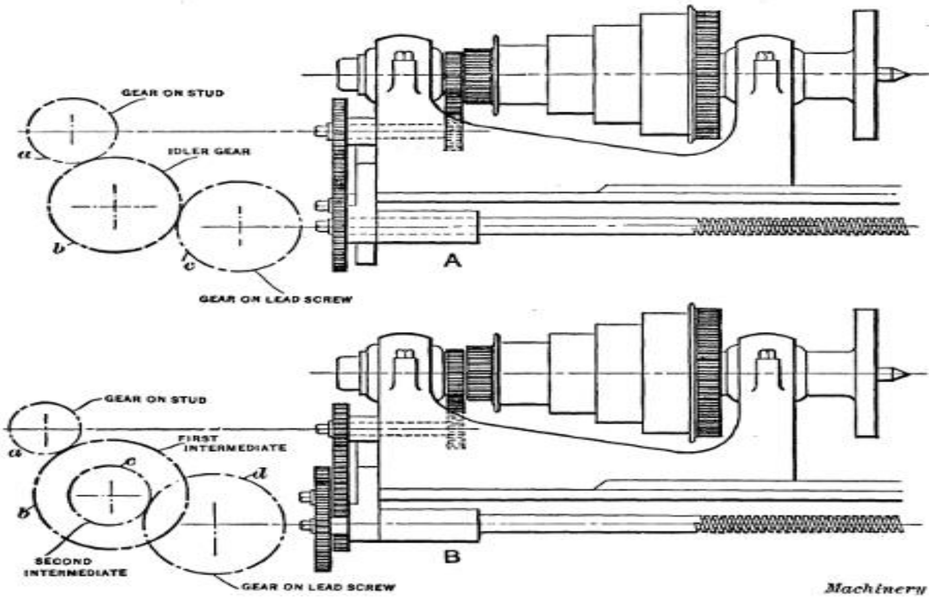
- Feed is basically the distances the tool advances in to the work pieces through one revolution of head stock spindle. Feed may be longitudinal or cross feed.
- The Feed is called longitudinal when the tool travels along the work piece parallel to the direction of lathe bed. Longitudinal Feed is used in cylindrical turning operation and is provided by movement of carriage.
- In cross feed the tool travels perpendicular to the direction of lathe bed. Cross feed is used in facing operation and provided by movement of cross slide.

The lead screw and the Feed rod is important component of feed mechanism.

Lead screw:

- It is used for thread cutting operation. Acme type of thread is generally used for manufacturing of lead screw.

- When half nut lever engages with lead screw, the carriage moves automatically for thread cutting operation.
- By the help of back gear arrangement, thread cutting operation is done.
- The lead screw gets its power from the spindle gear through a gear train located at the left end of the lathe.



Feed rod

- The feed rod transmits the motion required to move the saddle or carriage along the bed of lathe, is known as automatic feed when turning work piece.
- Movement of cross slide may also be achieved through the feed shaft.
- The fed rod gets its power from the spindle gear through a gear train located at the left end of the lathe.

Legs:

- These are the supports which carry the entire weight of the machine. These are the casting part which integrated with lathe bed. Both the legs should be of robust construction.

FEED MECHANISM:

- Feed is the distance the tool advances into the work piece through one revolution of head stock spindle a lathe tool has 3 types i.e. longitudinal, cross and angular.

Longitudinal feed:

- When the tool moves parallel to the lathe axis, the movement is termed as longitudinal feed. It is used in cylindrical turning operations and is effected by movement of carriage.

Cross feed:

- When the tool moves parallel to the lathe axis, the movement is termed as cross feed. It is used in facing operation & affected by movement of cross slide.

Angular feed:

- When the tool moves at an angle to the lathe axis, it is termed as angular feed. It is used in taper turning and affected by movement of compound rest.
- Angular feed is hand operated where cross feed & longitudinal feed can be both hand & power operated.

Lathe operation:

Lathe operations are performed by following methods. Operations which are performed in a lathe either by holding the work piece between centers or by a chuck:

1. **Straight turning**
2. **Shoulder turning**
3. **Chamfering**
4. **Thread cutting**
5. **Facing**
6. **Knurling**
7. **Internal thread cutting**
8. **Taper turning**
9. **Polishing**
10. **Polishing**
11. **Grooving**
12. **Drilling**
13. **Reaming**
14. **Forming**

Facing:

- Facing is the operation of for generation flat surface perpendicular to the rotational axis of spindle. The tool is fed to the axis of rotation of the work piece.

Turning:

- Turning in lathe is to remove excess material from the work piece to produce a cone-shaped or a cylindrical surface.

Straight turning:

- The work is turned straight when it is made to rotate about the lathe axis, and the tool is fed parallel to the lathe axis. It produces a cylindrical surface by removing excess metal from the work piece.

Taper Turning:

- A taper may be defined as a uniform increase or decrease in diameter of a piece of work mannered along its length.

Knurling:

- Knurling is the process of embossing a diamond shaped pattern on the surface of a work piece. The purpose of knurling is to provide an effective gripping surface or a work piece to prevent it from slipping when operated by hand.

Drilling:

- Drilling is the operation of production a cylindrical hole in a work piece by rotating cutting edge of a cutter known as drill.

Boring:

- It is the operation of enlarging and truing a hole produced by drilling, punching, casting co-forging.

Safety measures during machining:

Some safety precautions should be needed while working on lathe.

- Before operating the machine, one should fully understand its operations controls and how to stop it.
- All gears and gear ends of the lathe should be properly guarded.
- Safety goggles are preferred to avoid damage to eyes by flying chips.
- Avoid wearing rings, bracelet or watch.
- Machine should not be left running and operator should be alert during a job.
- Before starting a lathe spindle by power, spindle should be rotated by one revolution by hand to make it sure that no fouling is there.
- Safe distance from revolving chuck should be maintained.
- Sliding parts of the lathe should be cleaned and lubricated periodically.
- Chips should never be removed by hand. It can be removed by brush.
- Before starting the machine, the work should be clamped properly.
- Before moving the carriage, the carriage clamping screw should be unlocked.
- On hearing unusual noise, machine should be stopped immediately and should not be operated till the fault is clear.

Capstan & Turret lathes:

A capstan or a turret lathe is a production lathe used to manufacture any number of identical pieces in the minimum time. The main feature is the six sided block mounted on one end of the bed replacing the normal tailstock six tools can be mounted on cross slide two tool posts are mounted, one in the font and the other in the rear. Each one can hold four tools .Thus the total carrying capacity is a maximum 14 tools.

Difference between capstan & turret lathe:

Capstan lathe	Turret lathe
➢ Its turret head is mounted on slide, which moves on the guide ways produced on the saddle.	➢ Its turret to head is mounted `directly on the saddle.
➢ For feeding the tool to the work, the saddle is fixed at convenient distance from the work.	➢ For feeding the tool to the work, the entire saddle unit is moved.
➢ It is smaller in size compared to turret lathe.	➢ It is large in size as compared to capstan lathe.
➢ It is suitable for smaller size & lighter jobs. It is not suitable for heavy cutting condition.	➢ It is suitable for long and heavy work and severe cutting condition.
➢ The turret head may hexagonal or circular.	➢ Turret head is hexagonal.
➢ It is suitable to work for smaller bar up to 60 mm dia.	➢ It is used to work for large size bar up to 200mm dia.
➢ In capstan lathe, Collect is used to grip the Job.	➢ In turret lathe, power Jaw chuck is used to grip the Job.
➢ The tool traverse is faster and offer less fatigue to the hands of the operator.	➢ The tool feeding is relatively slower and provides more fatigue to operator hands.

Difference between CAPSTAN &TURRET and an ENGINE LATHE

CAPSTAN &TURRET	ENGINE LATHE
➢ In turret lathe, the tail stock is replaced by a turret which is a hexagonal block which contains 6 tools on each face.	➢ It can accommodate one tool Of limited size.
➢ The feed movement of each tool set on square or hexagonal turret is regularity by stops & feed strips.	➢ The feed movement is given by hand.
➢ It require 15 hp power to drive the spindle.	➢ It requires 3hp to drive the spindle.
➢ Turret lathes are suitable for producing large no. of identical	➢ The threads are cut by lead screws.

pieces.	
➢ The labor cost is less.	➢ Labor cost is more.
➢ Combination cuts can be taken by mounted two or more tools on the same face of the turret.	➢ Combination cuts cannot be done.

SLOTTING MACHINE

- A slotting machine or slotter is used for cutting different types of slots, keyways (both internal and External).
- A slotter machine is also used for machining irregular shapes, circular surfaces, concave and convex surfaces and other pre marked profiles both internally and externally.

Basic parts of slotter:

The main parts of slotter are

i. Base:-

- It is a heavy cast iron construction and is also known as bed.
- It acts as support for the column, the driving mechanism ram, table and all other fittings.
- At its top it carries horizontal ways, along which the table can be traversed.

ii) Column:-

- It is another heavy cast iron body which acts as a housing for the complete driving mechanism.
- At its front it carries vertical ways, along which the ram moves up and down.

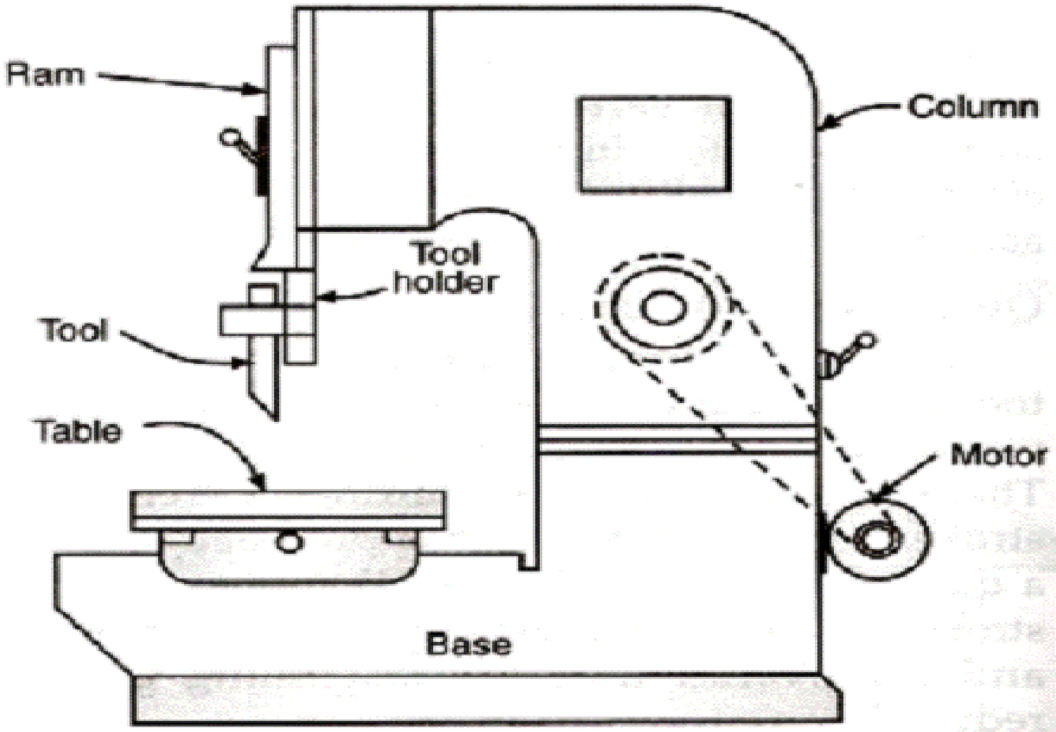
iii) Table:-

- Usually a circular table is provided on slotting machine.
- On the top of the table T-slots are provided to clamp the work or facilitate the use of fixture etc.
- Some heavy duty slotter either a rectangular or circular table can be mounted.

iv) Ram:-

- It moves in a vertical direction between the vertical guides ways provided in front of the column.
- At its bottom, it carries the tool post in which the tool is held.

- The cutting action takes place during the downward movement of the ram.



Types of slotting machine:

- Puncher slotter
- Production slotter
- Tool room slotter

Working mechanism:

- In case of slotter machine the machining is done by the downward movement of the cutting tool along with the ram while the job is fixed on the slotter table.

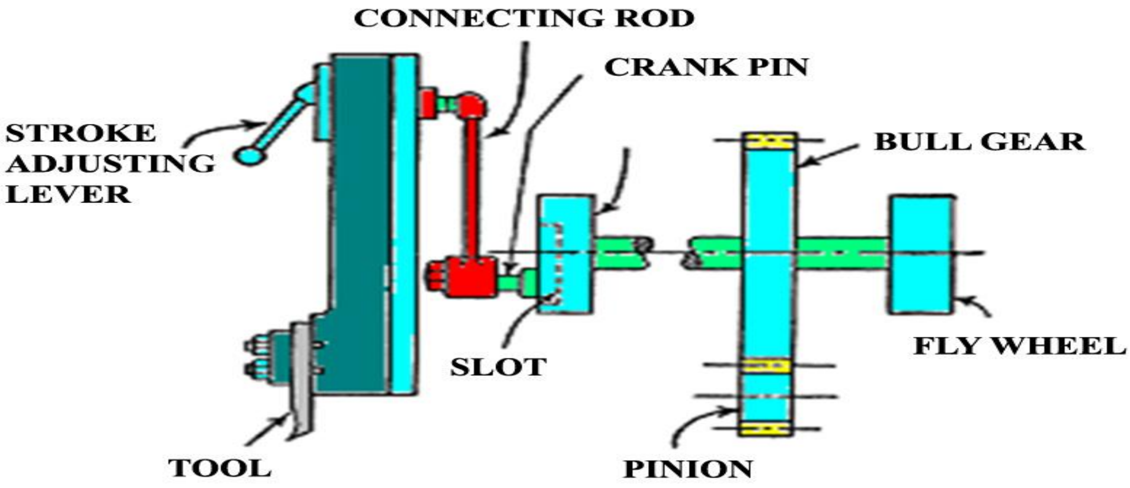
Generally three types of driving mechanism are used in slotting machine for driving ram:

- Slotted disc mechanism
- Slotted link mechanism
- Hydraulic mechanism

Slotted disc mechanism:-

- It is the simplest of all the methods commonly used for driving the ram ofa slotting machine.
- The driving mechanism consists of a pinion, a gear, a slotted disc and crank.
- The disc carries a T-slot through which the crank pin passes.

- The main driving pulley, generally situated at the rear side of the machine, Is driven by the motor through belts. It in turn drives the pinion which drives the gear.
- The gear being on the same shaft as the disc drives the latter.
- The crank and connecting rod mechanism convert the circular motion of the disc into reciprocating motion of the ram.
- The length of stroke of ram can vary by shifting the crank pin towards or away from the centre of the disc.
- The starting and finishing position of the ram stroke can be adjusted by means of the hand lever for stroke adjustment.
- The fly wheel provided at the rear side acts as shock absorber at the end of the stroke.



Slotted link gear mechanism:

- This mechanism consists of two driving wheels and both the wheels carry an eccentric each.
- Three bolts are provided by means of which the eccentrics can be made loose or fast with driving wheels as desired.
- A slotted link of bell crank type is provided between the driving wheels.
- The crank pin forms the fulcrum.
- A die usually of bronze works in the slot of the link, it is provided with a hardened steel bush, through which passes one of the three bolts.
- This bolt connects the two eccentrics and carries the above die, so that when the eccentric revolve, along with the driving wheels, the die slides in the slot.
- Other end of the link is attached to the ram by means of a connecting rod.
- A counter weight arm is linked to the top of the ram at one end and other end of arm carries the counter weight.

- In this mechanism when the eccentrics revolve, the die slides inside the slot of the link and in doing so, it makes the link swing about the fulcrum, provided by the crank pin.
- With the result the connecting rod and hence the ram is alternately pushed up and pulled down. This enables the reciprocating motion of the ram and tool.

Hydraulic mechanism:

- The hydraulic drive used in slotters as the same as in case of shapers. Only the axis of the cylinder in this case will be in a vertical direction.
- Both const. pressure and const. volume type drives are also used in this machine. (Follow the hydraulic mechanism of shaper)

Slotter tools:

- Slotter tools are either forged from solid bar of tool steel or are used in the form of bits held in suitable tool holder.
- The cutting action of a slotter is vertical; when a cut is being taken on the slotter there are fewer tendencies to shift the work from work table.
- The action of cutting presses the work on the table and tends to push the tool away from the job. For this reason it is desirable to make the tools or tool holder of stiff section.
- Since the cutting takes place parallel to the shank length. No side rake is provided on slotter tools.
- The back rake is provided at the end.
- Shape of the cutting end of the tool is made according to the shape of the slot to be produced.

DRILLING MACHINING

- Drilling is an operation through which holes are provided in a solid metal by mean of a reversing tool called **drill bit** and the device which is employed for this purpose is known as drilling machine.

Classification of Drilling machine:-

- Drilling machine is manufacture in various size and verities to suit the different type of work.

They can be broadly classified as:-

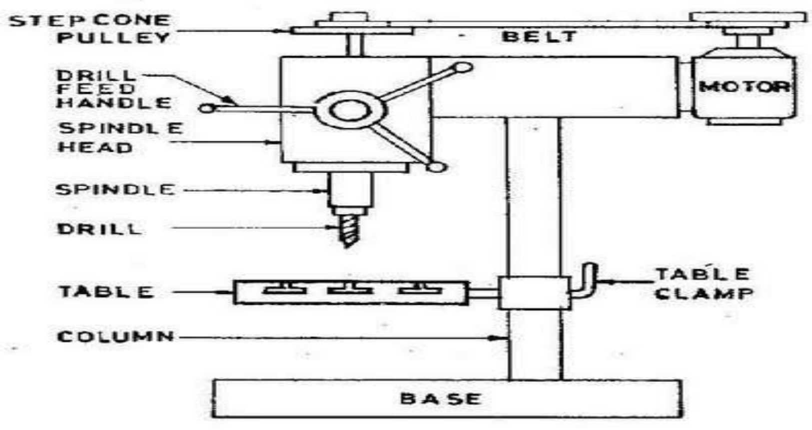
1. Portable drilling machine.
2. Bench drilling machine.

3. Up-right drilling machine (single spindle).
4. Up-right drilling machine (turret type).
5. Radial drilling machine.
6. Gang drilling machine.
7. Multiple spindle drilling.
8. Horizontal drilling machine.
9. Automatic drilling machine.

Bench or Sensitive drilling machine:-

Construction:-

- This type of drilling machine is used for very light work. Its construction is very simple and so is the operation.
- It consists of a cast iron base having a fixed column over it.
- The vertical column carries a swiveling table, the height of which can be adjusted vertically along the former. Also it can be swing to any desired position.
- At the top of the column the drive is provided which consist of an endless belt running over two pulleys.
- One of the pulleys mounted the motor shaft and other the machine shaft.
- Vertical moment of spindle is given by the feed handle to a rack and pinion arrangement.



Parts of the Bench drilling machining:

(1) Belt housing.
(2) Adjustable Table.
(3) Electronic motor.

(4) Drill Bit.
(5) Column.
(6) Chuck.
(7) Locking handle.
(8) Operating Handel.
(9) Base
(10) Cover over cone pulley.

Working:-

- As the motor is switched on, the motor shaft starts revolving and hence the v-pulley mounted over it.
- This through the v-belt transmits motion and power to the other v-pulley mounted over the drill spindle.
- Thus the spindle starts rotating and therefore the drill.
- When the drill is required to be feed into the work, it is pressed against the work by means of the feed handle or operating handle.
- As the handle rotates which is directly mounted on the pinion shaft the pinion rotates .It moves the rack longitudinally and hence the spindle and the drill.
- Different spindle speed can be obtained by shifting the v-belt to different parts of driving & driven pulleys, while the motor continuous to rotates on the same speed.
- On these machine the drills rotates at very high speed. So that the required cutting speed can be obtained on the periphery of small drill used on this machine.
- There is no arrangement for automatic feed on the machine.

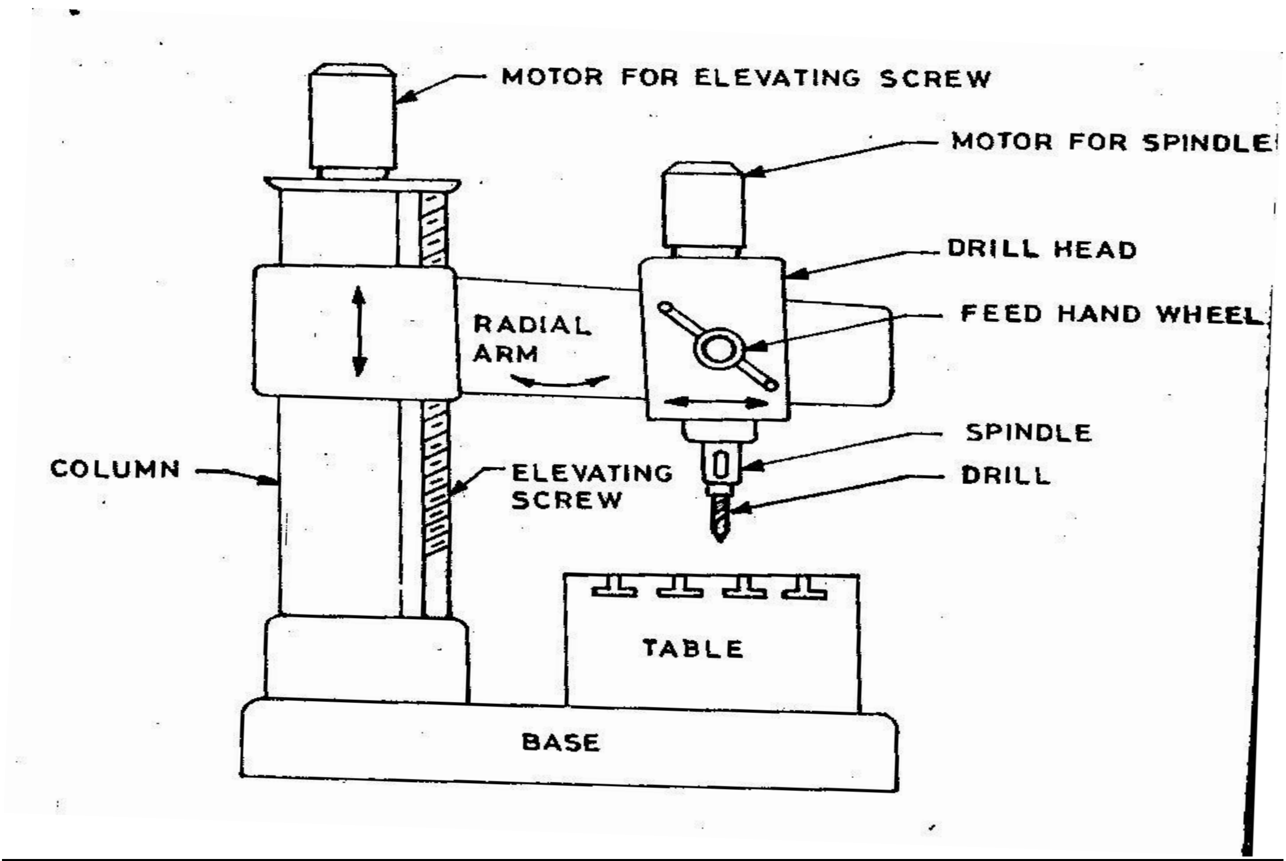
Radial Drilling Machine:-

- This machine is used for drilling holes in such work which is difficult to be handling frequently.
- The radial drilling machine is heavy duty machine and is use primarily to drill the parts which is too large or heavy to move under a stationary drill spindle like bench drilling machine.
- A radial drilling machine can drill up to 75mm diameter from the solid.

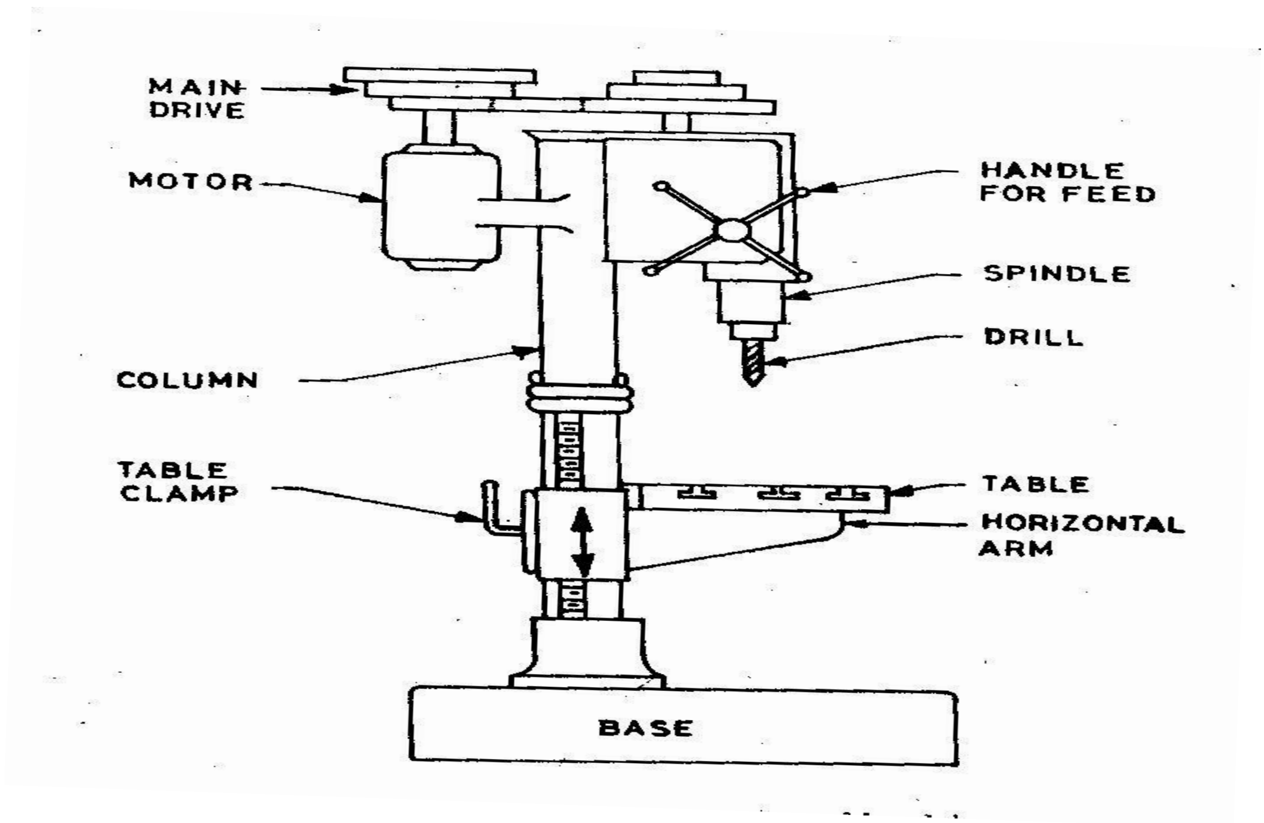
Working:

- The machine consists of a base, on which a cylindrical, vertical column is mounted over it. The column carries a radial arm.
- A separate motor is provided for elevating the lowering the arm in the column and the clamping leavers are for locking the arm at desired height.
- The arm can be swing round the column to any desired angle.

- The drilling head is mounted on the arm along which it can slide horizontally.
- A good radial drilling machine is interring lock with the elevating control. So, that the upward or downward motion will not start until and unless these reverse are released.
- A hole depth strip is incorporated in many radial drills to stops the machine automatically, as soon as the required depth of hole is obtained.
- In this machine the spindle the heads moves on cross rail (R) by means of hand wheel and is provided with locking arrangement to lock the head at any position on the arm.
- Vertical adjustment of the arm is made with the help of elevating motor. Thus the head can be raised, lowered and swing round to any position relative to base, power is transmitted from the motor to the spindle to v-belt drive.
- Based on the type and no of movement s the radial drilling machine can be broadly grouped as :-
    a. Plain radial drilling machine will drill only in vertical plane.
    b. On semi universal radial drilling machine the head may only swiveled on the arm to drill holes at various angles in a vertical plane.
    c. Universal machine has an additional swiveling arrangement in either the head or the arm can drill holes at any angles.



UP-RIGHT DRILLING MACHINE:-



- Pillar drilling machine is also known as upright drilling machine. It is used for heavier work and has back gear arrangement similar to a lathe.
- It's specially differs from a sensitive drill in weight, rigidity application of power, feed& the Wider range of spindle speed.

- The parts of pillar drilling machines are :-
  I. Base.
  II. Pillar.
  III. Main Drive.
  IV. Drill Spindle.
  V. Feed Handle.
  VI. Work Table.
- The vertical column can be either round or box type. Box type column is usually provided when the machine is constructed for relatively heaver work whereas round column are provided for lighter work.
- These machines are manufactured in various sizes having different drill capability up to a maximum hub 75mm. The most commonly used size is 38 mm steel.
- Cylindrical vertical pillars facilitate the swinging of table to any position and in combination with the rotary movement of the table. It enables any part of the surface to come under the tool without disturbing the work.

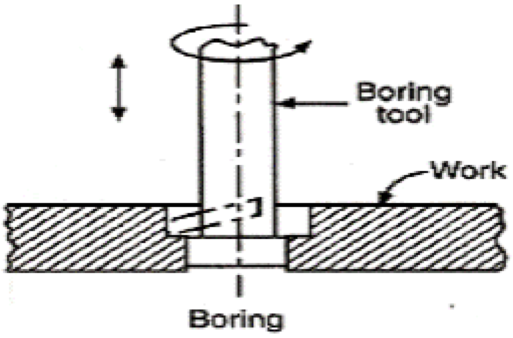
Working:-

- The Pillar drilling machine consists of a round column that raises from the base an arm around the table assembly and a drill head assembly.
- The arm and the table have 3 adjustments for locating work piece under the spindle.
- The arm and the table may be moved up and down on the column by the help of cross rail for accommodating work piece of different height.
- The table and the arm may be moved in an arc up to 180^0around the column and may be clamped any position.
- The table may be rotates 360^0 , about its own center , independent of the position of arm for locating work piece under the spindle this permits the setting of work below the spindle .
- Heavy and odd size work may be supported directly on the base of the machine and drill after the arm is swung out of the way.

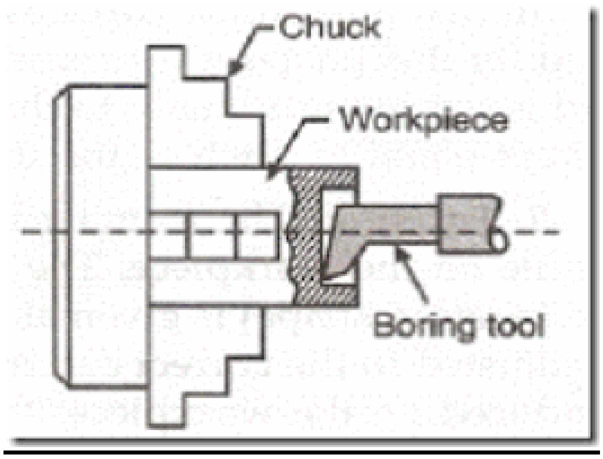
BORING

Boring is the process of using single point tool to enlarge and locate a previously made hole.

Basic Principle:-



- The operation of boring differs from drilling in that it implies the enlargement of an already existing hole.
- This hole can be due to previous drilling produce in casting or forging parts.
- The tool rotates within a stationary work piece and as fed axially in order to cut metal for enlarging the already existing hole on the work piece.
- When small holes are to be bored particularly in small job which can be conveniently held in chicks or face plate, can easily be done on centre lathe or capstan and turret medium size lathe.
- There are 3 types of boring machine
    - Horizontal boring machine
    - Vertical boring machine
    - Jig boring machine



DIFFERENCE BETWEEN DRILLING AND BORING:

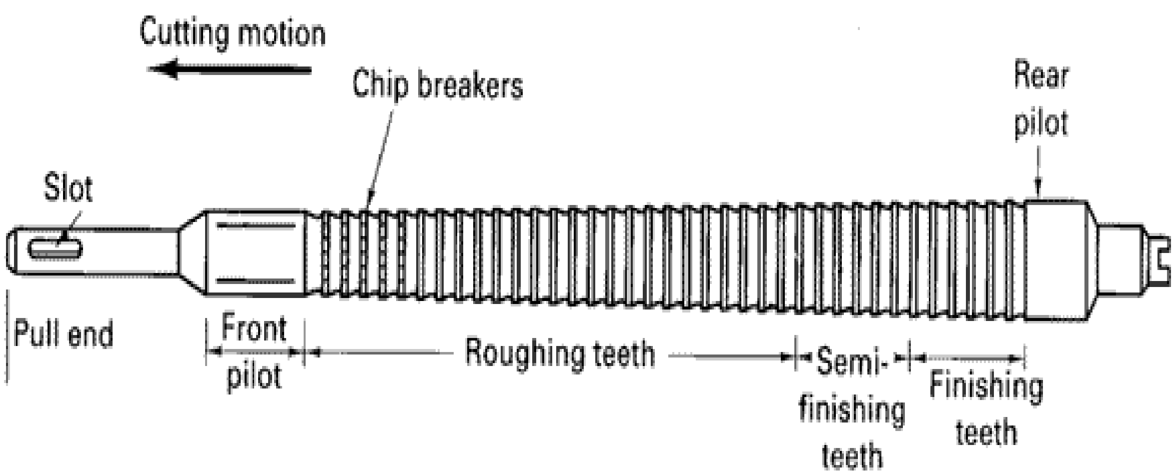
Drilling	Boring
➢ Drilling is used for creating a hole of required size in Work piece.	➢ Boring is used for enlarging the existing the hole which is made by Drilling.
➢ Drilling is a rough machining work.	➢ Boring is a finishing operation.
➢ A multi point cutting tool required is	➢ A single point cutting tool required is

called drill bit or twist drill.	called boring tool.
➢ Ex:-Pillar drilling machine ➢ Bench drilling machine ➢ Radial drilling machine.	➢ Ex:- Horizontal boring machine ➢ Vertical boring machine ➢ Jig boring machine

BROACHING MACHINING

- ❖ It is a machining operation in which a tool having a series of cutting teeth called broach is either pull or pushed by the broaching machine passed the surface of work piece. In doing so, each tooth of tool takes a small cut through the metal surface.
- ❖ Most of the cutting is done by the first and intermediate teeth where as the last few teeth finish the surface to the required size.
- ❖ The surface to be cut may be external or internal when the operation is performed on internal surface it is called internal or whole broaching and in case of external surface it is called external or surface broaching.
- ❖ According to the method of operation it is divided in to 2 types , they are :-
    I. Pull type.
    II. Push type.

- The operation of broaching involves the use of multi cutter called broach.
- The teeth of the broaching is so designed that the height of the cutting edge of the following cutting tool is slightly more, equal to speed per tooth, then that of the preceding tooth.
- Thus then when the broach is feed in a straight line, either over an external surface or through an internal surface. The metal is cat in several successive layers by the successive teeth of the broach.
- The thickness of each layer is same & is known as feed per tooth. The sum of the thickness of all layers taken together is called depth of cut of broaching tool.

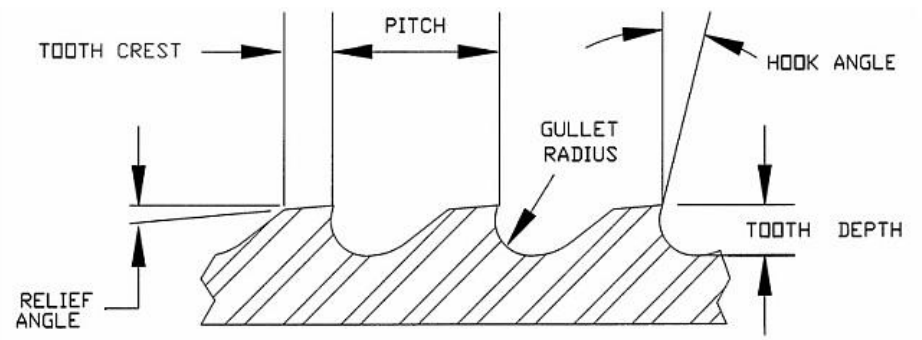


PULL TYPE BROACHING:-

- Figure shows a pull type broach being feed into a hollow work piece, on a vertical cool down type machine to machine internal surface of the work piece.
- In such machine the broaching tool is pulled through across the work piece which is stationary, the broach may be pulled up or pulled down across the work piece.
- A vertical pull down machine consist of work piece a broach elevator above the table and a puller machine below the table.
- When the elevator raises the broach above the table the work can be placed in to position. The elevator then lowers the pilot end of the broach through the whole by the work piece, where it is engaged by the puller.
- The elevator raises the upper end of the broach and the broach is pulled through the work piece there by giving to the hole in the work piece of required shape and size. Then the work piece is removed from the table. The broach is raised upward to se enlarged by the elevator mechanism.
- In vertical pull up machine the pulling ram is above the work table and the broach handling machine is below it. While the broach is lowered, the work is placed over the pilot.
- The handling mechanism raises the broach until it engages the puller head. Comes to rest against the underside of the table where it is held until the broach has been pulled through.

PUSH TYPE BROACHING:-

- In push type broaching machine the broaching tool is pushed through or across the work piece stationary.
- Fig shows push type broach being feed to stationary work on a horizontal broaching machine, to machine an external surface on the work piece.
- Like pull broaching machine the work piece is loaded on the work table or fixture.
- Then start the front end pilot through the work or pushed the work if it is surface broach. Then the broach is pushed through the work piece.



Advantages of Broaching:-

- Rate of production is very high.
- Job is completed in one stroke of the broach (Rough machining & finishing operation)
- Both internal and external surface can be machine.
- Finishes about 0.8 microns can be obtained.
- Broaching operation, it requires little skill the part of the operator.
- Less time consumption.

Application of Broaching:-

- A wide vertical of shapes, regular or irregular can be produce by both internal and external broaching process.
- Broaching can be used for many jobs that are done on drilling, boring, shaping, planning.
- Broaching is used to produce a wide verity of components in rifle and gun manufacturing parts for aircraft engines.
- Broaching is widely used in the manufacture of :-

  I. Turbine Blades.

  II. Rotors.

  III. Special Gear.

PLANNER MACHINE

- ✓ The planner like a shaper is a machine tool to produce plane and flat surfaces by a single point cutting tool.
- ✓ The planer is a machine tool designed to produce plane and flat surface on a work piece which is too large or too heavy. The work piece is securely fixed on a table called platen, and it reciprocates horizontally against a single edged cutting tool.
- ✓ The surface machined may be horizontal, vertical or at an angle.

OPERATIONS OF PLANER MACHINE:

The planer is used for:

1. Planning flat horizontal, vertical and curved surfaces.

2. Planning at an angle and machining dovetails.

3. Planning slots and grooves.

The planer are available in different types for doing different types and sizes of job; the most common being the standard and double housing planer.

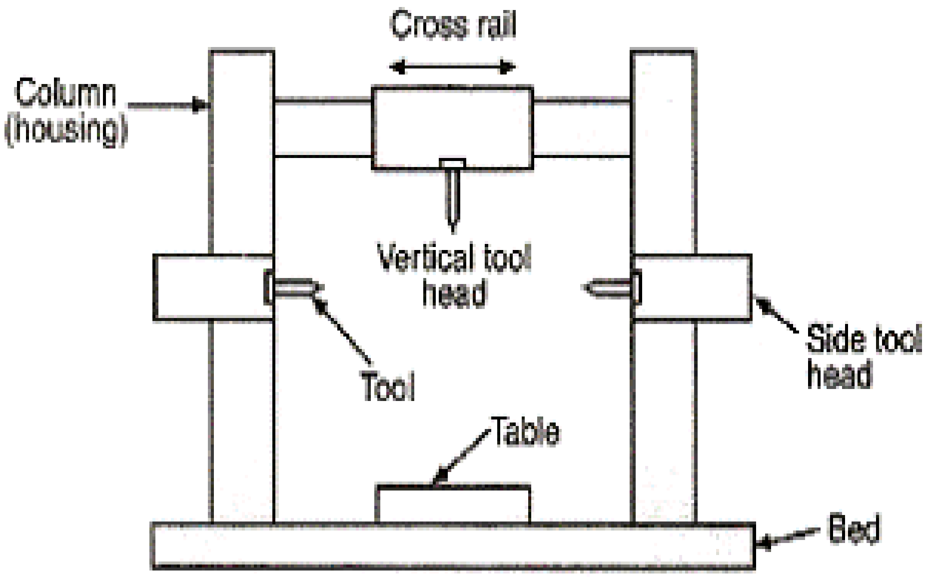
SIZE & SPECIFICATION

- ✓ Horizontal distance between the two vertical housings.
- ✓ Vertical distance between the table top and cross rail.
- ✓ Maximum length of the table travel or length of the stroke.
- ✓ Length of bed.
- ✓ Length of table.
- ✓ H.P of motor.
- ✓ Method of driving table:-geared or hydraulic.

PARTS OF A PLANER

The main parts of a planer is

- ✓ Bed
- ✓ Table or Platen
- ✓ Housings or Columns
- ✓ Cross rail
- ✓ Tool heads
- ✓ Controls



Bed:

- ✓ The bed is a long heavy base and table made of cast iron.
- ✓ Its top surface is flat and machined accurately. The flat top surface has slots in which the work piece can be securely clamped. The work piece needs rigid fixing so that it does not shift out of its position.
- ✓ The standard clamping devices used on planer machine are: Heavy duty vice, T-holders and clamps, angle plate, planer jack, step blocks and stop.

- ✓ The table movement may be actuated by a variable speed drive through a rack and pinion arrangement, or a hydraulic system.

Housing or Column:-

- ✓ These vertical members are situated on both side in case of a double housing planner and on one side only in case of an open side planer.
- ✓ Inside them, they carry the different mechanism for transmissions of power to the upper parts of the machine, from the main drive viz. cross rail elevating screws, vertical feed shaft and cross feed bar etc.
- ✓ At their front, they are very accurately machined to from vertical ways along which the cross rail slides up and down, where side tool-heads are used, they also slide vertically along the same guide ways.

CROSSRAIL:-

- ✓ It is a horizontal member of heavy structure which connects the two vertical housings of the machine. It provides additional rigidity to the machine.
- ✓ By means of the elevating screws it can be moved up and down along the ways provided on the housings.
- ✓ Clamps are provided to lock the cross rail in any desired position along the column.
- ✓ Accurately finished ways are provided at the front of the cross rail for the two vertical tool head.
- ✓ Inside the rail the feed rods are provided for vertical feed and cross feed to the tools.

Controls:-

- ✓ Various controls for starting, operating and stopping the various mechanism, automatic cutting off speed and feed regulation and similar other functions are usually provided within a quick approach of the operator of the machine.

TOOL HEAD:

- ✓ The tool head of the planer is similar to that of a shaper in construction and operation.

CLAMPING OF JOB:

- ✓ There are three important points to be hosted while clamping the job on the planer table.
- ✓ The work should be connected rigidly to the table so that it may not be shifted out of its position while cutting progresses.
- ✓ Proper clamping should be done all round the job.
- ✓ The job should be so held that the surface planed should remain in proper position with other surface.
- ✓ The job may be located on the planning machine table by the following methods.
- ✓ By standard clamping devices.

- ✓ By special fixtures.
- ✓ The standard clamping devices are t-bolts, stops, planer jacks, heavy duty vises, angle plates & planner centers etc.

PLANER TOOLS:

- ✓ The cutting tools which are uses in planer are single point cutting tool which are used in lathe and shaper.
- ✓ Planer tools may be solid forget type or bit type.
- ✓ The bit may be brazed, welded or mechanically held on a MS bar.
- ✓ As a planer tool has to take up heavy cuts, the tools are made heavier and larger in cross section.

Difference between Shaper and Planer

	Shaper	Planer
1.	Cutting stroke is slower than inactive stroke.	Cutting stroke is remain slower.
2.	Shaper machine is use for small workings.	Planer machine use for large workings.
3.	Through machining a single cutting tool is use.	Two or extra cutting tools be able to use through machining.
4.	Cutting tool move up and down in horizontal direction as make a cutting process.	Cutting tool remains motionless.
5.	Stroke length is small.	Stroke length is considerably bigger than that of a shaper.
6.	Stroke length is regulated through the stroke adjust screw.	Distance of table travel is keeping pace by stops with dogs.
7.	Cutting rate through the cutting stroke differ.	Planer has nearly stable cutting speeds.
8.	Work-piece is held tightly on a stable bed.	Work-piece is held firmly on a horizontally moving table.

SHAPER MACHINE

- A shaping machine is a versatile machine used to generate flat surface by means of single point cutting tool held in a properly designed tool box mounted on a reciprocating ram moves the cutting tool forward and backward in straight line.
- Shaper machine intended for producing flat surface, these surfaces may be horizontal, vertical or inclined.

Working Principle:-

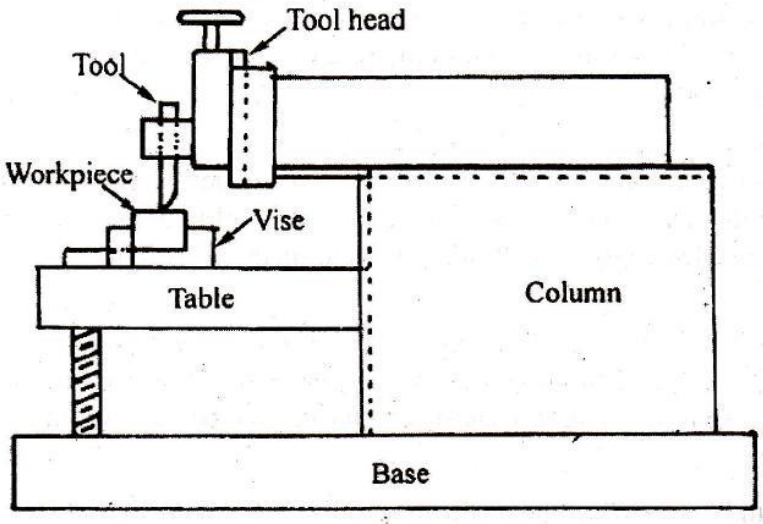
- In case of shaper the job is rigidly held in a suitable vice or clamp directly on the machine table. The tool is held on the tool post mounted on the ram of the machine.
- The ram reciprocates to and fro and, in doing so makes the tool to cut the material in the forward stroke.
- No cutting of materials takes place during the return stoke of the ram. Hence it is turned as ideal stroke.
- The job is given an indexed feel (equal amount after each cut) in a direction normal to the line of action of the cutting tool.

Classification of Shaper:-

- According to the length of shaper, type of driving mechanism, direction of travel of ram, the type of work, the type of design of table, shapers are classified many ways.
- The main classifications are :-
    - i. Standard shaper.
    - ii. Horizontal shaper.
    - iii. Vertical shaper.
    - iv. Draw cut shaper.
    - v. Gear shaper.
    - vi. Crank shaper.
    - vii. Counter shaper.
    - viii. Hydraulic shaper.
    - ix. Travelling head shaper.
    - x. Universal shaper.

Principal Part of Shaper:-

1. Base
2. Column.
3. Cross rail.
5. Ram
6. Tool Head.
7. Vice



Block diagram of shaper

4. Table.

Base:-

- It is a heavy & robust cast iron body which acts as a support for all the other parts of the machine which are mounted over it.
- It withstands all the machine pressure or vibration of the machine.

Column:-

- It is a box type cast iron body mounted on the base and acts as housing for operating mechanism of the machine and the electrical motor.
- It also acts as a supports for other parts of machine such as cross rail, ram, etc.
- On its top it carries machined ways in which the ram reciprocates & vertical guide ways at its front.

Cross rail:-

- It is a very heavy cast iron constriction attached to the column at its front on the vertical guide ways.
- It carries two mechanism one for elevating of the table or second is for transverse of table.

Table:-

- It is made up of cast iron and having box type construction. It holds and supports the work during the operation and slides along the cross rail to provide feed to the work.
- T-slots are provided on the top and side to holding the work to cut.

Ram:-

- It is also an iron casting semi circular and provided with ribbed construction inside for rigidity and strength. It carries the tool head and travels in dove tail guide ways to provide a straight line motion to the tool.
- It also carries the mechanism for adjustment of the ram for inside of it.

Tool Head:-

- It is a device in which the tool is held.
- It can slide up & down and it can be swung to ma desired angle to shake for a desired operation.

Vice:-

- It is a job holding device and is mounted upon the table.
- It holds & supports the work during the machining.

Working of shaper:

- Shaper machine works on the quick return mechanism. It is used to shape the metal or make flat surfaces, making grooves and slots.
- It cuts the metal in one stroke in back motion or in froth motion and the remaining one is useless. The working of shaper machine can be described as follow.
- First the job is fixed to the machine table. The single point cutting tool is mounted on the tool post situated on the ram.
- Now the motor start by manually which create reciprocating motion of ram by quick return mechanism.
- When the ram is in reciprocating motion, the tool rubs the work piece, which removes unwanted material from it. It cuts the metal in forward stroke.
- While return strokes the clapper provide the clearance between tool and work piece, which make sure no cutting in return stroke. If the tool cuts material in both in forward and return stroke it give poor surface finish and also cause for tool wear.

Size and Specification of shaper:-

According m/s copper engineering pvt.ltd INDIA the complete specification of shaper is:-

- Length of the stroke.
- Maximum horizontal travel of table.
- Maximum vertical travel of table.
- Maximum distance from table to ram
- Maximum vertical travel of tools slide.
- Length and width of table tough.
- Length and depth of table side.

- Power of motor.
- Number of ram cycle per minute.
- Range of ram cycle per minute.
- Maximum vice opening.
- Toolbox travels size of tool.
- Approximate net weight.
- Floor space.

Quick Return Mechanism:-

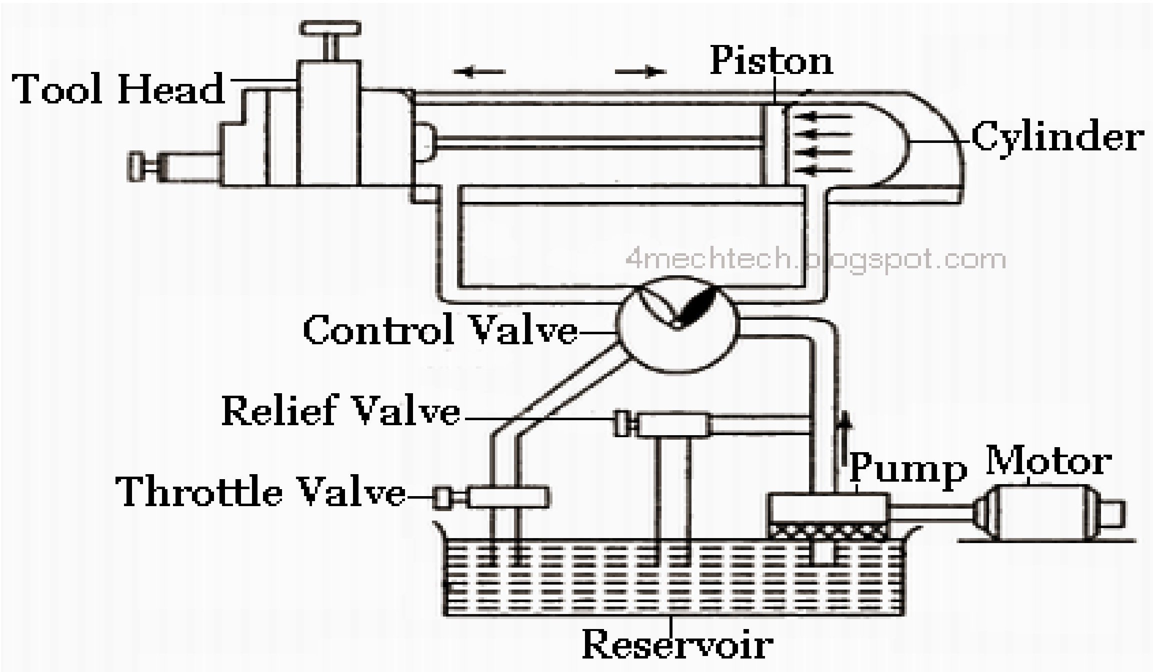
- In case of shaper machine the forward stroke is the cutting stroke and return strokes as the ideal stroke.
- No metal cutting is done during ideal stroke.
- The time spent in this stroke is obviously wastage, however fast this ideal stroke is made. It will definitely take some time and it is not possible, therefore to reduce it to 'zero' value.
- The objective is to use some such mechanism that will reduce its ideal time to minimum. Such mechanism is known as quick return mechanism.
- The three common mechanism used in this purpose are :-
    i. Crank and slotted link mechanism.
    ii. Hydraulic quick return mechanism.
    iii. Withworth quick return mechanism

Hydraulic Quick Return Mechanism:-

Parts of hydraulic shaper

1) Hydraulic gear pump.6) Ram.
2) Relief Valve. 7) Piston.
3) Throttle Valve. 8) Cylinder.
4) Control Valve. 9) Reservoir.
5) Tool Head.

- The hydraulic control system used as a quick return mechanism for the longitudinal movement of shaper. Shaper ram basically operated into 2 types:-
    i. Constant volume hydraulic mechanism.
    ii. Constant pressure Hydraulic mechanism.



Construction:-

- The shaper ram consist of a piston cylinder arrangement by which it moves to and fro motion longitudinally and a control valve.
- The oil stored in the reservoir is drawn through an oil filter by the double gear hydraulic pump which is driven by an electric motor .the reservoir is kept open to atmospheric pressure.
- Pump delivers a constant quantity of oil to control valve at a moderate pressure.
- From the control valve the oil can be delivering to either side of the piston in the feed control cylinder situated under the ram.
- Position of the control liver of the control valve determines as to which side of the piston the oil will be delivered.

Working:-

- The control lever is in position p1 and the oil under pressure is being deliver to the left hand side of the cylinder through the pipe opening at a .
- With the result the piston being fired from left to right in forward stroke of the ram.
- Oil on the right hand side of the piston, as the piston moves, is forced through the pipe connection at b to the control valve and then to the reservoir through the pipe connection ‘c’
- A rotary type of ported valve is in corporate in the control valve and the same is attached to the control lever. It carries the oil return ports. Through which the returning oil from the cylinder pipe to pipe ‘c’ and then back to reservoir.
- At the end of the stroke the stop attached to the ram body throws the control lever from piston p_1 to p_2 to rivers to control valve connection.

- The oil now flows in a reverse direction i.e. through the control value to the right hand side of the cylinder to enter into the latter into `B’.
- The return force of the ported value are opened towards the other side to allow the oil from left hand side of the piston to pipe `c’ and then to the reservoir.
- Thus makes the piston to move from right to left and ram to make its return stroke.
- At the end of the return stroke another stop is actuates the control lever from `b’ to `p1’ and again starts the forward stroke.

Crank and Slotted Link Mechanism:-

Construction:-

- The crank and slotted link driving mechanism consist of a slotted link called rocker arm, pivoted at its bottom end which forms the fulcrum.
- At its upper end it carries another short link which is attached to the block `B’ block `B’ can be clamped at the desired position by mean of hand lever `H’ .
- The rocker arm provided with a slide block in which revolves the crank pin `P’ the slide block can freely slide in the slot, provided in the rocker arm.
- At the back of the rocker arm a large cast steel gear called bull gear as provided, which is mounted on a pin attached to the frame of the machine.
- A slotted disk carrying a `T’ slot is secured to the bull gear at its front. The crank pin `P’ is fitted In this slot and can be moved to any desired position along the same by means of bevel gear `$B_1$’,`B_2’ and the adjusting screw `S’ .
- The bull gear pinion mounted on the power shaft drives the bull gear which, while rotating on account of the eccentricity between its center and that of the crankpin marks the rocker arm swing about the fulcrum. Thus in turns moves the ram to and fro.

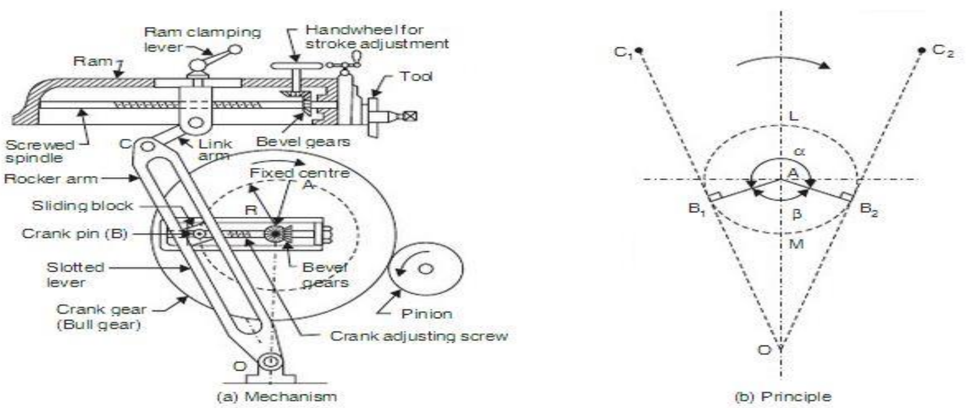


Fig. 2.2 Quick return mechanism

Working Principle:-

- The motion or power is transmitted to the bull gear through a pinion which receives is motion from an individual motor or overhead line shaft through speed control mechanism. Speed can be changed by shifting gears.
- A radial slide is bolted to the centre of the bull gear, carries a sliding block into which the crank pin is fitted. Rotation of the bull gear causes the crank pin to rotate at a uniform speed.
- Sliding block which is invented on the crank pin is fitted within the slotted link. The slotted link is pivoted at its bottom end attached to the frame of the column. The upper end is forked and connected to the ram block by a pin.
- As bull gear rotates causes the crank pin to rotate, the sliding block fastened to the crank pin will rotate on the crank pin circle, and at same time will move up and down in the slot giving a rocking movement which is communicated to the ram. The rotary motion of the bull gear converted to reciprocating movement of the ram.

Tool Head of Shaper:-

- ➢ Tool head is mounted at the front end of the ram and consist of a vertical slide which can be move up and down by rotates at its position inside a nut provided at the back of the slide. Thus casing the slide to move.
- ➢ At the back of the slide a graduated plate is provided called swivel plate. Which is bolted to the front of ram?
- ➢ The tool head is inclined with the vertical slide for machining inclined surface and the inclination can be red directly from the graduation on swivel plate.
- ➢ In front of the slide the apron is provided which carry the clapper box at its bottom. The apron is secured to the side by means of the bolt (B) & the bolt (b) passes through a slot.
- ➢ Bolt (B) facilitated swiveling the apron also to either slide, for this reason the bolt (B) is UN secured & clamp again after swiveling the apron.
- ➢ The clapper box to carries to parallel, vertical position at its front through which passes the pin (p).

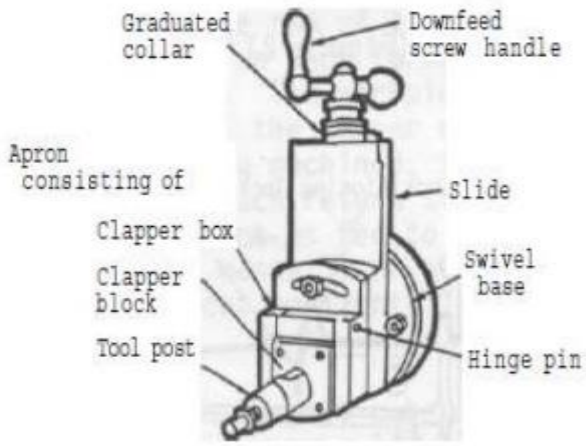


Figure 3 Shaper toolhead

- The clapper box carrying the tool holder is hanging about this pin such that in the forward stroke of the ram is gets a rigid support at its back by being a butted against the vertical surface of the clapper box & it's return stroke it swing out ward to prevent scratching of the wall by the tool .
- The tool is held vertically in the tool holder & clamped in position by means of tightening screw.

Automatic Table Feed Mechanism:-

- The automatic cross feed mechanism of the table is very simple & done by rotating a wheel mounted on the cross feed screw.
- It consists of a slotted disk which carries a T- slot and an adjustable pin is fitted in this slot.
- The adjustable pin is an attached to a connecting rod one side & other end of the connecting rod is attached to the liver end of the rocker arm of pawl mechanism.
- The rocker arm swinging about the screw 'c' & at its upper end carries a spring loaded pawl.
- Adjustable pin is set eccentric with the slotted disk center.
- The slotted disk at its back carries a spear gear, which is driven by the bull gear as the disk rotates through this gear the adjustable pin being eccentric with the disk center, causes the connecting rod to reciprocate.
- This in term makes the rocker arm to swing about the screw 'c'. To move the pawl even one or more teeth and thus transmit an intermittent motion to the cross feed screw which moves the table.

GRINDING MACHINE

- Grinding is a process of removing material by the abrasive action of a revolving wheel on the surface of a work piece, in order to bring it to the required shape and size.
- The wheel used for performing the grinding operation is known as grinding wheel.
- The grinding wheel consists of sharp crystals called abrasives, held together by a binding material or bond.

GRINDING WHEELS:

Grinding wheels are produced by mixing the appropriate grain size of the abrasive with the required bond and pressed into shape. The characteristics of the grinding wheel depend upon a no. of variable they are:

1) Abrasive types
2) Grain size or Grit
3) Bond
4) Grade
5) Structure

1) Abrasive types:

These are the extremely hard materials consisting of very small particles called grain which carry a no. of sharp cutting edge.

- These hard materials with high toughness and also have the ability to machining Smaller pieces when the force increases.
- The abrasives are of two types

(I) Natural (ii) Artificial

(I)Natural Abrasives:

- ✓ They are obtained directly from mine
- ✓ The common natural abrasives are sand stone, emery, corundum, quartz and diamond.
- ✓ Except Diamond all the natural abrasives are now considered absolute.

(ii)Artificial Abrasives:

- ✓ They are manufactured under controlled condition in closed electric furnaces in order to avoid the introduction of impurities & to achieve necessary mechanical properties. The artificial abrasives are.

- ✓ **Aluminum oxide (Al_2O_3) =** this abrasives carries very hard & tough grains having sharp cutting edge. It is obtained by fusing the impure aluminum oxide, called Bauxite mixed with ground coke & iron chips in an electric arc furnace.
- ✓ **Silicon carbide (sic) =** It is made from silicon dioxide, coke, sawdust and salt, mixed together and heated in a electric furnace at a temperature of 2600^0C.
- ✓ **CBN-** Cubic Boron Nitride is the hard abrasives which are produced in the4 laboratory using high temperature & high pressure process.
- ✓ CBN is less reactive with materials like hardened steels, nickel base & cobalt based super alloys. This is very expensive.
- ✓ **Diamond:** Diamond is the hardest known material that can be used as a cutting tool material. It has a very high chemical resistance capacity along with a low co-efficient of thermal expansion.

Grain or Grit:

- ❖ The term grain or grit denotes the approximate size of the abrasive particles & gives an idea of the coarseness or fineness of the grinding wheel.
- ❖ The choice of grain size or grit depends upon many factors

  (i) Quality of finish required.

  (ii) Amount of stock material removed.

  (iii) Physical properties of the material to be ground.

- ❖ The coarser grit will remove the stock at a faster rate & finer finish will always require a fine grit.
- ❖ Coarse grit wheels are more suitable for grinding soft & ductile materials whereas hard & brittle materials are best ground with fire grit wheels.

SELECTION OF GRINDING WHEELS:

- Selection of grinding wheel is a vital necessity to perm various different functions.

  (I) Quick material removes.

  (ii) High class surface finish.

  (iii) Maintain close dimensional tolerances.

- It is necessary; therefore that proper grain size, bond, grade, strength, shape and size of the wheel should be selected to meet the specific requirements of a job.

The factors upon which the selection will depend are as follows:-

  - o Properties of the material to be machined i.e. its hardness, toughness, strength etc.
  - o Quality of surface finish.
  - o Grinding allowance provided on the work piece.

- Dimensional accuracy required.
- Method of grinding wet or dry.
- Rigidity, size and type of machine
- Relative sizes of wheel and job.
- Type of grinding to be done.
- Speed & feed of the wheel.

Methods of grinding:

According to type surface to be grounded main kinds of grinding methods are as follow:

- **External cylindrical grinding:** produces a straight or tapered surface on a w/p when it is rotated about its own axis between centers as it passes lengthwise across the face of a revolving grinding wheel.
- **Internal cylindrical grinding:** it produces internal cylindrical holes & tapers. The work is chucked & rotated on its axis, while the grinding wheel rotates agest the work.
- **Surface grinding:**
  It produces flat surfaces & the work may be grounded either by periphery or by end face of the grinding wheel.

❖ **Face grinding:**
It is a method of grinding vertical flat surface & the wheel spindle may be vertical or horizontal.

❖ **From grinding:**
It is done by specially shaped grinding wheels to grind formed surfaces as gear teeth, threads, shaft, dovetails etc.

❖ **Set wheel grinding:**
It is a method of grinding short w/p without changing the grinding wheel.

❖ **Centre less grinding:**
It is a method of grinding external & internal cylindrical surfaces in which the work is supported among a regulating wheel, a grinding wheel & a work rest blade.

❖ **Off-hand grinding:**
It is rough grinding method in which work is held in hand and pressed against the rotating grinding wheel. For example grinding a chisel on pedestal grinder

Grinding operations are generally classified based on the type of surface produced. The grinding operation can be classified as:

- Cylindrical grinding for generating cylindrical surfaces.
- Surface grinding for generating flat surfaces.
- Centre less grinding for generating axi-symmetric surface.

Cylindrical grinding:

- Cylindrical grinding machine is used generally for producing external cylindrical surfaces. The machine is very similar to a centre lathe.
- In cylindrical grinding the work piece in rigidly held between two centres, in a chuck or in a suitable fixture. (One of these centres is in the head stock and the other in the fail stock).
- The work piece is rotated about its axis and feeding fast revolving grinding wheel. If the work surface to be ground in longer than the face width of the grinding wheel the work is traversed past the wheel or the wheel past the work.
- Traversing of wheel or work is done either by hydraulic or mechanical power or by hand.
- Feed is given to the work or the wheel at the end of each traversing movement. While mounting the work between centers, the headstock centre is not disturbed. It is the tailstock centre which is moved in or out, manually or hydraulically to insert & hold the work.

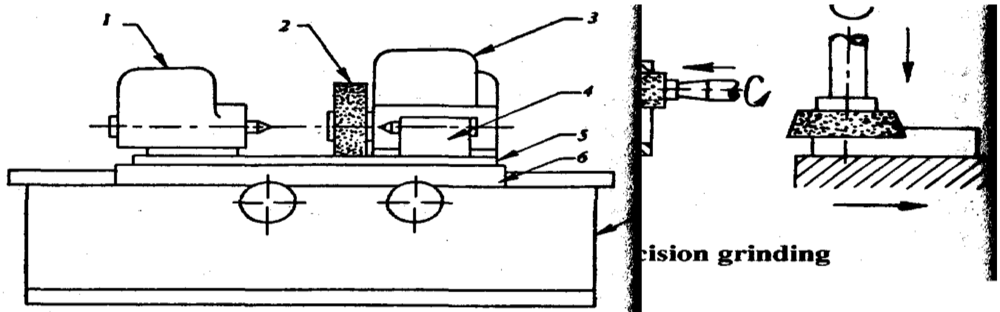


Figure 10.4 Block diagram of a plain centre-type grinder
1. Headstock, 2. Grinding wheel, 3. Wheelhead, 4. ailstock, 5. Upper table, 6. Lower table, 7. Base

1. Stand grinder, 2. Portable grinder, 3. Swing frame grinder.

<u>SURFACE GRINDER:-</u>

- ✓ A surface grinder produces and finishes flat surfaces by employing a revolving abrasive wheel.
- ✓ A surface grinder does operation smaller to those done on a shaper, planner or milling machine, but is capable of producing surface more accurately both as to size and surface quality.
- ✓ A surface grinder is basically a move able table with a horizontal spindle (or vertical spindle) grinding wheel mounted above it, these machine are made fully hand operated, partly automatic and fully automatic.

- ✓ The grinding wheel is mounted on column which always it to be raised and lowered at least 300 mm and more on the larger machine.
- ✓ The table can move longitudinally or cross wise.
- ✓ Work holding is usually by means by magnetic chuck or table.

Surface grinders fall into two generally classification

(i) Rotary type

- Horizontal spindle using the periphery of the grinding wheel.
- Vertical spindle using rim of the wheel.

(ii) Planner type

- Horizontal spindle using the rim of the wheel.
- Vertical spindle using the rim of the wheel.
- Horizontal spindle using the periphery the wheel.

I. Rotary type surface grinders

- Such machine have circular work table which revolve under the rotating grinding wheel.
- The horizontal rotary grinder also known as ring grinder consist of horizontal wheel spindle having a reciprocating motion similar to that of the shaper ram, and a revolving magnetic chuck table supported by columns at the front of the machine.
- The work table can be raised or lowered and has provisions for tilting the table for can cave or convex grinding.
- The machine is equipped with a coolant supply tank and pump for wet grinding.
- This machine is used for the production of flat, concave or convex surface which make it readily adaptable for either tool room or multiple production purpose.
- The **vertical spindle rotary grinder** has a cylindrical wheel mounted on a vertical spindle and supported on a vertical column. This vertical column provides a means rising a lowering the wheel.
- The work table consists of revolving magnetic chuck supported on ways or slides, which provided a means of moving the work to and from the wheel.
- The machine is used a cup, cylindrical and segmented grinding wheel and is widely used for high production applications, for finishing application the wheel axis should be exactly perpendicular to the surface to be ground and for roughing purpose the axis is kept slightly tilled.

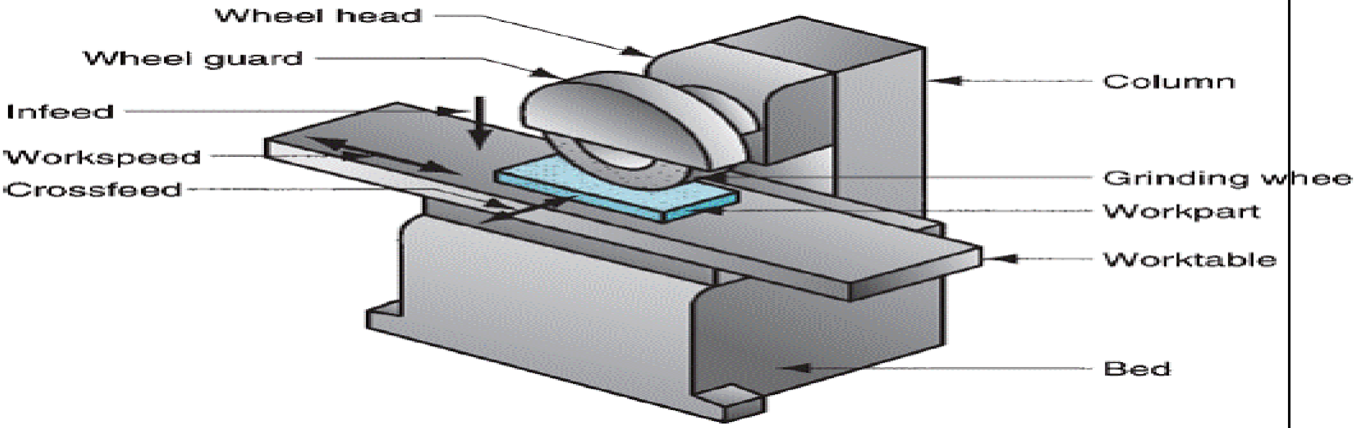
This machine does not give as good a surface finish as the horizontal rotary grinder.

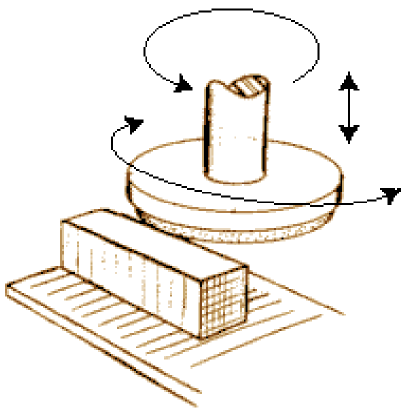
II. Planner type surface grinders

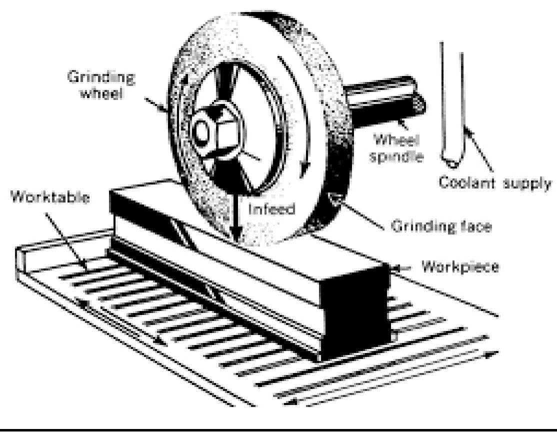
- Planner type surface grinder or reciprocating table type surface grinder make use of a reciprocating motion to move the work table back an fourth under the grinding wheel. The grinding wheel may have horizontal spindle or vertical spindle.
- Horizontal spindle planner type surface grinder has a horizontal spindle carrying the grinding wheel rectangular work table. The table is provided with a longitudinally feed movement. The cross-feed is provided either on the table or on the wheel head. The table top has T-slots for mounting magnetic chuck, vice, fixtures, etc.
- **Vertical spindle planner type grinders** use cup, cylinder or segmented wheels for faster stock removal and where accuracies are not stringent.

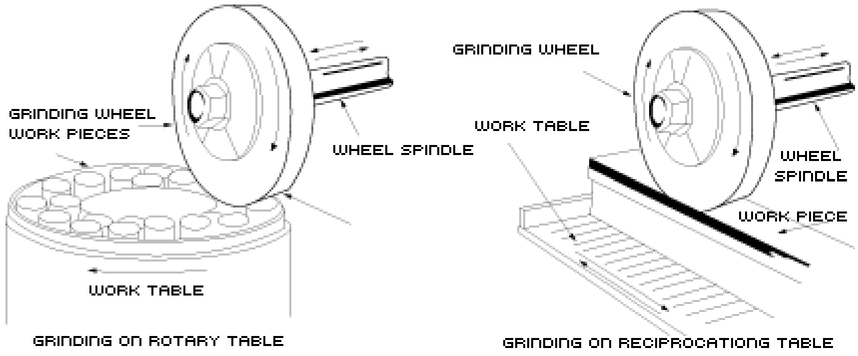
Such machines are usually of higher capacity and are used as production machine.

This machine performs an operation similar to face milling. The worktable reciprocated and the tool fed intermittently downward; these motion are known as travels and in feed respectively.









CENTRE LESS GRINDING:

- ❖ Centre less grinding makes it possible to grind the cylindrical work pieces without actually fixing the work piece using centres or a chuck. As a result no work rotation in separately provided
- ❖ It carries a heavy base and two wheel heads, one carrying the grinding wheel (larger one) and the other regulating wheel (smaller one)
- ❖ This process consist of two wheels, one larger grinding wheel & another smaller regulating wheel and the work is held on a work rest blade.
- ❖ The regulating wheel is mounted at an angle to the plane of the grinding wheel. The centre of the work piece is slightly above the centre of the grinding wheel.
- ❖ The work piece is supported by the rest blade and held against the regulating wheel by the grinding force.
- ❖ As a result the work rotates at the same surface speed as that of the regulating wheel.
- ❖ The axial feed of the work piece is controlled by the angle of tilt of the regulating wheel. Typical work speeds are about 10-50 m/min.
- ❖ The regulating wheel essentially carries rubber bore and helps in rotation of work piece due to friction.
- ❖ There are three types of centre-less grinding operations. They are through feed, in feed and end feed centre less grinding.

Through feed:

- ❖ In this method, the work piece is supported & revolved in between two wheels one grinding wheel and another is regulating wheel.
- ❖ Simultaneously the work is given an axial movement also by the regulating wheel.
- ❖ For this, the axis of the regulating wheel is inclined at 2 to 10 degrees with the vertical. The amount of stock to be removed determines as to how many time a work piece has to pass between the wheels.

In feed grinding:

- This method is similar to the plunge cut grinding method used on cylindrical grinders. Both regulating and grinding wheels are more in width than the work length to be ground.
  - Axis of the regulating wheel is inclining a little, about half degree from the horizontal.
  - This method is used for grinding shouldered or formed components.

End feed grinding:

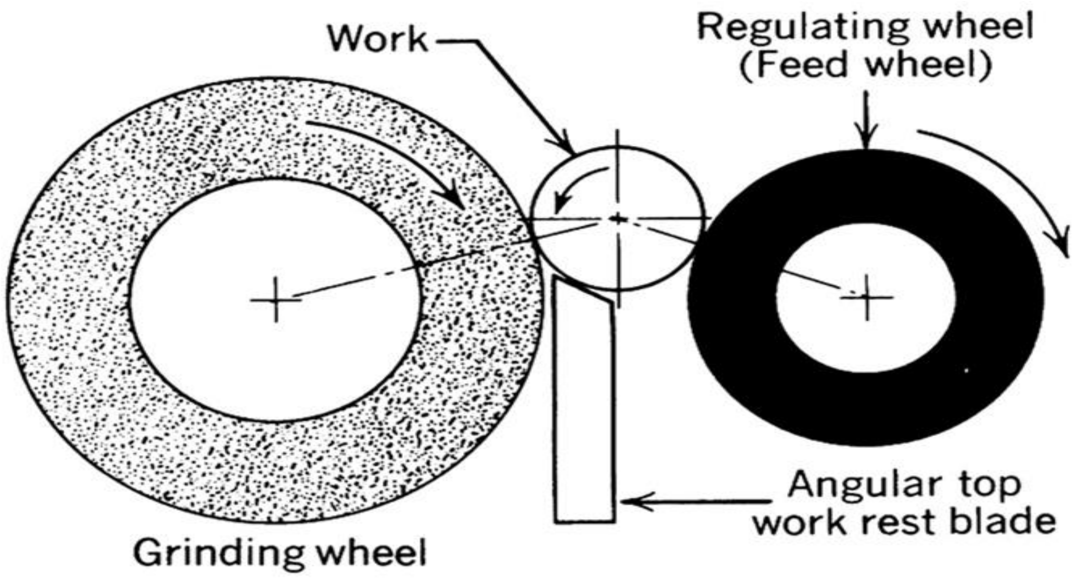
- In this method both the wheels i.e. the grinding wheel and the regulating wheel are dressed to contain the required shape or form.
- The work piece is fed longitudinally from the side of the wheels. As it advances between the revolving wheels, its surface is ground till its farther end touches the end stop.
- This method can be used for grinding of both spherical and tapered surfaces, but it suits best to the grinding of short tapered surfaces.

Advantages:

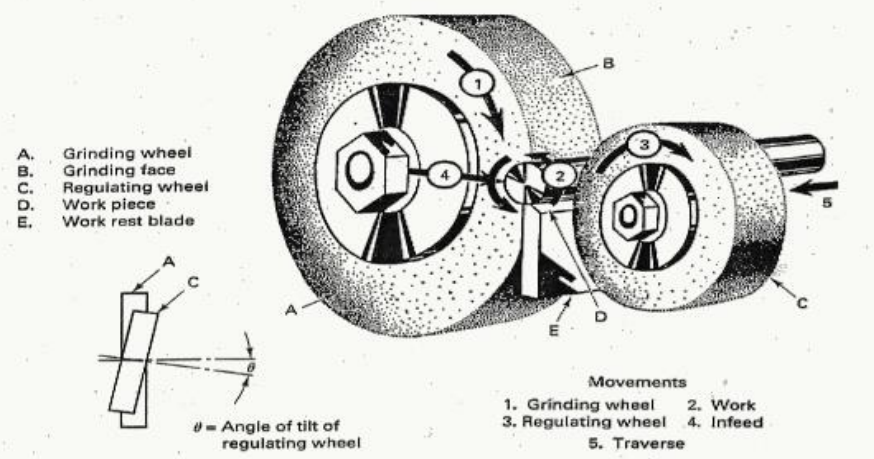
- There is no need for having and maintaining centre & centre holes.
- Work pieces can be loaded & unloaded from the machine rapidly. Grinding is almost continuous for through feed grinding.
- Backing up the work piece by the regulating wheel and work rest blade practically eliminates and deflection of the work piece. This permits maximum material removal rates.

Disadvantages:

- The set-up time for a centre less grinding operation is usually large.
- This process is useful only for large volume production.
- This process is not suitable for large work piece.



Centre less Grinding



MILLING MACHINE

- Milling in the name given to the machining process in which the removal of metal takes place due to the cutting action of a revolving cutter when the work in fed past it.
- A milling m/c is a type of metal cutting device which remove metal with a fast rotating multi-touch cutter.
- Generally smaller jobs are employed for machining in milling m/c. If larger jobs are handled, then the m/c will perhaps be slower. Because of using multi tooth cutters & various forms of cutters, a milling m/c can be economically employed for generating verities of surfaces quite speedily.

Working principle:

❖ As shown in figure the work in rigidly clamped on the table of the machine and revolving multi teeth cutter mounted either on a spindle or an arbor. The cutter revolves at a high speed and the work fed slowly past the cutter. The work can be fed in a vertical longitudinal or cross direct Types of milling machines.

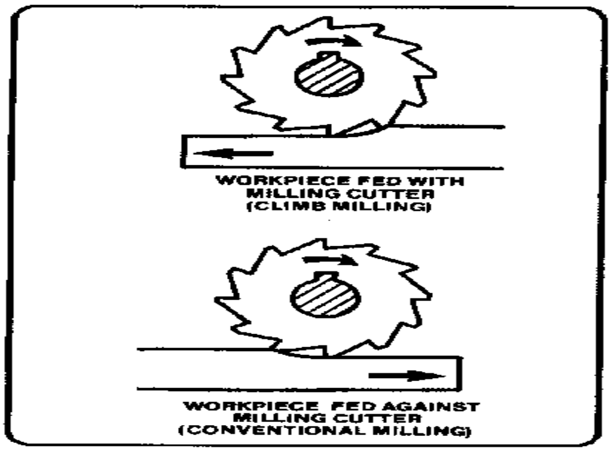


Figure 8-26. Direction of feed.

Types of milling machines:

Milling machines are classified as follows:

- ✓ Column & knee type milling machine.
- ✓ Fixed bed type or manufacturing type milling machine.
- ✓ Planer type milling machine.
- ✓ Production milling machine.
- ✓ Special purpose milling machine.

Column & knee type milling machines are further divided into following types.

–Hand milling machine

–Plain or Horizontal milling machine

–Vertical milling machine.

–Universal milling machine.

–Universal milling machine

Fixed bed type milling machines are divided into following types.

–Plain type (having single horizontal spindle)

–Duplex head (having double horizontal spindle)

–Triplex head (having two horizontal & one vertical spindle)

Planer type milling machines are used for heavy work up to a maximum of four tool heads can be mounted over it which can be adjusted vertically & transverse directions.

Production milling machines are further divided into following types.

–Rotary table or continuous type

–Drum type

–Tracer controlled

Special purpose milling machines are also divided into following types.

–Thread milling machine

–Profile milling machine.

–Gear milling or gear hobbling machine

–Cam milling machine

– Planetary type milling machine

– Double end milling machine

– Skin milling machine

Column and knee type milling machine: This milling machine has two main structural elements.

- a column shaped main frame.
- a knee shaped projection.
- Column contains the spindle and its driving mechanism
- Knee moves vertically on the column.

Horizontal milling Machine:

- ❖ In this type milling machine the vertical column serves as housing for electrical, the main drive, spindle bearings etc.
- ❖ The knee acts as a support for the saddle work table and other accessories like indexing head etc.
- ❖ Over aim provides support for the yoke which, turn supports the free end of the arbor. The arbor carrying the cutter rotates about an axis.
- ❖ The table can be given straight motions in three dire longitudinal, cross & vertical but can't be swiveled.
- ❖ For giving vertical movement to the table the knee itself, together with the whole unit above it, slides up & down along the ways provided in front of the column.
- ❖ For giving cross movement to the table, the saddle in moved towards or away from the column along with the whole unit above it.

Vertical Milling Machine:

- ❖ It derives its name from the vertical position of the spindle. This machine is available in both types the fixed bed type as well as column & knee type.

❖ It carries a vertical column on a heavy base. The over arm in this machine is made integral with the column and carries a housing at its front. This housing, called head can be of fixed type or swiveling type.

❖ In fixed type, the spindle always remains vertical & can be adjusted up & down. In swiveling type of head can be swiveled to any desired angle to machine the inclined surface.

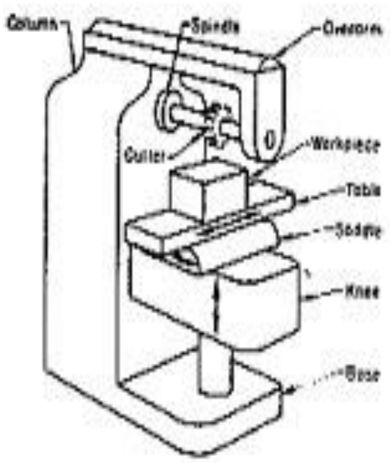
❖ The knee carries an enclosed screw jack, by means of which it is moved up & down along the parallel vertical guide ways provided on the front side of the column.

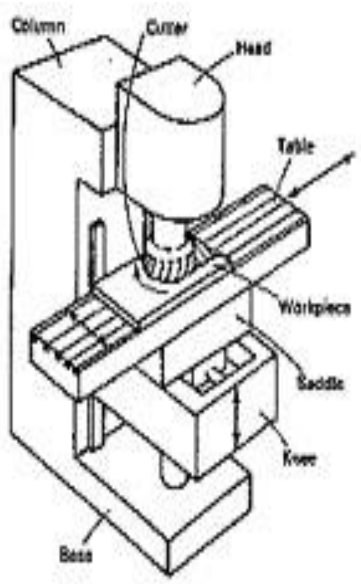
❖ The saddle is mounted on the knee & can be moved along the horizontal guide ways provided on the knee, towards or away from the column. This enables the table to move in cross direction.

❖ The table is mounted on guide ways, provided on the saddle, which are in a direction normal to the direction of the guide ways on the knee.

❖ By means of a lead screw, provided under the table, the table can be moved in longitudinal direction.

❖ Thus the work gets up and down movement by the knee, cross movement by the saddle & longitudinal movement by the table.





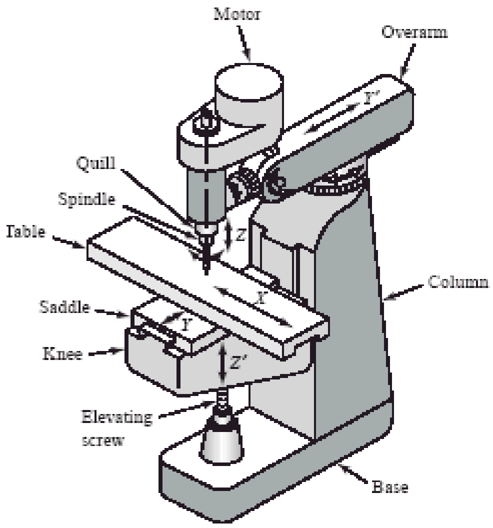
Universal milling machine:

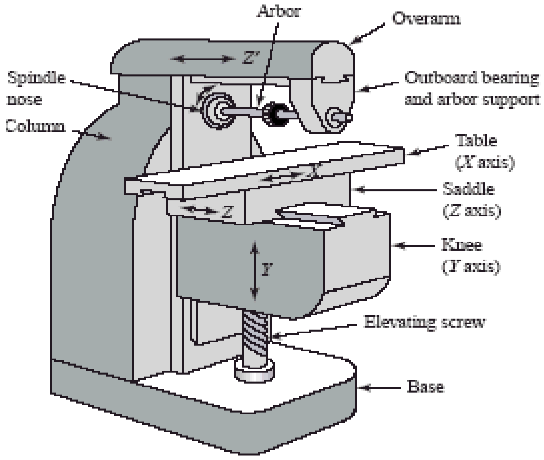
❖ It is the most versatile of all the milling machines its table can be swiveled on the saddle in a horizontal plane.

❖ For this, circular guide ways are provided on the saddle along which it can be swiveled.

❖ A graduated circular base is in corporate under the table, with a datum mark on the saddle, to read directly the angle through which the table has been swiveled.

- ❖ This special feature enables the work to be set at an angle with the cutter for milling helical & spiral flutes & grooves.
- ❖ Its over arm can be pushed back or remove & a vertical milling head can be fitted in place of the arbor to use it as a vertical milling machine.





Main parts of Universal milling machine:

- ❖ **Base:** It is a heavy casting provided at the bottom if the machine, it is accurately machined on both the top & bottom surface.
- ❖ It is actually acts as load bearing member for all other parts of the machine. Column of the machine is secured to it.
- ❖ Also it carries the screw jack which supports & moves the knee. In addition to this, it also serves as a reservoir for the coolant.
- ❖ **Column:** It is a very prominent part of milling machine; all the various parts & controls are fitted to this.
- ❖ On the front face of the column are made the vertical parallel ways in which the knee moves up & down. At its rear side it carries the in closed motor drive.
- ❖ Top of the column carries dovetail horizontal ways for the over arm.
- ❖ **Knee:** It is a rigid casting, which is capable of sliding up & down along the vertical ways on the front face of the column. This enables the adjustment of the table height or in other words the distance between the cutter and job mounted on the table are adjusted.
- ❖ The adjustment is provided by operating the elevating jack, provided below the knee, by means of hand wheel or power feed.
- ❖ Machined horizontal ways are provided on the top surface of the knee for the cross traverses of the saddle, hence the table.
- ❖ **Saddle:** It is the intermediate part between the knee & the table & acts as a support for the table.

- ❖ It can be adjusted cross wise, along the ways provided on the top of the knee, to prove cross feed to the table.
- ❖ At its top, it carries horizontal ways, along which moves the table during the longitudinal traverse.
- ❖ **Table:** It acts as a support for the work. The work is mounted on it either directly or held in the dividing head.
- ❖ It is made of cast iron, with its top surface accurately machined.
- ❖ Its top carries longitudinal T-slots to accommodate the clamping bolts for fixing the work or securing the fixtures.
- ❖ Longitudinal feed is provided to it by means of a hand wheel fitted on side of the feed screw.
- ❖ In universal milling machine the table is made to have a graduated circular base resting on the saddle. Such table can be swiveled in a horizontal plane.
- ❖ **Over arm:** It is the heavy support provided on the top of the milling machine. It can slide horizontally, along the ways provided on the top of the column and adjusted to a desired position in order to provide support to the projecting arbor by accommodating its free end in the yoke. Braces can be employed to correct the over arm & the knee.

Milling Machine attachments:

The milling machine attachments are used for the following purposes:

- ✓ **To hold the cutters**: including arbors, collects, adaptors etc.
- ✓ **To hold the work piece** on the table in a desired position and impart additional movements, if regd. such as vices, circular table, indexing head tail stock etc.
- ✓ **To act as auxiliary spindles**; in conjunction with the main spindle, in order to avoid the necessity various special types of machines, such as vertical milling attachment, spiral milling attachment, etc.
- ✓ **Arbors, Adaptors & collects:** They all are used for holding the milling cutters during the operation. This is a common method of mounting the cutters, although they are made on the M/c spindle directly also.
- ✓ **Vices:** Vices are the common devices used for holding the work on milling machine, such as plain vice, swivel vice, vertical vice, precision angelica.

INDEXING METHODS:

By indexing we mean, division of the job periphery into a desired number of equal divisions. It is accomplish by a controlled movement of the crank such that the job rotates through a definite angle after each cut is over.

Methods of Indexing:

(1) Direct Indexing (2) Simple Indexing

(3) Compound Indexing (4) Differential Indexing

(5) Angular Indexing

DIRECT INDEXING:

- The index plate is directly mounted on the spindle and rotated by hand. It can be used only where the number of divisions to be obtained is such that the number of slots on the periphery of the index plate is a multiple of the former.

Required ratio = N/n

Where ‘N’ = No. of slots on the periphery of the Index plate

‘n’ = No. of divisions required to be obtained.

for example, if the circumference of a job has to be divided into 6 equal divisions and the index plate has 24 slots, then the required ratio will be = 24/6 = 4 i.e. the index plate will be required to move through 4 slots after each cut is over.

SIMPLE INDEXING:

- This method of Index is used when the direct method of Indexing cannot be employed for obtaining the required number of divisions on the work for this a universal dividing head is used. This method of indexing involves the use of the crank, worm wheel and index plate.

Let us consider that the work has to be divided into 23 equal divisions, then the corresponding crank movement will be given by crank movement = 40 /N

Where ‘N’ = Number of divisions required

= 40/23 = $1\frac{17}{23}$ turns

Now, in the obtained result the whole number indicates the number of full turns the crank has to move through and the fraction represents the part of the turn that the crank has to make. I.e. 17/23 of a revolution.

Thus, for the above indexing for each division on the job, the crank will make one complete revolution and will move further through 17 holes on 23 holes circle.

COMPOUND INDEXING:

- This method of indexing is employed when the number of divisions required is outside the range that can be obtained by simple indexing. It involves the use of two separate simple indexing movements and is performed in two stages.

- By turning the crank a definite amount in one direction in the same way as in simple indexing.
- By turning the index plate together with the index crank in the same direction or in the opposite direction through the calculated number of spaces of another whole circle.
- The effective indexing movement will be the algebraic sum of the movement of the index crank and of the index plate.

  For example the work has to be divided into 96 equal divisions.

  So, the crank is turned 3 holes on a 18 holes circle and the index plate and crank both turned further 5 holes on 20 holes circles on account of these two

  3/18 + 5/20 = (30+45) / 180 = 75/180 = 5/12 of a revolution

  So, '1' revolution of crank, make the work piece 40 equal division.

5/12 revolution of crank, the work will divided

40/(5/12) or 40 x 12 / 5 = 96 divisions.

The various types of milling operations are:

– Slab milling	– Angular milling
– Face milling	– Form milling
– Straddle milling	– Gang milling

SURFACE FINISHING

- The parts produced through different types of metal machining operation like, turning, boring, drilling, milling, shaping, etc., although fairly accurate in sizes but do not carry a very high degree of surface finish.
- As such many cases, they do not readily suit the service they are intended for and are to be subjected to one or further operations to obtain the desire surface finish on them.
- Surface finish is a precision operation which is employed for producing extremely high surface finish. This process is also called micro finishing operation for these reason that the surface finished through these process are specified in micro units such as microns or micro-inches.
- The surface finish is needed when very close dimensional accuracy is required in addition to a high degree of finish. The surface finishing operations are:-

  a. Lapping

  b. Some grinding operation

  c. Honing

  d. Surface finishing

SUPER FINISHING:-

- Super finishing is a abrasive process which utilizes either a bonded abrasive like for cylindrical surface or a cup wheel for flat surfaces.
- It is generally used for:-
  a. Reducing surface stresses and burns and thus restoring surface integrity
  b. Correcting in equalities in geometry
  c. Achieves higher surface finish
  d. Removes chatter marks
- Super finishing produces a high wear resistant surface on any object which is symmetrical
- Typical surfaces that are super finished are cylindrical, flat; conical, spherical, super finishing is used for both internal as well as external surfaces.
- Stock removal in the super finishing process is of the order of 0.005 to 0.025mm on diameter.
- An abrasive block shaped to the appropriate from reciprocates across the face of the work with a similar amount of over run at each of the stroke. At the same time the work piece rotates about its axis. This two motions impacts to the work –a super finish.

LAPPING

- Lapping is a low speed, low pressure final finishing operation done with loose abrasive grains.
- The process is employed to get:-
  a. Extreme accuracy of dimension
  b. Correct of minor imperfection of shape
  c. Refinement of the surface finish
- It is an abrading process employed for improving the surface finish by reducing roughness and other irregular activities on the surface.
- The basic purpose of lapping in to minimize the extremely minute irregularities left on the job surface after some machining operations.
- The service life of components which are in close contact during machining can be greatly increased by the lapping process which removes valleys and hills present on the machined surface.
- Stock removal rates with silicon carbide are generally more compound to aluminum oxide. Similarly aluminum oxide gives a better surface finish for the same grain size.
- Lapping is done by charging a lap made of soft material with abrasive particles and rubbing it over the work piece surface with a slight pressure. Lapping is done

manually or by specially designed machine, the lap materials generally used are cast iron, soft steel, and brass, bronze.

- Lapping operations can be classified as

EQUALISING LAPPING:-

- It is the operation of running to mating parts or shapes together with an abrasive between them. When to such surfaces run together in contact with the abrasive, their surface finish is improved and any deviation of shape corrected.

FORM LAPPING:-

- The name itself indicates it is the shape of lap. The lap used in the operation will be a form lap that is containing the shape to be lapped.
- Lapping is done by the following methods :-
    - Hand lapping
    - Machine lapping

HAND LAPPING:-

- In hand lapping, either the lap or the work piece is held by hand and the motion of the other enables the rubbing of the two surfaces in contact.
- This method is widely used in lapping process work dies, molding dies and metals molds for casting.
- EX:-Lapping Of Surface Plates, Engine Valves, and Valve Seat Etc.

MACHINE LAPPING: -

- Machine lapping is performed for obtaining highly finished surface on many articles like races of ball and roller bearing, gears, crank shafts, pistons, gauge blocks, automobile parts etc.
- A typical vertical spindle machine consists of two wheels, one above and the other below
- The work pieces are placed between the two and the loose abrasive grains with vehicle and fed.
- Now a day's some modifications of this machine is there, that is it consists of two bonded abrasives wheels in place of above rotating wheels, no loose abrasive is required in this case.
- In both the machines, the lower wheels rotate and the upper one does not, but floats over the work pieces.
- These two machines can be used only for circular and flat work.

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

HYDRAULIC MACHINES & INDUSTRIAL FLUID POWER

5TH SEMESTER

PREPARED BY

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HYDRAULIC TURBINES

Turbines are defined as the hydraulic machines which converts hydraulic energy in to mechanical energy. This mechanical energy is used in running an electric generator which is directly coupled to the shaft of Turbine. Thus mechanical energy is converted in to electrical energy. The electric power which is obtained from the hydraulic energy is known as the Hydro-electric power.

Efficiency of a Turbine: The following are the important efficiencies of a Turbine.

a) Hydraulic Efficiency, η_h
b) Mechanical Efficiency, η_m
c) Volumetric Efficiency, η_v
d) Overall Efficiency, η_0

a) Hydraulic Efficiency (η_h): it is defined as the ratio of power given by the water to the runner of a turbine (runner is a rotating part of a turbine and on the runner vanes are fixed) to the power supplied by the water at the inlet of the turbine. The power at the inlet of the turbine is more and this power goes on decreasing as the water flows over the vanes of the turbine due to hydraulic losses as the vanes are not smooth. Hence power delivered to the runner of the turbine will be less than the power available at the inlet of the turbine.

$$\eta_h = \frac{\text{Power delivered to the runner}}{\text{Power supplied at inlet}} = \frac{\text{R.P}}{\text{W.P}}$$

R.P = Power delivered to the runner $= \frac{W}{g}\frac{[V_{w_1}+V_{w_2}]\times u}{1000}$ kW------------for Pelton Turbine

$$= \frac{W}{g}\frac{[V_{w_1}u_1+V_{w_2}u_2]\times u}{1000} \text{ kW------ Radial flow Turbine.}$$

W.P = power supplied at inlet of turbine $= \frac{W \times H}{1000}$ kW

Where W = weight of water striking the vanes of the turbine per second = $\rho\ g\ Q$

Q = Volume of water per second

V_{w_1} =Velocity of whirl at inlet.

V_{w_2} = Velocity of whirl at outlet

u = Tangential velocity of vane

u_1 = Tangential velocity of vane at inlet of radial vane.

u_2 = Tangential velocity of vane at outlet of radial vane.

H = Net head on the Turbine.

Power supplied at the inlet of the turbine in S I Units is known as Water Power.

$$W.P = \frac{\rho \times g \times Q \times H}{1000} \quad K.W \qquad (\text{For water } \rho = 1000 Kg/m^3)$$

$$= \frac{1000 \times g \times Q \times H}{1000} = g \times Q \times H \ \text{kW}$$

b) Mechanical Efficiency (η_m): The power delivered by the water to the runner of a turbine is transmitted to the shaft of the turbine. Due to mechanical losses, the power available at the shaft of the turbine is less than the power delivered to the runner of the turbine. The ratio of power available at the shaft of the turbine (Known as S.P or B.P) to the power delivered to the runner is defined as Mechanical efficiency.

$$\eta_m = \frac{\text{Power at the shaft of the turbine}}{\text{Power delivered by the water to the runner}} = \frac{\text{S.P}}{\text{R.P}}$$

c) Volumetric Efficiency (η_v): The volume of the water striking the runner of the turbine is slightly less than the volume of water supplied to the turbine. Some of the volume of the water is discharged to the tailrace without striking the runner of the turbine. Thus the ratio of the volume of the water supplied to the turbine is defined as Volumetric Efficiency.

$$\eta_v = \frac{\text{Volume of water actually striking the Runner}}{\text{Volume of water supplied to the Turbine}}$$

d) Overall Efficiency (η_0) It is defined as the ratio of power available at the shaft of the turbine to the power supplied by the water at the inlet of the turbine.

$$\eta_0 = \frac{\text{Power available at the shaft of the turbine}}{\text{Power supplied at the inlet of the turbine}} = \frac{\text{Shaft power}}{\text{Water power}}$$

$$= \frac{S.P}{W.P} = \frac{S.P}{W.P} \times \frac{R.P}{R.P}$$

$$= \frac{S.P}{R.P} \times \frac{R.P}{W.P}$$

$$\boldsymbol{\eta_0 = \eta_m \times \eta_h}$$

If shaft power (S.P) is taken in kW, Then water power should also be taken in kW. Shaft power is represented by P.

Water power in $kW = \frac{\rho \times g \times Q \times H}{1000}$ Where ρ = 1000Kg/m^3

$$\eta_0 = \frac{\text{Shaft Power in kW}}{\text{Water Power in kW}} = \frac{P}{\frac{\rho \times g \times Q \times H}{1000}}$$ Where P = Shaft Power

CLASSIFICATION OF HYDRAULIC TURBINES:

The Hydraulic turbines are classified according to the type of energy available at the inlet of the turbine, direction of flow through the vanes, head at the inlet of the turbine and specific speed of the turbine. The following are the important classification of the turbines.

1. According to the type of energy at inlet:
   (a) Impulse turbine and
   (b) Reaction turbine
2. According to the direction of flow through the runner:
   (a) Tangential flow turbine
   (b) Radial flow turbine.
   (c) Axial flow turbine
   (d) Mixed flow turbine.
3. According to the head at inlet of the turbine:
   (a) High head turbine
   (b) Medium head turbine and
   (c) Low head turbines.
4. According to the specific speed of the turbine:
   (a) Low specific speed turbine
   (b) Medium specific speed turbine
   (c) High specific speed turbine.

If at the inlet of turbine, the energy available is only kinetic energy, the turbine is known as **Impulse turbine**. As the water flows over the vanes, the pressure is atmospheric from inlet to outlet of the turbine. If at the inlet of the turbine, the water possesses kinetic energy as well as pressure energy, the turbine is known as **Reaction turbine**. As the water flows through runner, the water is under pressure and the pressure energy goes on changing in to kinetic energy. The runner is completely enclosed in an air-tight casing and the runner and casing is completely full of water.

If the water flows along the tangent of runner, the turbine is known as **Tangential flow turbine**. If the water flows in the radial direction through the runner, the turbine is called **Radial flow turbine.** If the water flows from outward to inwards radially, the turbine is known as **Inward** radial flow turbine, on the other hand, if the water flows radially from inward to outwards, the turbine is known as **outward** radial flow turbine. If the water flows through the runner along the direction parallel to the axis of rotation of the runner, the turbine is called **axial flow** turbine. If the water flows through the runner in the radial direction but leaves in the direction parallel to the axis of rotation of the runner, the turbine is called **mixed flow** turbine.

PELTON WHEEL (Turbine)

It is a tangential flow impulse turbine. The water strikes the bucket along the tangent of the runner. The energy available at the inlet of the turbine is only kinetic energy. The pressure at the inlet and out let of turbine is atmospheric. This turbine is used for high heads and is named after L.A.Pelton an American engineer.

The water from the reservoir flows through the penstocks at the out let of which a nozzle is fitted. The nozzle increases the kinetic energy of the water flowing through the penstock. At the outlet of the nozzle, the water comes out in the form of a jet and strikes the buckets (vanes) of the runner. The main parts of the Pelton turbine are:

1. Nozzle and flow regulating arrangement (spear)
2. Runner and Buckets.
3. Casing and
4. Breaking jet

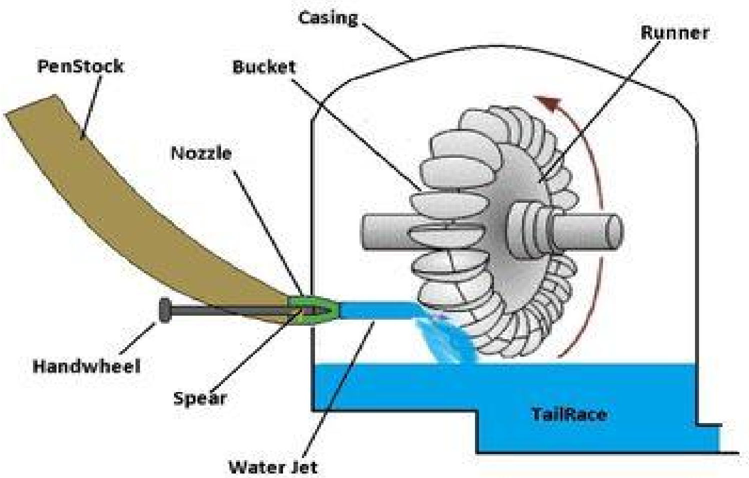
1. Nozzle and flow regulating arrangement: The amount of water striking the buckets (vanes) of the runner is controlled by providing a spear in the nozzle. The spear is a conical needle which is operated either by hand wheel or automatically in an axial direction depending upon the size of the unit. When the spear is pushed forward in to the nozzle, the amount of water striking the runner is reduced. On the other hand, if the spear is pushed back, the amount of water striking the runner increases.

2. Runner with buckets: It consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed. The shape of the buckets is of a double hemispherical cup or bowl. Each bucket is divided in to two symmetrical parts by a dividing wall, which is known as splitter.

The jet of water strikes on the splitter. The splitter divides the jet in to two equal parts and the jet comes out at the outer edge of the bucket. The buckets are shaped in such a way that the jet gets deflected through an angle of 160°or 170°. The buckets are made of cast Iron, cast steel, Bronze or stainless steel depending upon the head at the inlet of the turbine.

3. Casing: The function of casing is to prevent the splashing of the water and to discharge the water to tailrace. It also acts as safeguard against accidents. It is made of Cast Iron or fabricated steel plates. The casing of the Pelton wheel does not perform any hydraulic function.

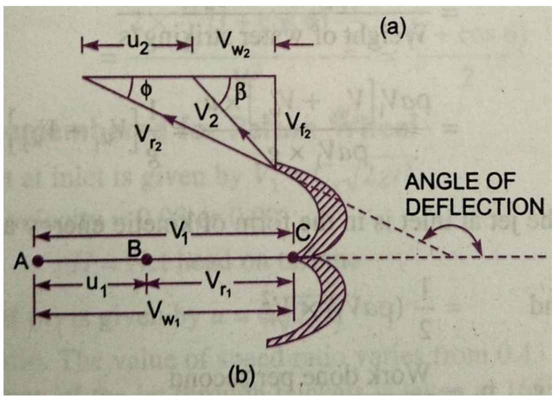
4. Breaking jet: When the nozzle is completely closed by moving the spear in the forward direction, the amount of water striking the runner reduces to zero. But the runner due to inertia goes on revolving for a long time. To stop the runner in a short time, a small nozzle is provided, which directs the jet of water on the back of the vanes. This jet of water is called



Breaking jet.

Velocity triangles and work done for Pelton wheel:

The jet of water from the nozzle strikes the bucket at the splitter, which splits up the jet into two parts. These parts of the jet, glides over the inner surfaces and comes out at the outer edge. The splitter is the in let tip and outer edge of the bucket is the outlet tip of the bucket. The inlet velocity triangle is drawn at the splitter and outer velocity triangle is drawn at the outer edge of the bucket.



Let

H = Net head acting on the Pelton Wheel

$$= H_g - h_f$$

Where H_g= Gross Head

$$h_f = \frac{4fLV^2}{D^* \times 2g}$$

Where =diameter of penstock,

D^*

D = Diameter of wheel,

d = Diameter of Jet,

N = Speed of the wheel in r.p.m

Then V_1 = Velocity of jet at inlet

$= \sqrt{2gH}$ $\qquad u = u_1 = u_2 = \frac{\pi DN}{60}$

The Velocity Triangle at inlet will be a straight line where

$$V_{r_1} = V_1 - u_1 = V_1 - u$$

$$V_{w_1} = V_1 \qquad \alpha = 0^0 \qquad and \ \ \theta = 0^0$$

From the velocity triangle at outlet, we have

$$V_{r_2} = V_{r_1} \ and \ V_{w_2} = V_{r_2} \cos\emptyset - u_2$$

The force exerted by the Jet of water in the direction of motion is

$$F_x = \rho a V_1 [V_{w_1} + V_{w_2}] \quad \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(1)$$

As the angle β is an acute angle, +ve sign should be taken. Also this is the case of series of vanes, the mass of water striking is $\rho a V_1$ and not $\rho a V_{r_1}$. In equation (1) „a" is the area of the jet $= \frac{\pi}{4} d^2$

Now work done by the jet on the runner per second

$$= F_x \times u = \rho a V_1 [V_{w_1} + V_{w_2}] \times u \qquad Nm/s$$

Power given to the runner by the jet $= \frac{\rho a V_1 [V_{w_1} + V_{w_2}] \times u}{1000} kW$

Work done/s per unit weight of water striking/s $= \frac{\rho a V_1 [V_{w_1} + V_{w_2}] \times u}{Weight\ of\ water \frac{striking}{s}}$

$$= \frac{\rho a V_1 [V_{w_1} + V_{w_2}] \times u}{\rho a V_1 \times g} = \frac{1}{g} [V_{w_1} + V_{w_2}] \times u \quad \_\_\_\_\_\_(3)$$

The energy supplied to the jet at inlet is in the form of kinetic energy

∴ K.E. of jet per second $= \frac{1}{2} m V^2 = \frac{1}{2} (\rho a V_1) \times {V_1}^2$

∴ **Hydraulic efficiency,** $\eta_h = \frac{Work\ done\ per\ second}{K.E. of\ jet\ per\ second}$

$$= \frac{\rho a V_1 [V_{w_1} + V_{w_2}] \times u}{\frac{1}{2} (\rho a V_1) \times {V_1}^2}$$

$$= \frac{2 [V_{w_1} + V_{w_2}] \times u}{{V_1}^2} \quad \_\_\_\_\_\_\_\_\_\_\_(4)$$

Now

$$V_{w_1} = \quad V_1 \ and \ V_{r_1} = V_1 - u_1 = (V_1 - u)$$

$\therefore$ $$V_{r_2} = (V_1 - u)$$

And $$V_{w_2} = V_{r_2} \cos\emptyset - u_2$$

$$= V_{r_2} \cos\emptyset - u$$
$$= (V_1^2 - u) \cos\emptyset - u$$

Substituting the values of V_{w_1} and V_{w_2} in equation (4)

$$\eta_h = \frac{2[V_1 + (V_1 - u)\cos\emptyset - u]\times u}{V_1^{\ 2}} = \frac{2[V_1 - u + (V_1 - u)\cos\emptyset]\times u}{V_1^{\ 2}}$$

$$= \frac{2(V_1 - u)[1 + \cos\emptyset]u}{V_1^{\ 2}} \quad \_\_\_\_\_\_\_\_ \ (5)$$

The efficiency will be maximum for a given value of V_1 when

$$\frac{d}{du}(\eta_h) = 0 \ \ or \ \ \frac{d}{du}\left[\frac{2u(V_1 - u)[1 + \cos\emptyset]}{V_1^{\ 2}}\right] = 0$$

Or $$\frac{(1 + \cos\emptyset)}{V_1^{\ 2}} \ \frac{d}{du}\left(2uV_1 - 2u^2\right) = 0$$

Or $$\frac{d}{du}[2uV_1 - 2u^2] = 0 \qquad \left(\because \frac{1 + \cos\phi}{V_1^{\ 2}} \neq 0\right)$$

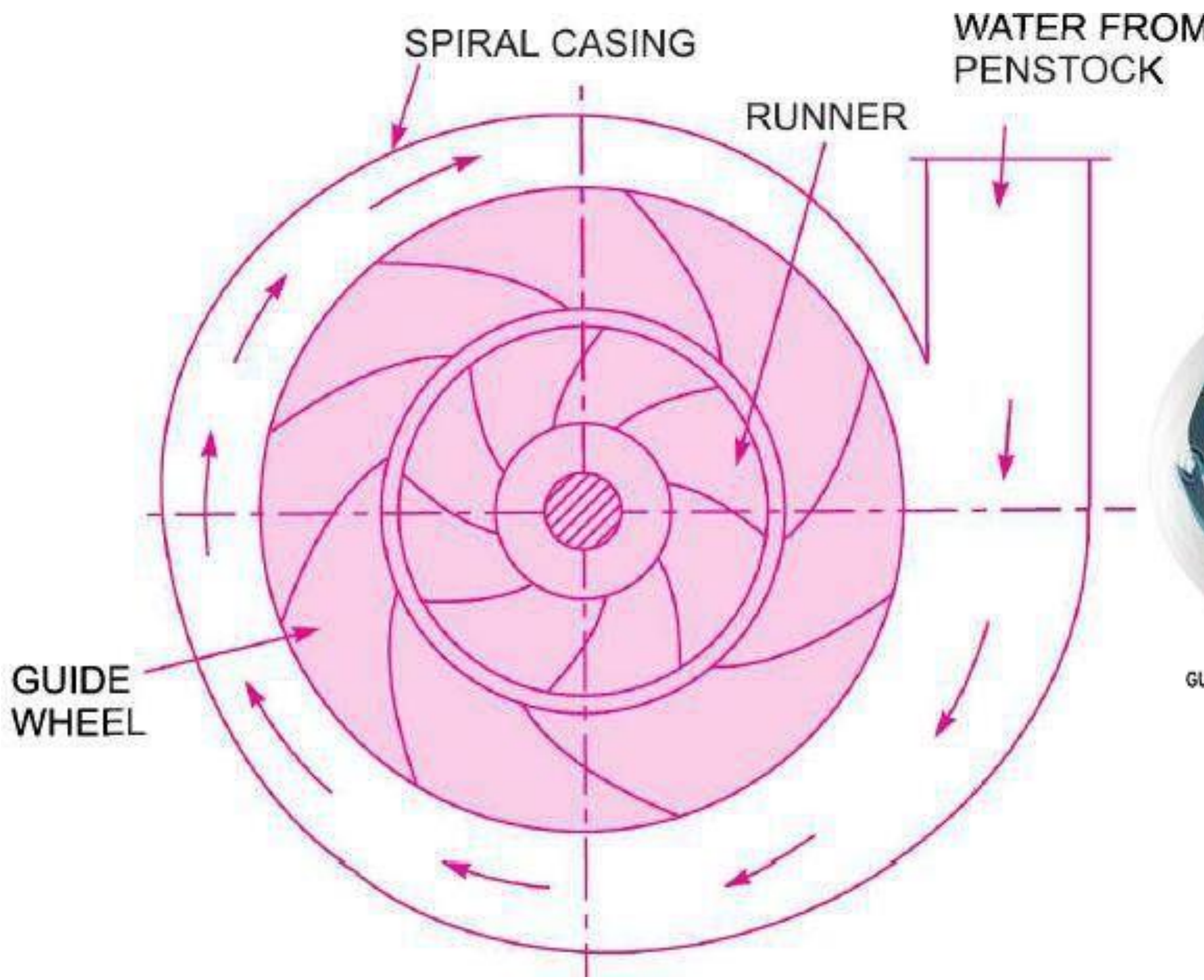
Or $2V_1 - 4u = 0$ Or $u = \frac{V_1}{2}$ ____________ (6)

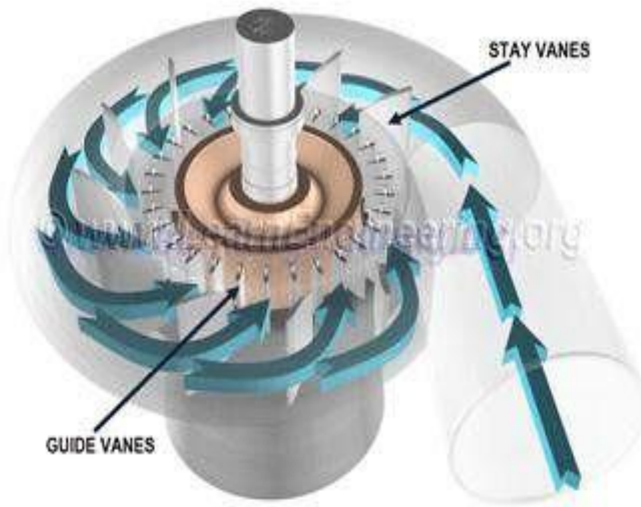
Equation (6) states that hydraulic efficiency of a Pelton wheel will be maximum when the velocity of the wheel is half the velocity of the jet water at inlet. The expression for maximum efficiency will be obtained by substituting the value of $u = \frac{V_1}{2}$ in equation (5)

Max. $$\eta_h = \frac{2\left(V_1 - \frac{V_1}{2}\right)(1 + \cos\emptyset) \times \frac{V_1}{2}}{V_1^{\ 2}}$$

$$= \frac{2 \times \frac{V_1}{2}(1 + \cos\emptyset)\frac{V_1}{2}}{V_1^{\ 2}} = \frac{(1 + \cos\emptyset)}{2}$$

RADIAL FLOW REACTION TURBINE





RADIAL FLOW REACTION TURBINE

Radial flow turbines are those tubines in which the water flows in the radial direction. The water may flow radially from outwards to inwards (*i.e.*, towards the axis of rotation) or from inwards to outwards. If the water flows from outwards to inwards through the runner, the turbine is known as inward radial flow turbine. And if the water flows from inwards to outwards, the turbine is known as outward radial flow turbine.

Reaction turbine means that the water at the inlet of the turbine possesses kinetic energy as well as pressure energy. As the water flows through the runner, a part of pressure energy goes on changing into kinetic energy. Thus the water through the runner is under pressure. The runner is completely enclosed in an air-tight casing and casing and the runner is always full of water.

MAIN PARTS OF REACTION TURBINE

1. Casing,
2. Guide mechanism,
3. Runner, and
4. Draft-tube.

1. Casing. As mentioned above that in case of reaction turbine, casing and runner are always full of water. The water from the penstocks enters the casing which is of spiral shape in which area of cross-section of the casing goes on decreasing gradually. The casing completely surrounds the runner of the turbine. The casing as shown in Fig. 18.10 is made of spiral shape, so that the water may enter the runner at constant velocity throughout the circumference of the runner. The casing is made of concrete, cast steel or plate steel.

2. Guide Mechanism. It consists of a stationary circular wheel all round the runner of the turbine. The stationary guide vanes are fixed on the guide mechanism. The guide vanes allow the water to strike the vanes fixed on the runner without shock at inlet. Also by a suitable arrangement, the width between two adjacent vanes of guide mechanism can be altered so that the amount of water striking the runner can be varied.

3. Runner. It is a circular wheel on which a series of radial curved vanes are fixed. The surface of the vanes are made very smooth. The radial curved vanes are so shaped that the water enters and leaves the runner without shock. The runners are made of cast steel, cast iron or stainless steel. They are keyed to the shaft.

4. Draft-tube. The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. The water at exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race. This tube of increasing area is called draft tube.

INWARD RADIAL FLOW TURBINE

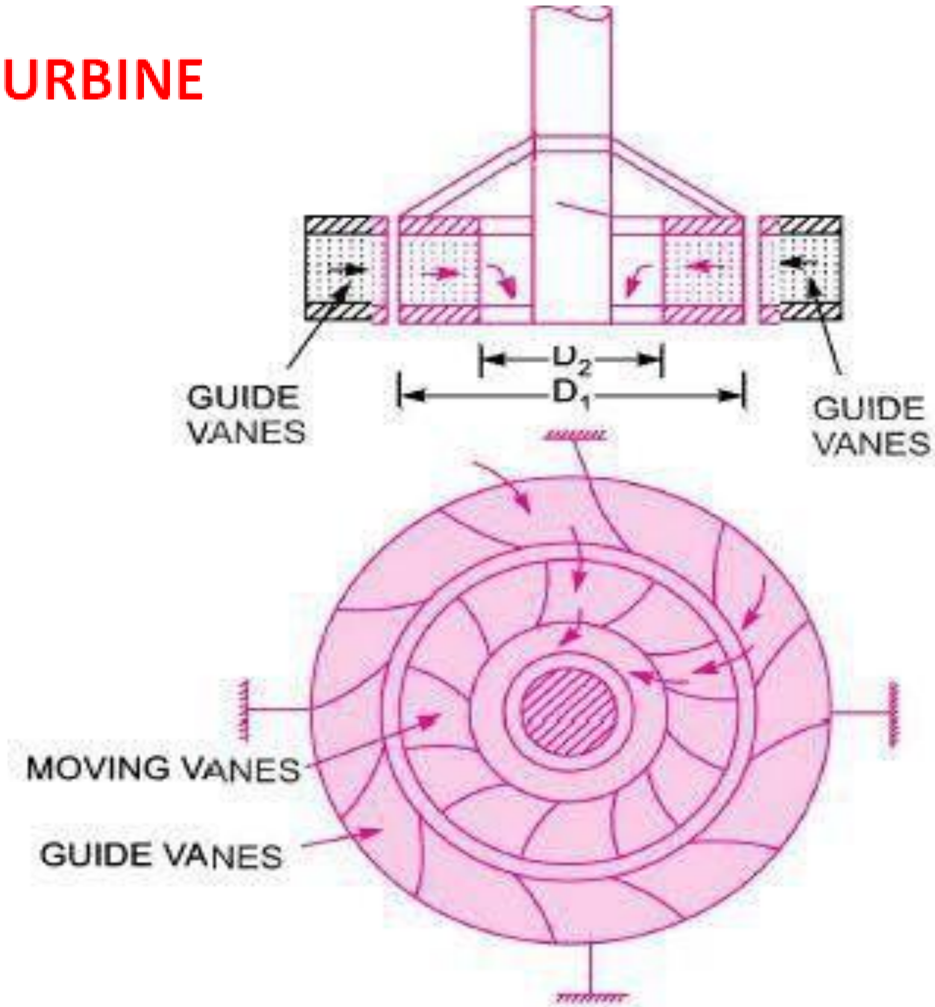


Fig. *Inward radial flow turbine.*

Inward Radial Flow Turbine. Fig. shows inward radial flow turbine, in which case the water from the casing enters the stationary guiding wheel. The guiding wheel consists of guide vanes which direct the water to enter the runner which consists of moving vanes. The water flows over the moving vanes in the inward radial direction and is discharged at the inner diameter of the runner. The outer diameter of the runner is the inlet and the inner diameter is the outlet.

VELOCITY TRIANGLE OF INWARD RADIAL FLOW TURBINE

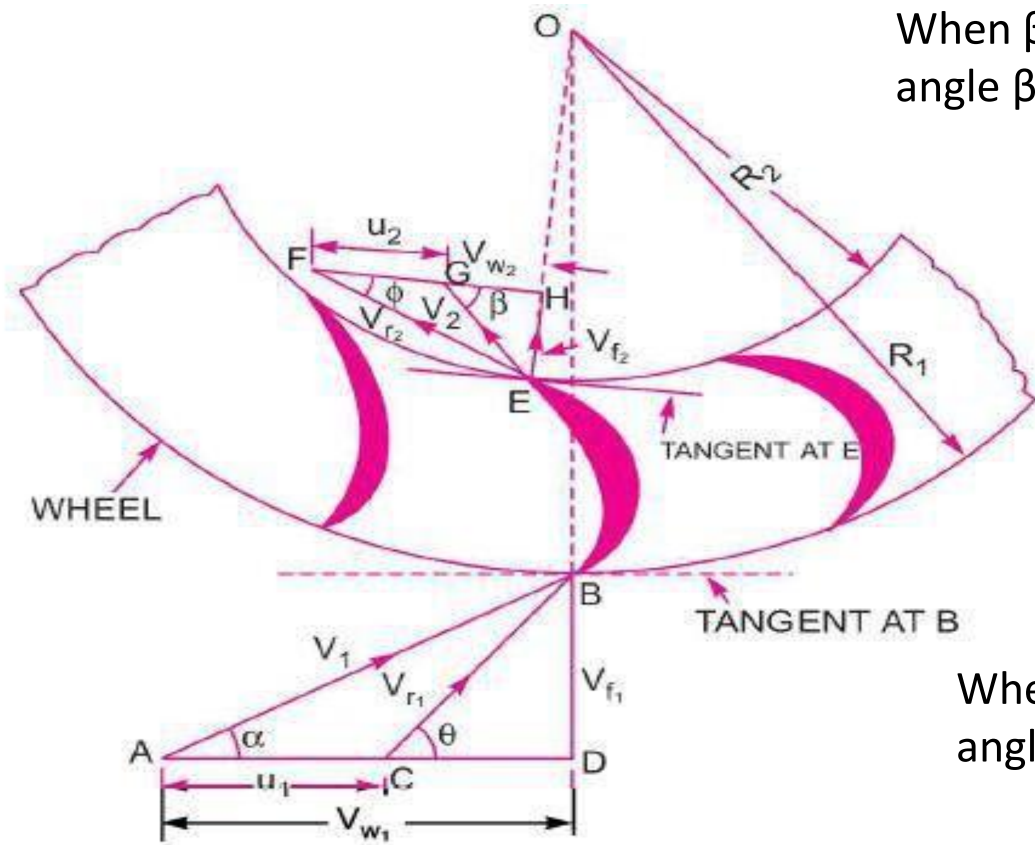
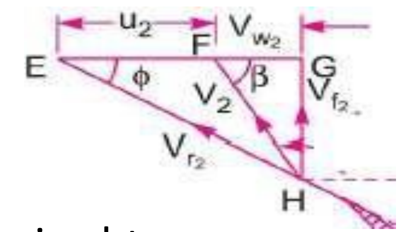


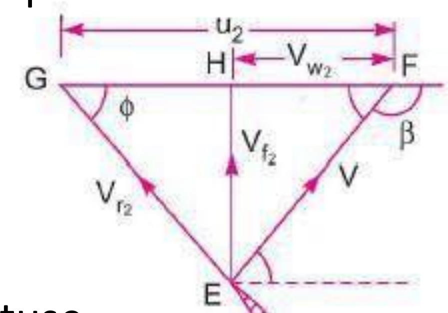
Fig. *Series of radial curved vanes mounted on a whee*

Outlet velocity triangle

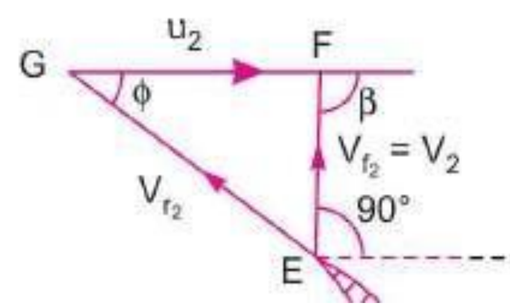
When β is acute angle β<90



When is obtuse angle β>90



When is obtuse angle β=90



Let R_1 = Radius of wheel at inlet of the vane,

R_2 = Radius of the wheel at the outlet of the vane,

ω = Angular speed of the wheel.

Then $u_1 = \omega R_1$ and $u_2 = \omega R_2$

The velocity triangles at inlet and outlet are drawn as shown in Fig.

The mass of water striking per second for a series of vanes

= Mass of water coming out from nozzle per second

$= \rho a V_1$, where a = Area of jet and V_1 = Velocity of jet.

Momentum of water striking the vanes in the tangential direction per sec at inlet

= Mass of water per second × Component of V_1 in the tangential direction

$= \rho a V_1 \times V_{w_1}$ ($\because$ Component of V_1 in tangential direction $= V_1 \cos \alpha = V_{w_1}$)

Similarly, momentum of water at outlet per sec

$= \rho a V_1 \times$ Component of V_2 in the tangential direction

$= \rho a V_1 \times (-V_2 \cos \beta) = -\rho a V_1 \times V_{w_2}$ ($\because$ $V_2 \cos \beta = V_{w_2}$)

–ve sign is taken as the velocity V_2 at outlet is in opposite direction.

Now, angular momentum per second at inlet

= Momentum at inlet × Radius at inlet

$= \rho a V_1 \times V_{w_1} \times R_1$

Angular momentum per second at outlet

= Momentum of outlet × Radius at outlet

$= -\rho a V_1 \times V_{w_2} \times R_2$

Torque exerted by the water on the wheel,

$$T = \text{Rate of change of angular momentum}$$

$$= [\text{Initial angular momentum per second} - \text{Final angular momentum per second}]$$

$$= \rho a V_1 \times V_{w_1} \times R_1 - (-\rho a V_1 \times V_{w_2} \times R_2) = \rho a V_1 [V_{w_1} \times R_1 + V_{w_2} R_2]$$

Work done per second on the wheel

$$= \text{Torque} \times \text{Angular velocity} = T \times \omega$$

$$= \rho a V_1 [V_{w_1} \times R_1 + V_{w_2} R_2] \times \omega = \rho a V_1 [V_{w_1} \times R_1 \times \omega + V_{w_2} R_2 \times \omega]$$

$$= \rho a V_1 [V_{w_1} u_1 + V_{w_2} \times u_2] \qquad (\because \quad u_1 = \omega R_1 \text{ and } u_2 = \omega R_2)$$

If the angle β in Fig. 17.23 is an obtuse angle then work done per second will be given as

$$= \rho a V_1 [V_{w_1} u_1 - V_{w_2} u_2]$$

$\therefore$ The general expression for the work done per second on the wheel

$$= \rho a V_1 [V_{w_1} u_1 \pm V_{w_2} u_2] \quad \text{..............................1}$$

If the discharge is radial at outlet, then $\beta = 90°$ and work done becomes as

$$= \rho a V_1 [V_{w_1} u_1] \quad \text{...2} \qquad (\because \quad V_{w_2} = 0)$$

The work done per second on the runner by water is given by equation

$$= \rho a V_1 [V_{w_1} u_1 \pm V_{w_2} u_2]$$

$$= \rho Q [V_{w_1} u_1 \pm V_{w_2} u_2] \qquad (\because \quad aV_1 = Q)$$

The equation also represents the energy transfer per second to the runner.

where V_{w_1} = Velocity of whirl at inlet,

V_{w_2} = Velocity of whirl at outlet,

u_1 = Tangential velocity of wheel at inlet

$= \dfrac{\pi D_1 \times N}{60}$, where D_1 = Outer dia. of runner,

u_2 = Tangential velocity of wheel at outlet

$= \dfrac{\pi D_2 \times N}{60}$, where D_2 = Inner dia. of runner, N = Speed of the turbine in .r.p.m.

The work done per second per unit weight of water per second.

$$= \frac{\text{Work done per second}}{\text{Weight of water striking per second}}$$

$$= \frac{\rho Q \left[V_{w_1} u_1 \pm V_{w_2} u_2\right]}{\rho Q \times g} = \frac{1}{g}\left[V_{w_1} u_1 \pm V_{w_2} u_2\right] \qquad \text{.......1}$$

The equation 1 represents the energy transfer per unit weight/s to the runner. This equation is known by **Euler's equation** of hydrodynamics machines. This is also known as fundamental equation of hydrodynamic machines. This equation was given by Swiss scientist *L.* Euler.

In equation 1 +ve sign is taken if angle β is an acute angle. If β is an obtuse angle then –ve sign is taken. If $\beta = 90°$, then $V_{w_2} = 0$ and work done per second per unit weight of water striking/s become as

$$= \frac{1}{g} V_{w_1} u_1 \qquad \text{..........................2}$$

Hydraulic efficiency is obtained from equation (18.2) as

$$\eta_h = \frac{\text{R.P.}}{\text{W.P.}} = \frac{\dfrac{W}{1000g}[V_{w_1} u_1 \pm V_{w_2} u_2]}{\dfrac{W \times H}{1000}} = \frac{(V_{w_1} u_1 \pm V_{w_2} u_2)}{gH} \qquad \text{..................3}$$

where R.P. = Runner power *i.e.*, power delivered by water to the runner

W.P. = Water power

If the discharge is radial at outlet, then $V_{w_2} = 0$

$$\eta_h = \frac{V_{w_1} u_1}{gH} \qquad \text{.......................4}$$

Definitions. The following terms are generally used in case of reaction radial flow turbines which are defined as :

(*i*) **Speed Ratio.** The speed ratio is defind as = $\dfrac{u_1}{\sqrt{2gH}}$

where u_1 = Tangential velocity of wheel at inlet.

(*ii*) **Flow Ratio.** The ratio of the velocity of flow at inlet (V_{f_1}) to the velocity given $\sqrt{2gH}$ is known as flow ratio or it is given as

$$= \frac{V_{f_1}}{\sqrt{2gH}}, \text{ where } H = \text{Head on turbine}$$

(*iii*) **Discharge of the Turbine.** The discharge through a reaction radial flow turbine is given by

$$Q = \pi D_1 B_1 \times V_{f_1} = \pi D_2 \times B_2 \times V_{f_2}$$

where D_1 = Diameter of runner at inlet,

B_1 = Width of runner at inlet,

V_{f_1} = Velocity of flow at inlet, and

D_2, B_2, V_{f_2} = Corresponding values at outlet.

If the thickness of vanes are taken into consideration, then the area through which flow takes place is given by $(\pi D_1 - n \times t)$

where n = Number of vanes on runner and t = Thickness of each vane

The discharge Q, then is given by $Q = (\pi D_1 - n \times t)\, B_1 \times V_{f_1}$

(*iv*) The head (H) on the turbine is given by $H = \dfrac{p_1}{\rho \times g} + \dfrac{V_1^2}{2g}$

where p_1 = Pressure at inlet.

(*v*) **Radial Discharge.** This means the angle made by absolute velocity with the tangent on the wheel is 90° and the component of the whirl velocity is zero. Radial discharge at outlet means $\beta = 90°$ and $V_{w_2} = 0$, while radial discharge at outlet means $\alpha = 90°$ and $V_{w_1} = 0$.

(*vi*) If there is no loss of energy when water flows through the vanes then we have

$$H - \frac{V_2^2}{2g} = \frac{1}{g}[V_{w_1} u_1 \pm V_{w_2} u_2].$$

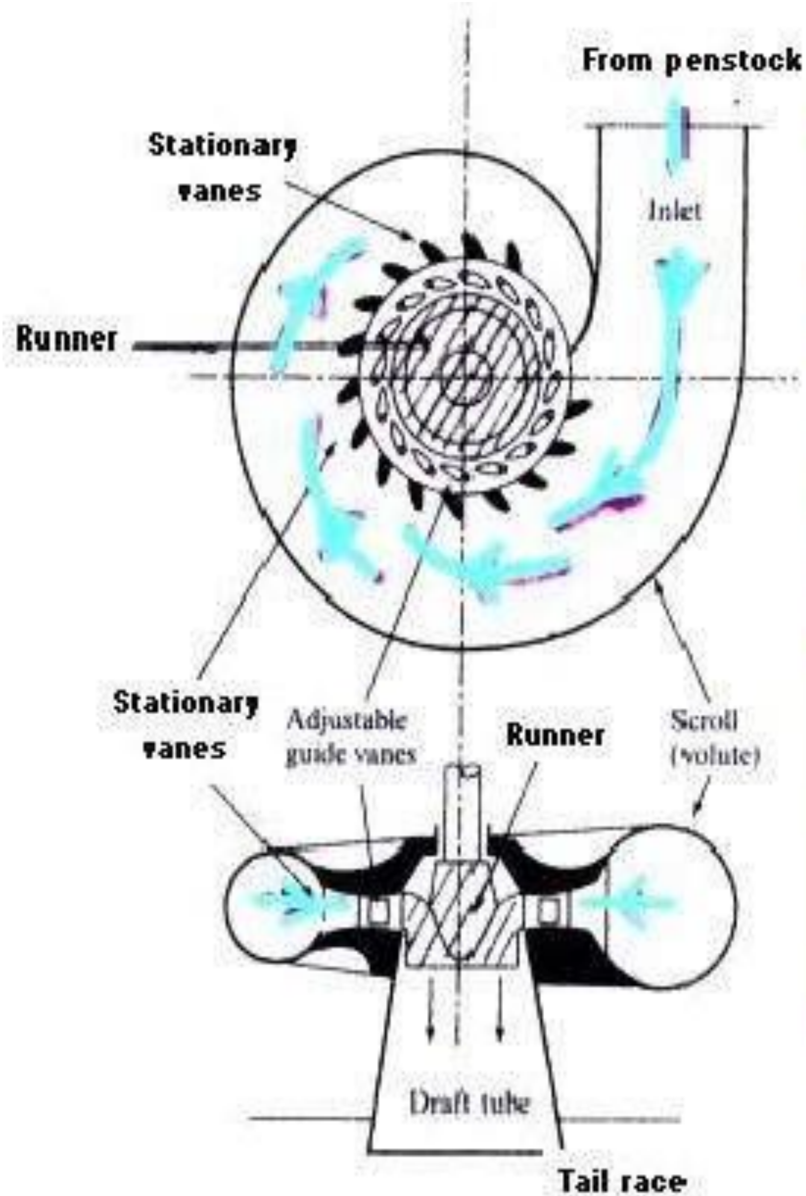
Francis turbine

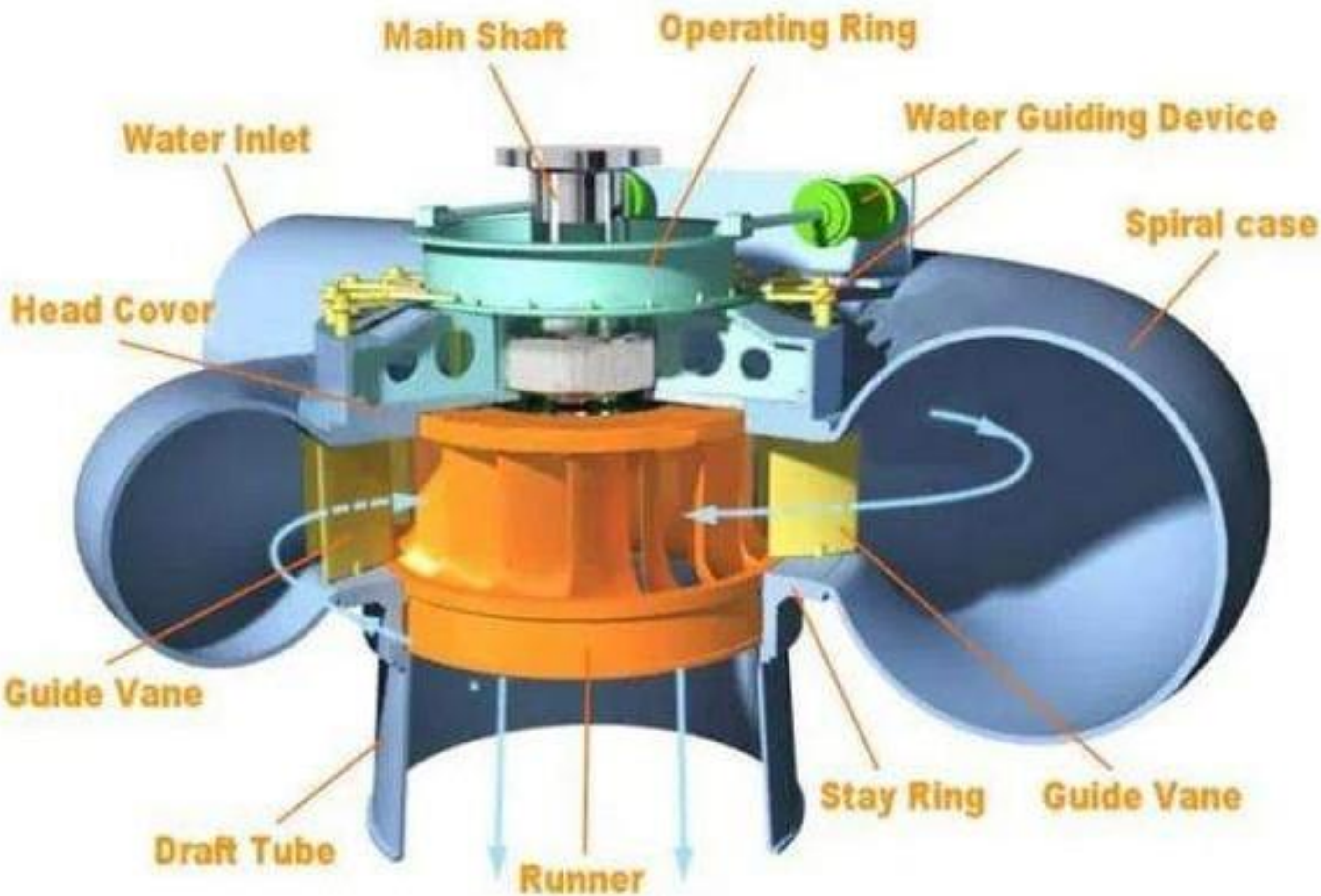
- **As name suggest, this is a type of reaction turbine which is developed by an American engineer, Sir J.B. Francis.**

- **Francis turbine is basically an inward flow reaction turbine with radial discharge at its outlet.**

- **In modern Francis turbine, the water will enter the runner of the turbine in the radial direction at outlet and will leave in the axial direction at the inlet of the runner. Therefore, the modern Francis turbine will be termed as mixed flow turbine.**

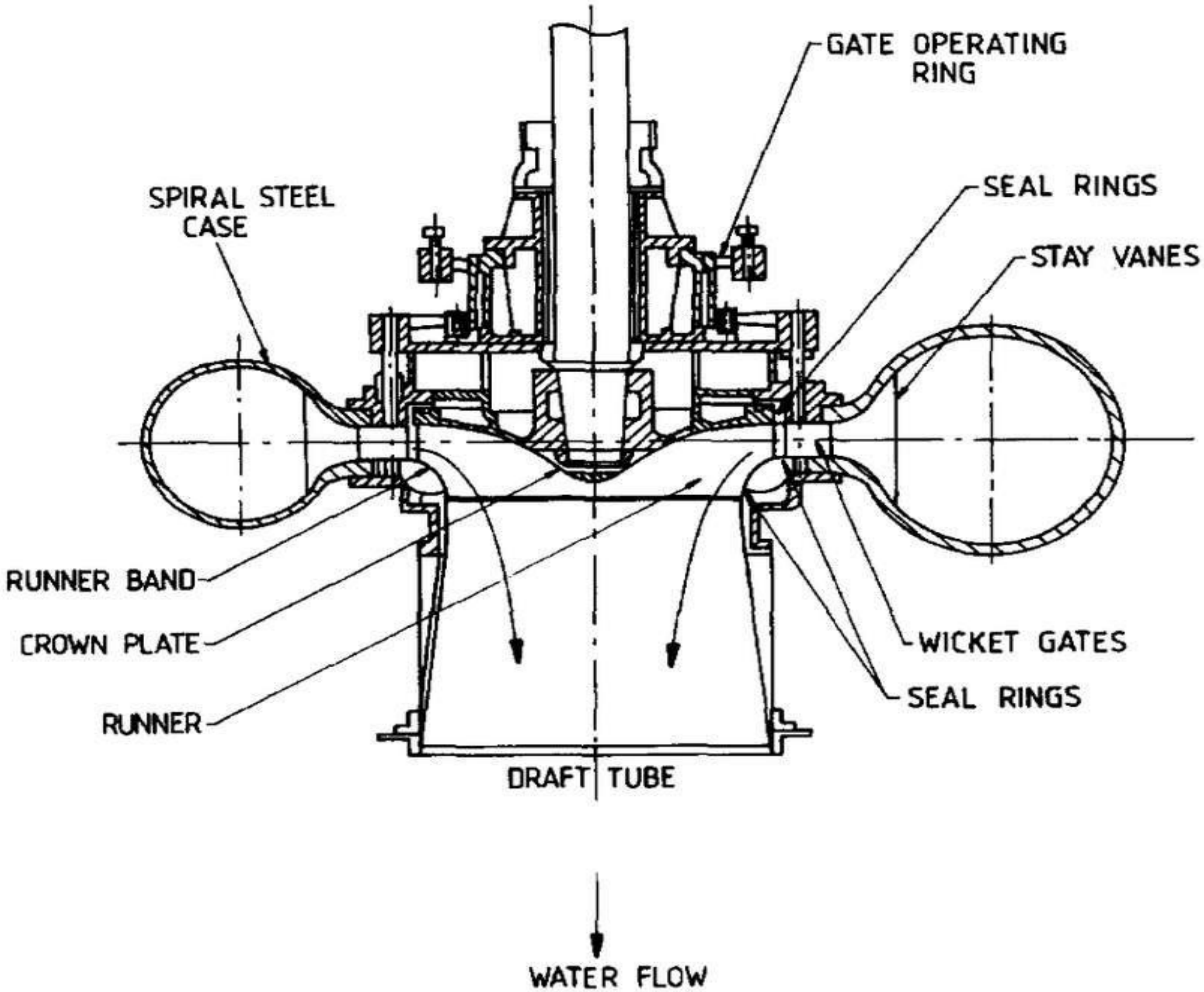
Francis turbine





Francis Turbine

Francis turbine



Francis turbine

Francis turbine

PARTS OF FRANCIS TURBINE

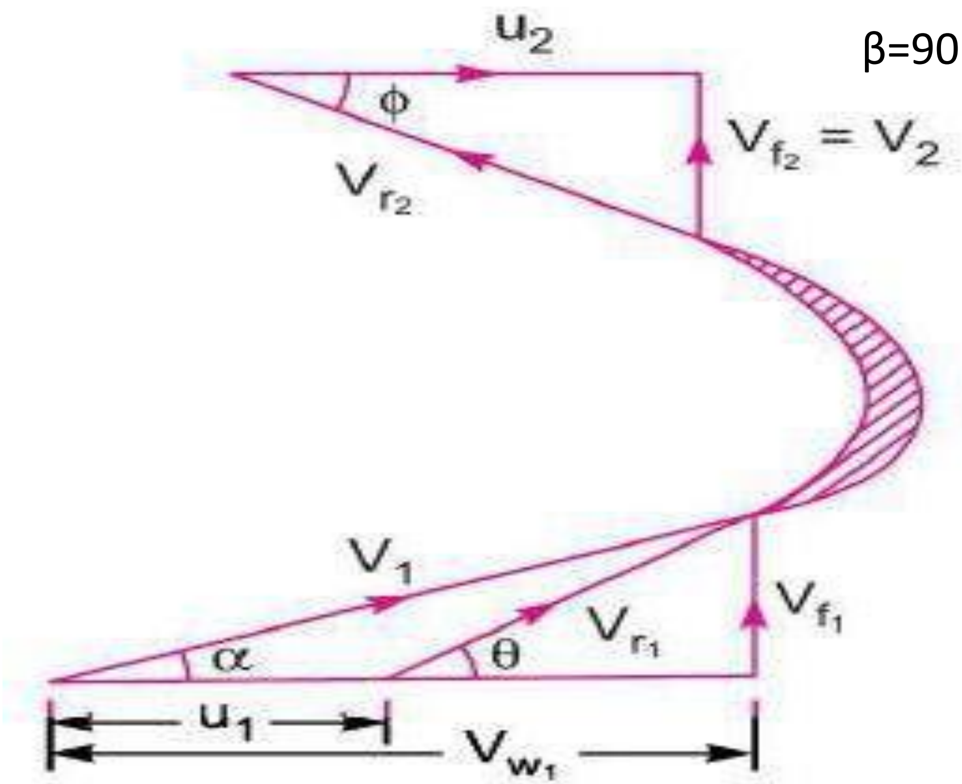
Spiral casing: The spiral casing around the runner of the turbine is known as the volute casing or scroll case. Throughout its length, it has numerous openings at regular intervals to allow the working fluid to impinge on the blades of the runner. These openings convert the pressure energy of the fluid into kinetic energy just before the fluid impinges on the blades. This maintains a constant velocity despite the fact that numerous openings have been provided for the fluid to enter the blades, as the cross-sectional area of this casing decreases uniformly along the circumference.

Guide and stay vanes: The primary function of the guide and stay vanes is to convert the pressure energy of the fluid into kinetic energy. It also serves to direct the flow at design angles to the runner blades.

Runner blades: Runner blades are the heart of any turbine. These are the centers where the fluid strikes and the tangential force of the impact causes the shaft of the turbine to rotate, producing torque. Close attention to design of blade angles at inlet and outlet is necessary, as these are major parameters affecting power production.

Draft tube: The draft tube is a conduit that connects the runner exit to the tail race where the water is discharged from the turbine. Its primary function is to reduce the velocity of discharged water to minimize the loss of kinetic energy at the outlet. This permits the turbine to be set above the tail water without appreciable drop of available head.

VELOCITY TRIANGLE AND WORKDONE OF FRANCIS TURBINE



Velocity triangle of francis turbine

β=90

Vw2=0

The velocity triangle at inlet and outlet of the Francis turbine are drawn in the same way as in case of inward flow reaction turbine. As in case of Francis turbine, the discharge is radial at outlet, the velocity of whirl at outlet (*i.e.*, V_{w_2}) will be zero. Hence the work done by water on the runner per second will be

$$= \rho Q[V_{w_1} u_1]$$

And work done per second per unit weight of water striking/s = $\dfrac{1}{g}\left[V_{w_1} u_1\right]$

Hydraulic efficiency will be given by, $\eta_h = \dfrac{V_{w_1} u_1}{gH}$.

Important Relations for Francis Turbines. The following are the important relations for Francis Turbines :

1. The ratio of width of the wheel to its diameter is given as $n = \dfrac{B_1}{D_1}$. The value of n varies from 0.10 to .40.

2. The flow ratio is given as,

Flow ratio = $\dfrac{V_{f_1}}{\sqrt{2gH}}$ and varies from 0.15 to 0.30.

3. The speed ratio = $\dfrac{u_1}{\sqrt{2gH}}$ varies from 0.6 to 0.9.

PROBLEM 1 *A Francis turbine with an overall efficiency of 75% is required to produce 148.25 kW power. It is working under a head of 7.62 m. The peripheral velocity = 0.26 $\sqrt{2gH}$ and the radial velocity of flow at inlet is 0.96$\sqrt{2gH}$. The wheel runs at 150 r.p.m. and the hydraulic losses in the turbine are 22% of the available energy. Assuming radial discharge, determine :*

(i) The guide blade angle, *(ii) The wheel vane angle at inlet,*
(iii) Diameter of the wheel at inlet, and *(iv) Width of the wheel at inlet.*

Solution. Given :

Overall efficiency $\eta_o = 75\% = 0.75$

Power produced, S.P. = 148.25 kW

Head, $H = 7.62$ m

Peripheral velocity, $u_1 = 0.26\sqrt{2gH} = 0.26 \times \sqrt{2 \times 9.81 \times 7.62} = 3.179$ m/s

Velocity of flow at inlet, $V_{f_1} = 0.96\sqrt{2gH} = 0.96 \times \sqrt{2 \times 9.81 \times 7.62} = 11.738$ m/s.

Speed, $N = 150$ r.p.m.

Hydraulic losses = 22% of available energy

Discharge at outlet = Radial

$$V_{w_2} = 0 \text{ and } V_{f_2} = V_2$$

Hydraulic efficiency is given as

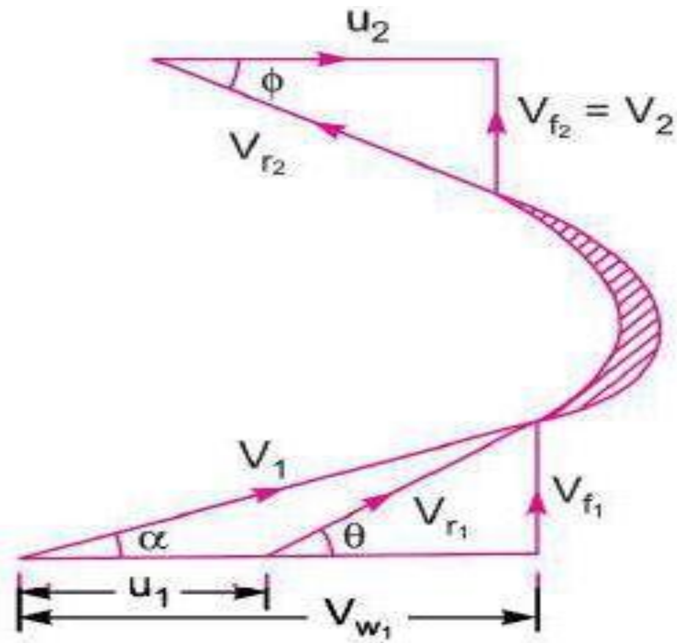
$$\eta_h = \frac{\text{Total head at inlet} - \text{Hydraulic loss}}{\text{Head at inlet}} = \frac{H - .22\,H}{H} = \frac{0.78\,H}{H} = 0.78$$

But $$\eta_h = \frac{V_{w_1} u_1}{gH}$$

$\therefore$ $$\frac{V_{w_1} u_1}{gH} = 0.78$$

$\therefore$ $$V_{w_1} = \frac{0.78 \times g \times H}{u_1}$$

$$= \frac{0.78 \times 9.81 \times 7.62}{3.179} = 18.34 \text{ m/s.}$$



(*i*) *The guide blade angle*, *i.e.*, α. From inlet velocity triangle,

$$\tan \alpha = \frac{V_{f_1}}{V_{w_1}} = \frac{11.738}{18.34} = 0.64$$

$\therefore$ $$\alpha = \tan^{-1} 0.64 = \mathbf{32.619°} \text{ or } \mathbf{32° \ 37'}. \textbf{ Ans.}$$

(*ii*) *The wheel vane angle at inlet*, *i.e.*, θ

$$\tan \theta = \frac{V_{f_1}}{V_{w_1} - u_1} = \frac{11.738}{18.34 - 3.179} = 0.774$$

$\therefore$ $$\theta = \tan^{-1} .774 = \mathbf{37.74} \text{ or } \mathbf{37° \ 44.4'}. \textbf{ Ans.}$$

(*iii*) *Diameter of wheel at inlet* (D_1).

Using the relation, $$u_1 = \frac{\pi D_1 N}{60}$$

$$D_1 = \frac{60 \times u_1}{\pi \times N} = \frac{60 \times 3.179}{\pi \times 50} = \mathbf{0.4047\ m.\ Ans.}$$

(*iv*) *Width of the wheel at inlet* (B_1)

$$\eta_o = \frac{\text{S.P.}}{\text{W.P.}} = \frac{148.25}{\text{W.P.}}$$

But $$\text{W.P.} = \frac{\text{WH}}{1000} = \frac{\rho \times g \times Q \times H}{1000} = \frac{1000 \times 9.81 \times Q \times 7.62}{1000}$$

$\therefore$ $$\eta_o = \frac{148.25}{\dfrac{1000 \times 9.81 \times Q \times 7.62}{1000}} = \frac{148.25 \times 1000}{1000 \times 9.81 \times Q \times 7.62}$$

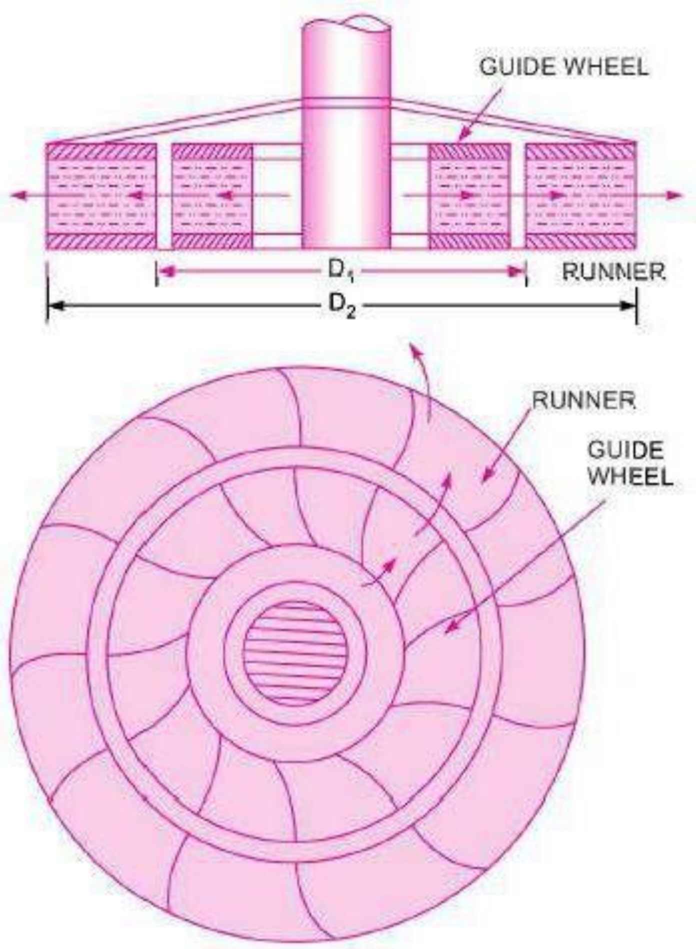
or $$Q = \frac{148.25 \times 1000}{1000 \times 9.81 \times 7.62 \times \eta_o} = \frac{148.25 \times 1000}{1000 \times 9.81 \times 7.62 \times 0.75} = 2.644\ \text{m}^3/\text{s}$$

$$Q = \pi D_1 \times B_1 \times V_{f_1}$$

$$2.644 = \pi \times .4047 \times B_1 \times 11.738$$

$$B_1 = \frac{2.644}{\pi \times .4047 \times 11.738} = \mathbf{0.177\ m.\ Ans.}$$

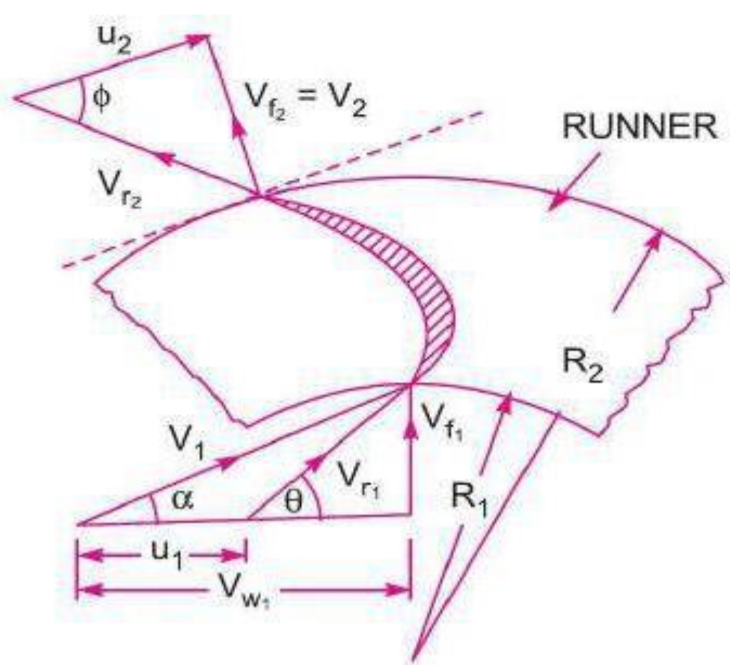
OUTWARD FLOW REACTION TURBINE



Outward Radial Flow Reaction Turbine. Fig. shows outward radial flow reaction turbine in which the water from casing enters the stationary guide wheel. The guide wheel consists of guide vanes which direct water to enter the runner which is around the stationary guide wheel. The water flows through the vanes of the runner in the outward radial direction and is discharged at the outer diameter of the runner. The inner diameter of the runner is inlet and outer diameter is the outlet.

The velocity triangles at inlet and outlet will be drawn by the same procedure as adopted for inward flow turbine. The work done by the water on the runner per second, the horse power developed and hydraulic efficiency will be obtained from the velocity triangles. In this case as inlet of the runner is at the inner diameter of the runner, the tangential velocity at inlet will be less than that of at outlet, *i.e.*,

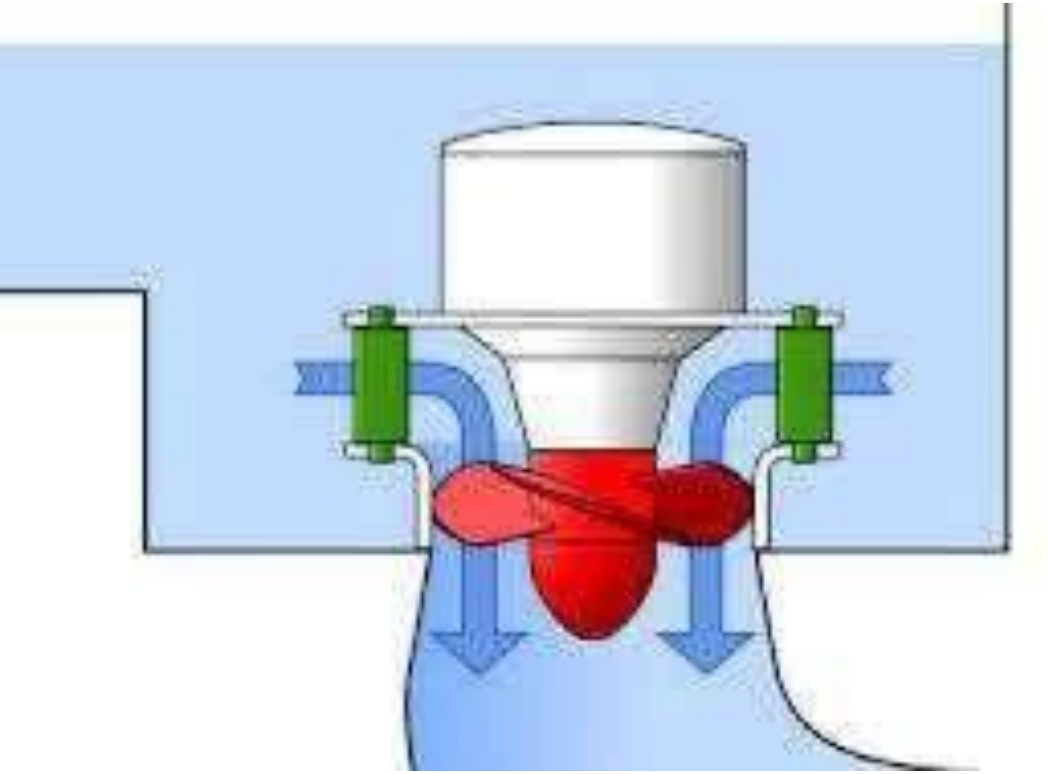
$$u_1 < u_2 \text{ as } D_1 < D_2.$$



AXIAL FLOW TURBINE

(KAPLAN TURBINE)

AXIAL FLOW TURBINE

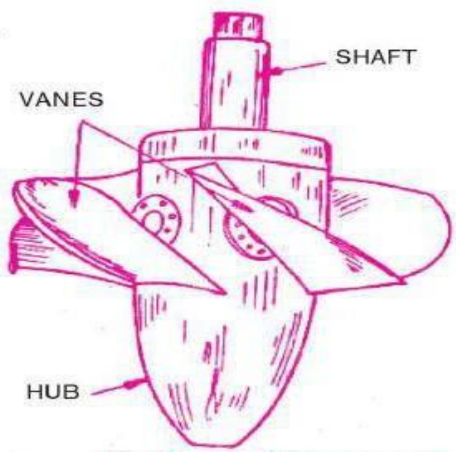


KAPLAN TURBINE

If the water flows parallel to the axis of the rotation of the shaft, the turbine is known as axial flow turbine. And if the head at the inlet of the turbine is the sum of pressure energy and kinetic energy and during the flow of water through runner a part of pressure energy is converted into kinetic energy, the turbine is known as reaction turbine.

For the axial flow reaction turbine, the shaft of the turbine is vertical. The lower end of the shaft is made larger which is known as 'hub' or 'boss'. The vanes are fixed on the hub and hence hub acts as a runner for axial flow reaction turbine. The following are the important type of axial flow reaction turbines :

1. Propeller Turbine, and
2. Kaplan Turbine.

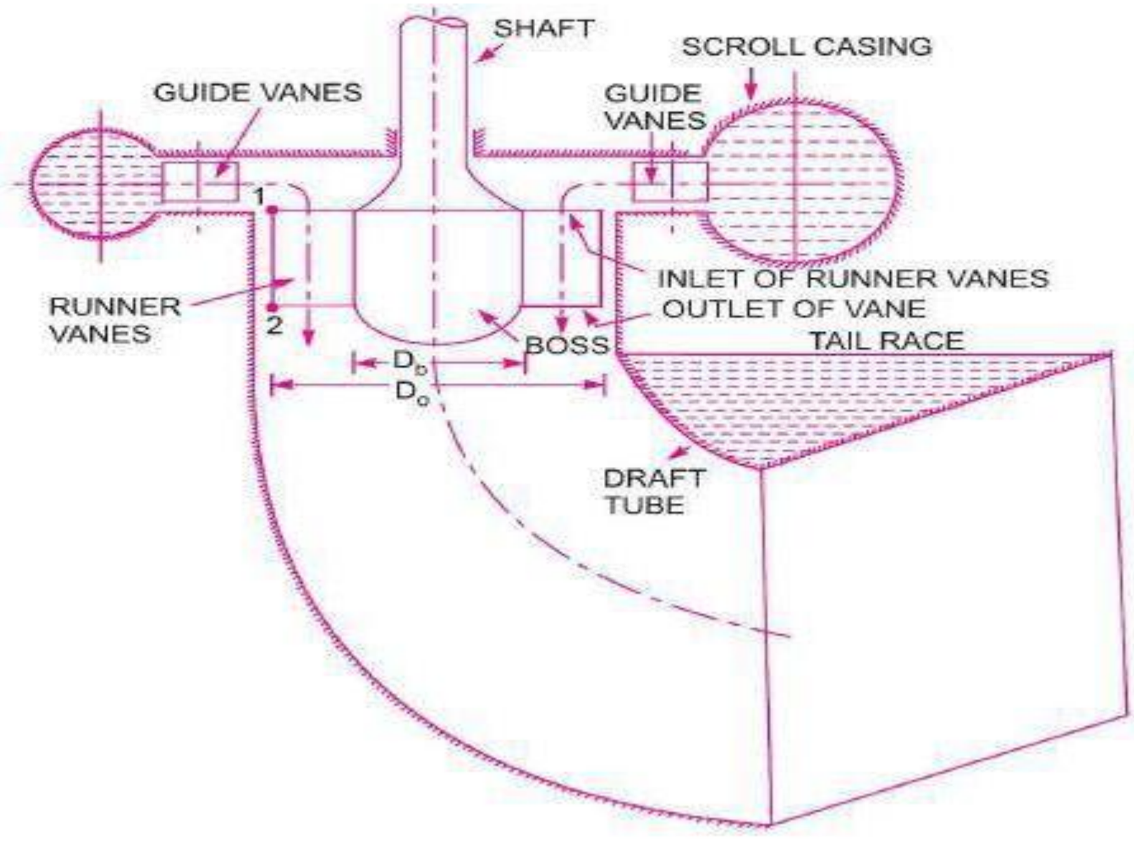


Kaplan turbine runner.

When the vanes are fixed to the hub and they are not adjustable, the turbine is known as propeller turbine. But if the vanes on the hub are adjustable, the turbine is known as a *Kaplan Turbine*, after the name of V Kaplan, an Austrian Engineer. This turbine is suitable where a large quantity of water at low head is available. Fig. shows the runner of a Kaplan turbine, which consists of a hub fixed to the shaft. On the hub, the adjustable vanes are fixed as shown in Fig.

Main parts of Kaplan turbine

1. Scroll casing,
2. Guide vanes mechanism,
3. Hub with vanes or runner of the turbine, and
4. Draft tube.



Main components of Kaplan turbine.

Fig. shows all main parts of a Kaplan turbine. The water from penstock enters the scroll casing and then moves to the guide vanes. From the guide vanes, the water turns through 90° and flows axially through the runner as shown in Fig. The discharge through the runner is obtained as

$$Q = \frac{\pi}{4}\left(D_o^2 - D_b^3\right) \times V_{f_1}$$

where D_o = Outer diameter of the runner,

D_b = Diameter of hub, and

V_{f_1} = Velocity of flow at inlet.

Some Important Point for Propeller (Kaplan Turbine). The following are the important points for propeller or Kaplan turbine :

1. The peripheral velocity at inlet and outlet are equal

$$\therefore \qquad u_1 = u_2 = \frac{\pi D_o N}{60}, \text{ where } D_o = \text{Outer dia. of runner}$$

2. Velocity of flow at inlet and outlet are equal

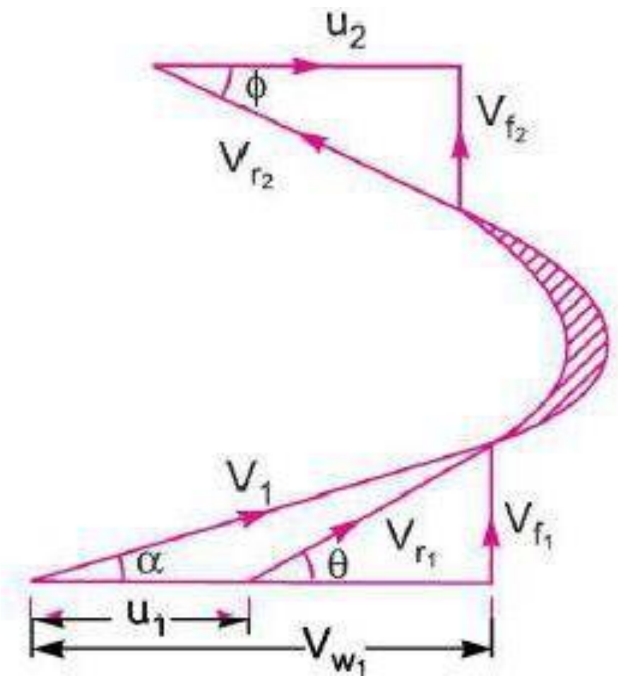
$$\therefore \qquad V_{f_1} = V_{f_2}.$$

3. Area of flow at inlet = Area of flow at outlet

$$= \frac{\pi}{4}\left(D_o^2 - D_b^2\right).$$

VELOCITY TRIANGLE OF KAPLAN TURBINE

The inlet and outlet velocity triangles are drawn at the extreme edge of the runner vane corresponding to the points 1 and 2 as shown in Fig. .



DRAFT TUBE

The draft-tube is a pipe of gradually increasing area which connects the outlet of the runner to the tail race. It is used for discharging water from the exit of the turbine to the tail race. This pipe of gradually increasing area is called a draft-tube. One end of the draft-tube is connected to the outlet of the runnner while the other end is sub-merged below the level of water in the tail race. The draft-tube, in addition to serve a passage for water discharge, has the following two purposes also :

1. It permits a negative head to be established at the outlet of the runner and thereby increase the net head on the turbine. The turbine may be placed above the tail race without any loss of net head and hence turbine may be inspected properly.

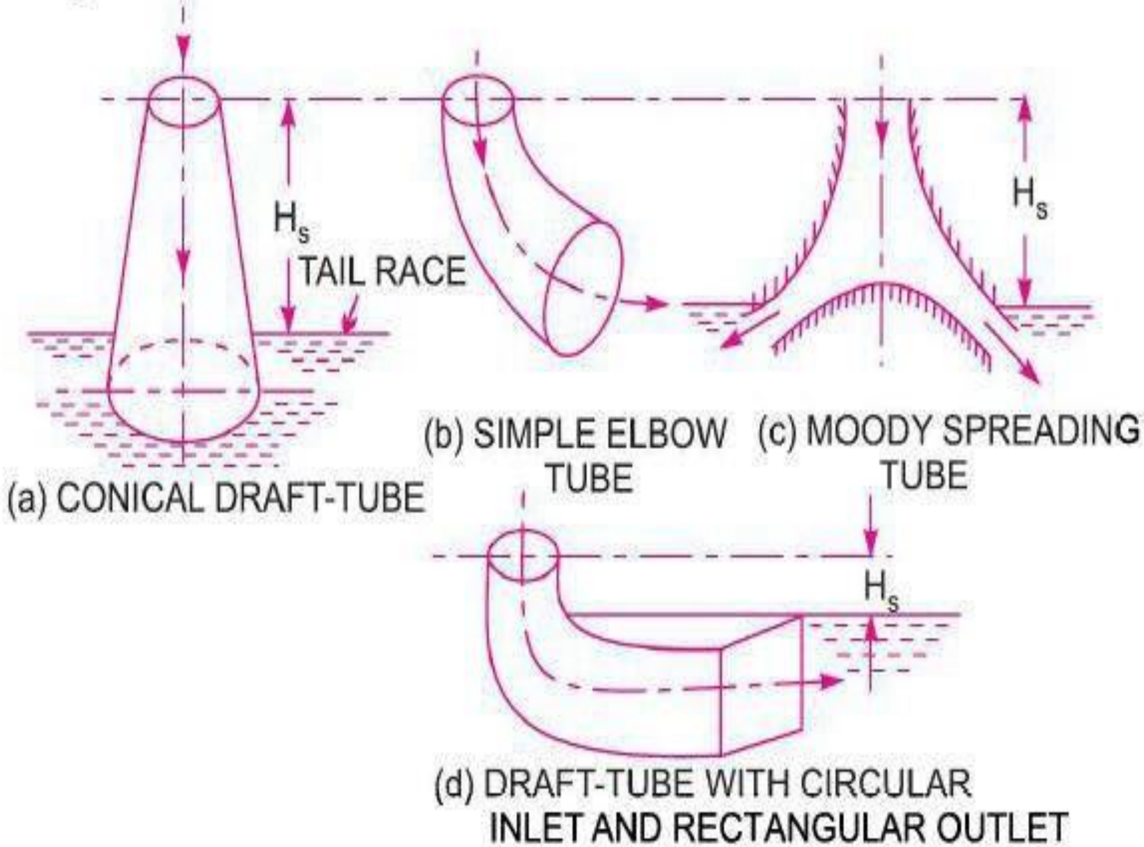
2. It converts a large proportion of the kinetic energy ($V_2^2/2g$) rejected at the outlet of the turbine into useful pressure energy. Without the draft tube, the kinetic energy rejected at the outlet of the turbine will go waste to the tail race.

Hence by using draft-tube, the net head on the turbine increases. The turbine develops more power and also the efficiency of the turbine increases.

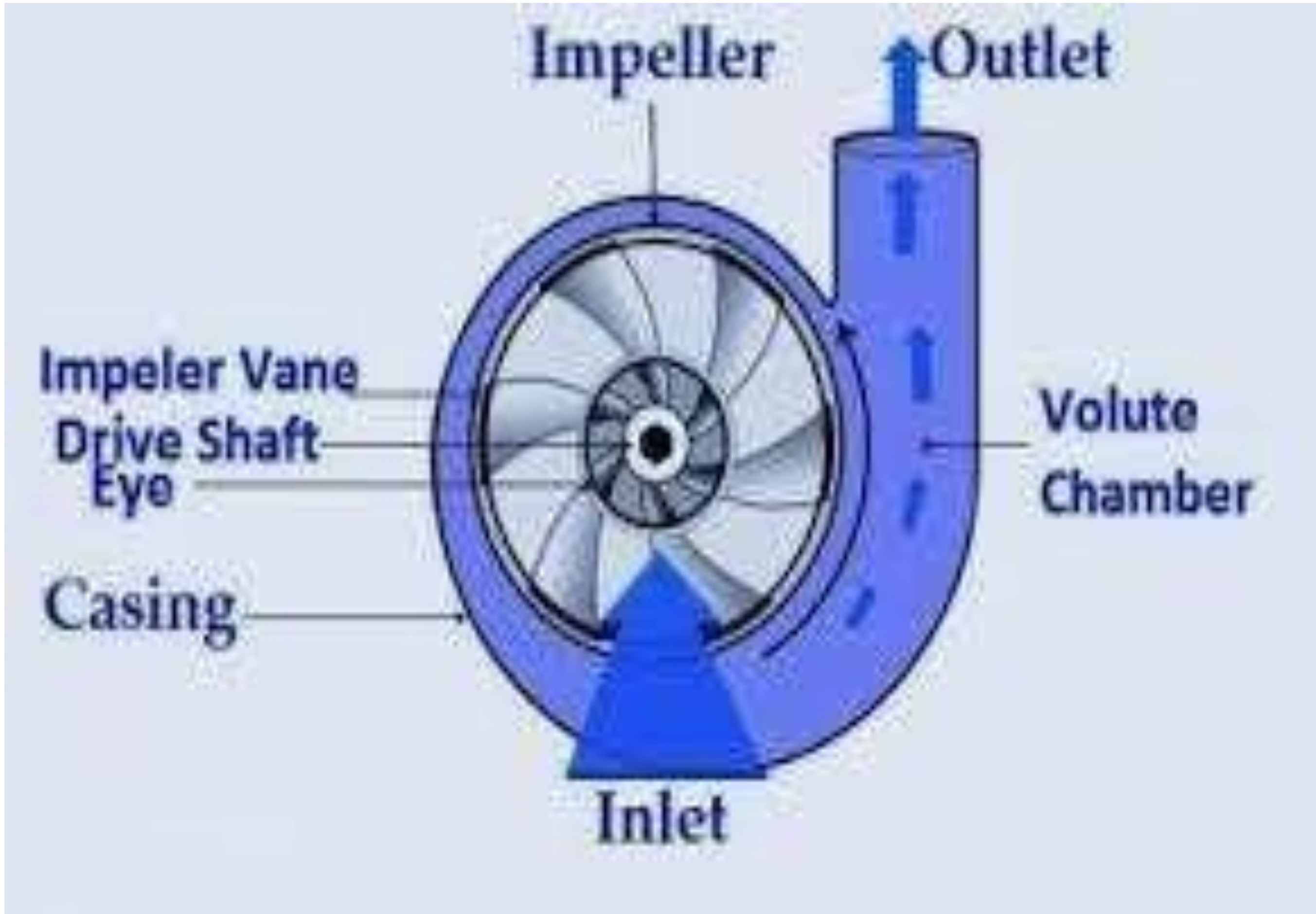
If a reaction turbine is not fitted with a draft-tube, the pressure at the outlet of the runner will be equal to atmospheric pressure. The water from the outlet of the runner will discharge freely into the tail race. The net head on the turbine will be less than that of a reaction turbine fitted with a draft-tube.

TYPES OF DRAFT TUBE

1. Conical draft-tubes,
2. Simple elbow tubes,
3. Moody spreading tubes, and
4. Elbow draft-tubes with circular inlet and rectangular outlet.



CENTRIFUGAL PUMP


Impeller
Outlet
Impeler Vane
Drive Shaft
Eye
Volute
Chamber
Casing
Inlet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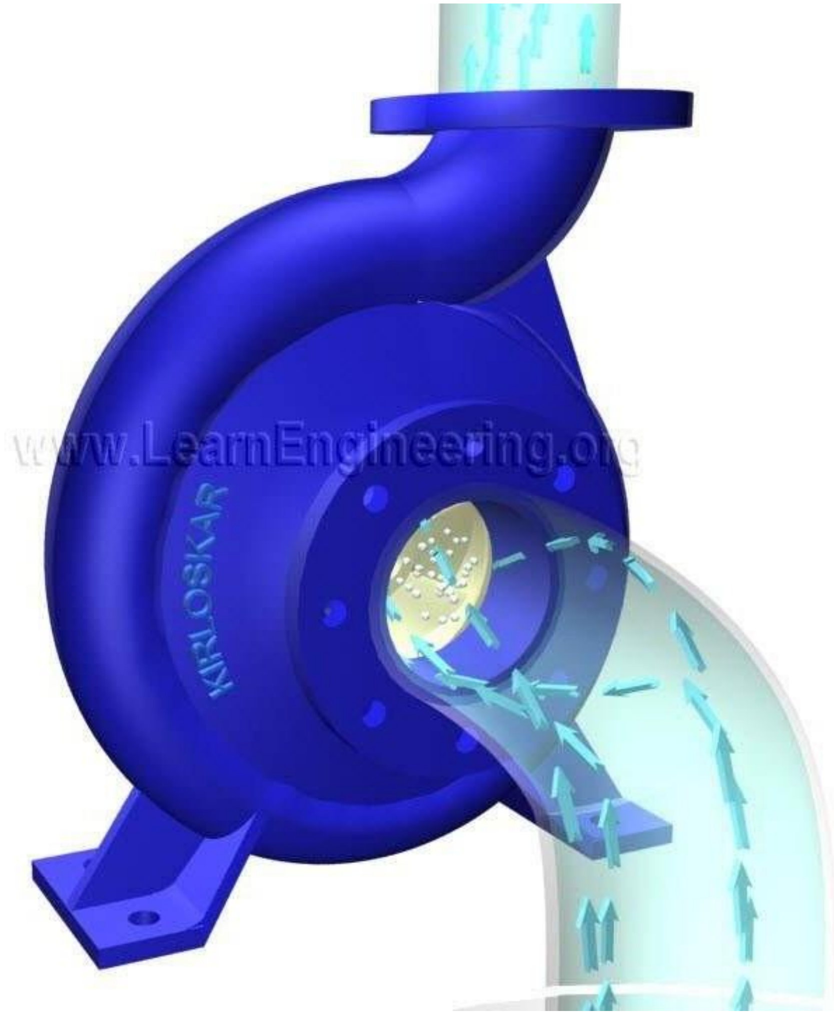
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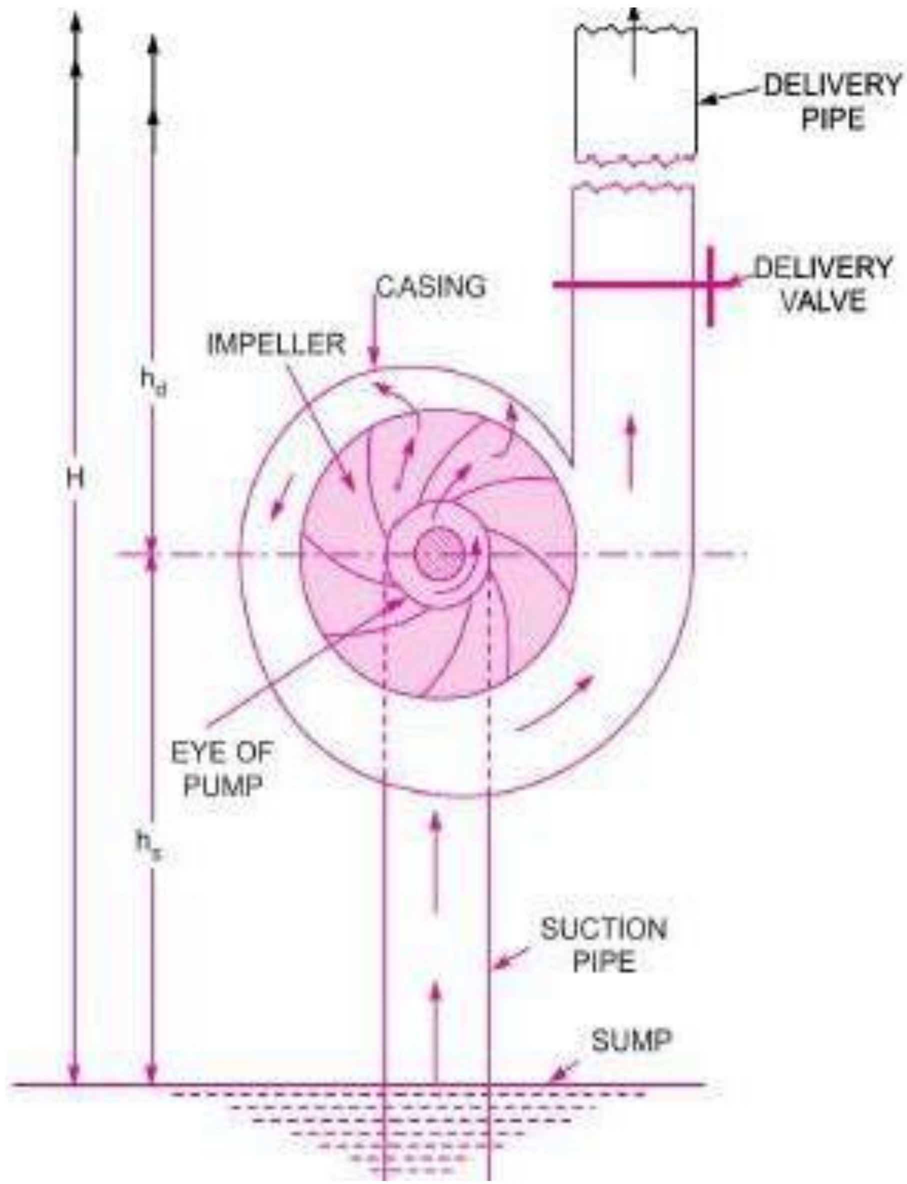


DELIVERY PIPE
DELIVERY VALVE
CASING
IMPELLER
h_d
H
EYE OF PUMP
h_s
SUCTION PIPE
SUMP

The hydraulic machines which convert the mechanical energy into hydraulic energy are called pumps. The hydraulic energy is in the form of pressure energy. If the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydraulic machine is called centrifugal pump.

The centrifugal pump acts as a reverse of an inward radial flow reaction turbine. This means that the flow in centrifugal pumps is in the radial outward directions. The centrifugal pump works on the principle of forced vortex flow which means that when a certain mass of liquid is rotated by an external torque, the rise in pressure head of the rotating liquid takes place. The rise in pressure head at any point of the rotating liquid is proportional to the square of tangential velocity of the liquid at that point $\left(i.e., \text{ rise in pressure head } = \frac{V^2}{2g} \text{ or } \frac{\omega^2 r^2}{2g}\right)$. Thus at the outlet of the impeller, where radius is more, the rise in pressure head will be more and the liquid will be discharged at the outlet with a high pressure head. Due to this high pressure head, the liquid can be lifted to a high level.

MAIN PARTS OF CENTRIFUGAL PUMP

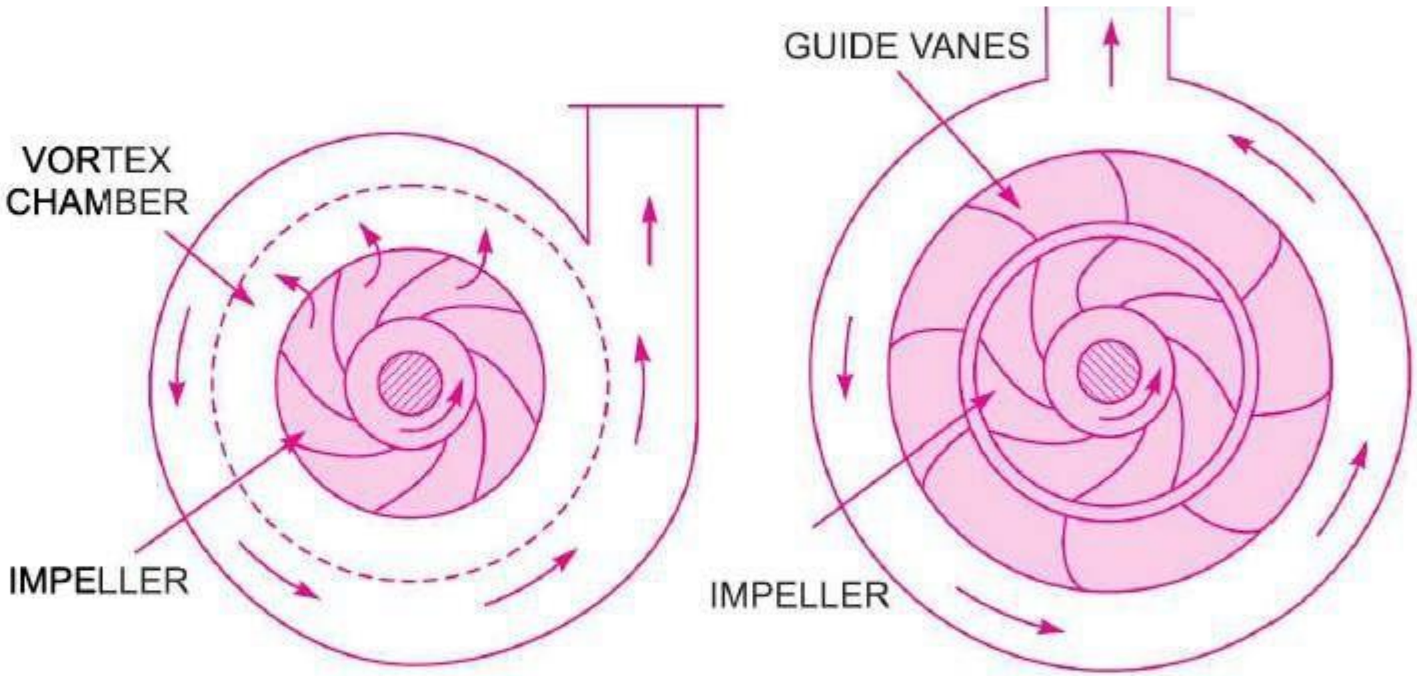
The following are the main parts of a centrifugal pump :

1. Impeller.
2. Casing.
3. Suction pipe with a foot valve and a strainer.
4. Delivery pipe.

All the main parts of the centrifugal pump are shown in Fig.

1. Impeller. The rotating part of a centrifugal pump is called 'impeller'. It consists of a series of backward curved vanes. The impeller is mounted on a shaft which is connected to the shaft of an electric motor.

2. Casing. The casing of a centrifugal pump is similar to the casing of a reaction turbine. It is an air-tight passage surrounding the impeller and is designed in such a way that the kinetic energy of the water discharged at the outlet of the impeller is converted into pressure energy before the water leaves the casing and enters the delivery pipe. The following three types of the casings are commonly adopted :



(a) VORTEX CASING

(b) CASING WITH GUIDE BLADES

(*b*) **Vortex Casing.** If a circular chamber is introduced between the casing and the impeller as shown in Fig. (*a*), the casing is known as Vortex Casing. By introducing the circular chamber, the loss of energy due to the formation of eddies is reduced to a considerable extent. Thus the efficiency of the pump is more than the efficiency when only volute casing is provided.

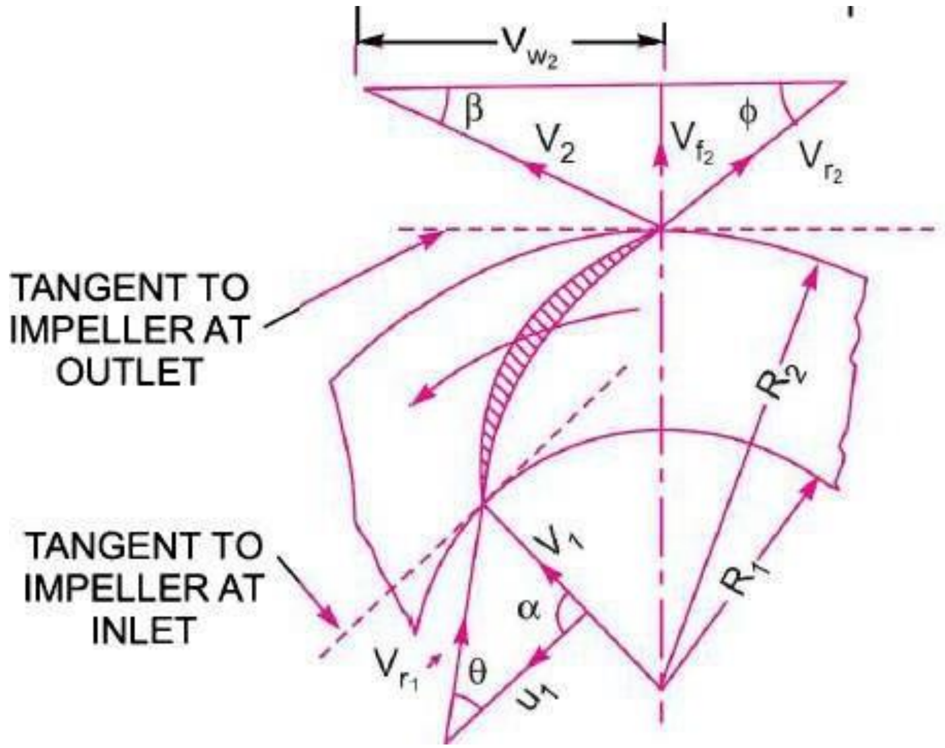
(*c*) **Casing with Guide Blades.** This casing is shown in Fig. (*b*) in which the impeller is surrounded by a series of guide blades mounted on a ring which is known as diffuser. The guide vanes are designed in such a way that the water from the impeller enters the guide vanes without stock.

Also the area of the guide vanes increases, thus reducing the velocity of flow through guide vanes and consequently increasing the pressure of water. The water from the guide vanes then passes through the surrounding casing which is in most of the cases concentric with the impeller as shown in Fig. (*b*).

3. Suction Pipe with a Foot valve and a Strainer. A pipe whose one end is connected to the inlet of the pump and other end dips into water in a sump is known as suction pipe. A foot valve which is a non-return valve or one-way type of valve is fitted at the lower end of the suction pipe. The foot valve opens only in the upward direction. A strainer is also fitted at the lower end of the suction pipe.

4. Delivery Pipe. A pipe whose one end is connected to the outlet of the pump and other end delivers the water at a required height is known as delivery pipe.

WORKDONE AND VELOCITY TRIANGLE CENTRIFUGAL PUMP



In case of the centrifugal pump, work is done by the impeller on the water. The expression for the work done by the impeller on the water is obtained by drawing velocity triangles at inlet and outlet of the impeller in the same way as for a turbine. The water enters the impeller radially at inlet for best efficiency of the pump, which means the absolute velocity of water at inlet makes an angle of 90° with the direction of motion of the impeller at inlet. Hence angle $\alpha = 90°$ and $V_{w_1} = 0$. For drawing the velocity triangles, the same notations are used as that for turbines.

Let N = Speed of the impeller in r.p.m.,

D_1 = Diameter of impeller at inlet,

u_1 = Tangential velocity of impeller at inlet,

$$= \frac{\pi D_1 N}{60}$$

D_2 = Diameter of impeller at outlet,

u_2 = Tangential velocity of impeller at outlet

$$= \frac{\pi D_2 N}{60}$$

V_1 = Absolute velocity of water at inlet,

V_{r_1} = Relative velocity of water at inlet,

α = Angle made by absolute velocity (V_1) at inlet with the direction of motion of vane,

θ = Angle made by relative velocity (V_{r_1}) at inlet with the direction of motion of vane, and V_2, As the water enters the impeller radially which means the absolute velocity of water at inlet is in the radial direction and hence angle $\alpha = 90°$ and $V_{w_1} = 0$.

A centrifugal pump is the reverse of a radially inward flow reaction turbine. But in case of a radially inward flow reaction turbine, the work done by the water on the runner per second per unit weight of the water striking per second is given by equation (18.19) as

$$= \frac{1}{g}[V_{w_1}u_1 - V_{w_2}u_2]$$

$\therefore$ Work done by the impeller on the water per second per unit weight of water striking per second

$$= -\text{ [Work done in case of turbine]}$$

$$= -\left[\frac{1}{g}\left(V_{w_1}u_1 - V_{w_2}u_2\right)\right] = \frac{1}{g}\left[V_{w_2}u_2 - V_{w_1}u_1\right]$$

$$= \frac{1}{g}V_{w_2}u_2 \qquad (\because \quad V_{w_1} = 0 \text{ here})$$

Work done by impeller on water per second

$$= \frac{W}{g}.V_{w_2}u_2$$

where W = Weight of water = $\rho \times g \times Q$

where Q = Volume of water

and Q = Area × Velocity of flow = $\pi D_1 B_1 \times V_{f_1}$

$= \pi D_2 B_2 \times V_{f_2}$

where B_1 and B_2 are width of impeller at inlet and outlet and V_{f_1} and V_{f_2} are velocities of flow at inlet and outlet.

DEFINITIONS OF HEADS AND EFFICIENCIES OF A CENTRIFUGAL PUMP

1. Suction Head (h_s). It is the vertical height of the centre line of the centrifugal pump above the water surface in the tank or pump from which water is to be lifted as shown in Fig. This height is also called suction lift and is denoted by 'h_s'.

2. Delivery Head (h_d). The vertical distance between the centre line of the pump and the water surface in the tank to which water is delivered is known as delivery head. This is denoted by 'h_d'.

3. Static Head (H_s). The sum of suction head and delivery head is known as static head. This is represented by 'H_s' and is written as

$$H_s = h_s + h_d.$$

4. Manometric Head (H_m). The manometric head is defined as the head against which a centrifugal pump has to work. It is denoted by 'H_m'. It is given by the following expressions :

(*a*) H_m = Head imparted by the impeller to the water – Loss of head in the pump

$$= \frac{V_{w_2} u_2}{g} - \text{Loss of head in impeller and casing}$$

$$= \frac{V_{w_2} u_2}{g} \quad \text{...if loss of pump is zero}$$

(*b*) H_m = Total head at outlet of the pump – Total head at the inlet of the pump

$$= \left(\frac{P_o}{\rho g} + \frac{V_o^2}{2g} + Z_o\right) - \left(\frac{p_i}{\rho g} + \frac{V_i^2}{2g} + Z_i\right)$$

where $\frac{p_o}{\rho g}$ = Pressure head at outlet of the pump = h_d

$\frac{V_o^2}{2g}$ = Velocity head at outlet of the pump

= Velocity head in delivery pipe = $\frac{V_d^2}{2g}$

Z_o = Vertical height of the outlet of the pump from datum line, and

$\frac{p_i}{\rho g}, \frac{V_i^2}{2g}$, Z_i = Corresponding values of pressure head, velocity head and datum head at the inlet of the pump,

i.e., h_s, $\frac{V_s^2}{2g}$ and Z_s respectively.

(c) $$H_m = h_s + h_d + h_{f_s} + h_{f_d} + \frac{V_d^2}{2g}$$

where h_s = Suction head, h_d = Delivery head,

h_{f_s} = Frictional head loss in suction pipe, h_{f_d} = Frictional head loss in delivery pipe, and

V_d = Velocity of water in delivery pipe.

EFFICIENCY OF CENTRIFUGAL PUMP

(*a*) **Manometric Efficiency (η_{man}).** The ratio of the manometric head to the head imparted by the impeller to the water is known as manometric efficiency. Mathematically, it is written as

$$\eta_{man} = \frac{\text{Manometric head}}{\text{Head imparted by impeller to water}}$$

The power at the impeller of the pump is more than the power given to the water at outlet of the pump. The ratio of the power given to water at outlet of the pump to the power available at the impeller, is known as manometric efficiency.

$$\text{The power given to water at outlet of the pump} = \frac{WH_m}{1000}\ \text{kW}$$

$$\text{The power at the impeller} = \frac{\text{Work done by impeller per second}}{1000}\ \text{kW}$$

$$= \frac{W}{g} \times \frac{V_{w_2} \times u_2}{1000}\ \text{kW}$$

$$\eta_{man} = \frac{\dfrac{W \times H_m}{1000}}{\dfrac{W}{g} \times \dfrac{V_{w_2} \times u_2}{1000}} = \frac{g \times H_m}{V_{w_2} \times u_2}.$$

(*b*) **Mechanical Efficiency (η_m).** The power at the shaft of the centrifugal pump is more than the power available at the impeller of the pump. The ratio of the power available at the impeller to the power at the shaft of the centrifugal pump is known as mechanical efficiency. It is written as

$$\eta_m = \frac{\text{Power at the impeller}}{\text{Power at the shaft}}$$

$$\text{The power at the impeller in kW} = \frac{\text{Work done by impeller per second}}{1000}$$

$$= \frac{W}{g} \times \frac{V_{w_2} u_2}{1000}$$

$$\eta_m = \frac{\dfrac{W}{g}\left(\dfrac{V_{w_2} u_2}{1000}\right)}{\text{S.P.}}$$

(*c*) **Overall Efficiency (η_o).** It is defined as ratio of power output of the pump to the power input to the pump. The power output of the pump in kW

$$= \frac{\text{Weight of water lifted} \times H_m}{1000} = \frac{WH_m}{1000}$$

Power input to the pump $= \text{Power supplied by the electric motor}$

$= \text{S.P. of the pump.}$

$$\therefore \qquad \eta_o = \frac{\left(\dfrac{WH_m}{1000}\right)}{\text{S.P.}}$$

Also $\qquad \eta_o = \eta_{man} \times \eta_m.$

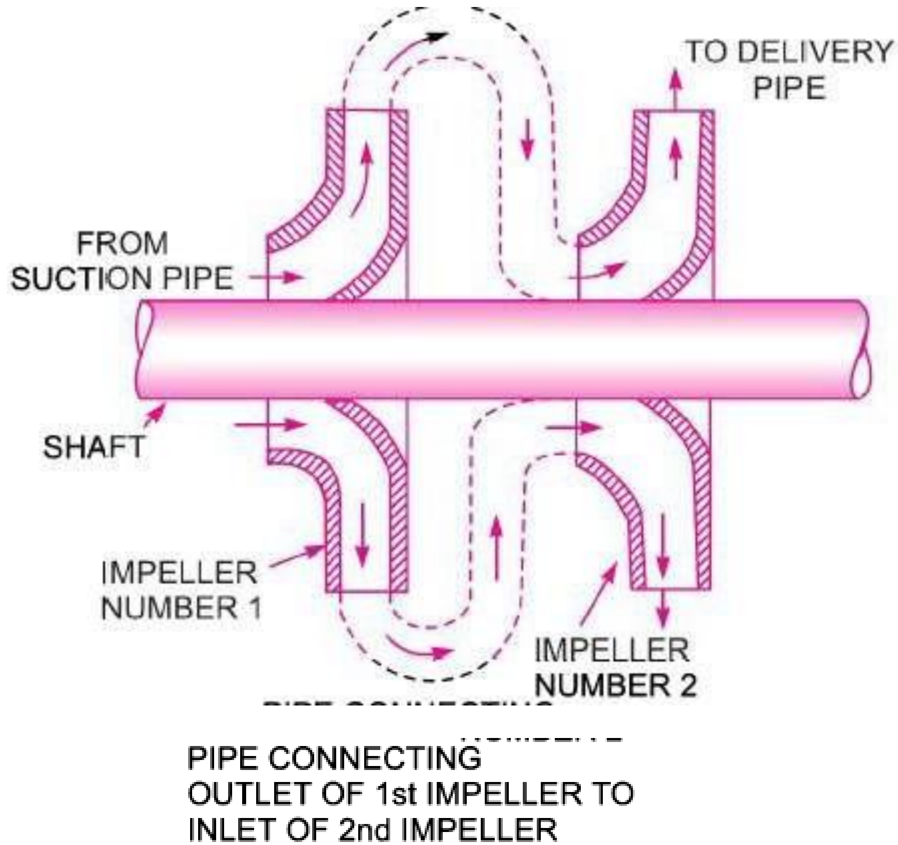
MULTISTAGE CENTRIFUGAL PUMPS

If a centrifugal pump consists of two or more impellers, the pump is called a multistage centrifugal pump. The impellers may be mounted on the same shaft or on different shafts. A multistage pump is having the following two important functions :

1. To produce a high head, and
2. To discharge a large quantity of liquid.

If a high head is to be developed, the impellers are connected in series (or on the same shaft) while for discharging large quantity of liquid, the impellers (or pumps) are connected in parallel.

Multistage Centrifugal Pumps for High Heads.



Two-stage pumps with impellers in series.

Let n = Number of identical impellers mounted on the same shaft,

H_m = Head developed by each impeller.

Then total head developed

$$= n \times H_m$$

The discharge passing through each impeller is same

Multistage Centrifugal Pumps for High Discharge.

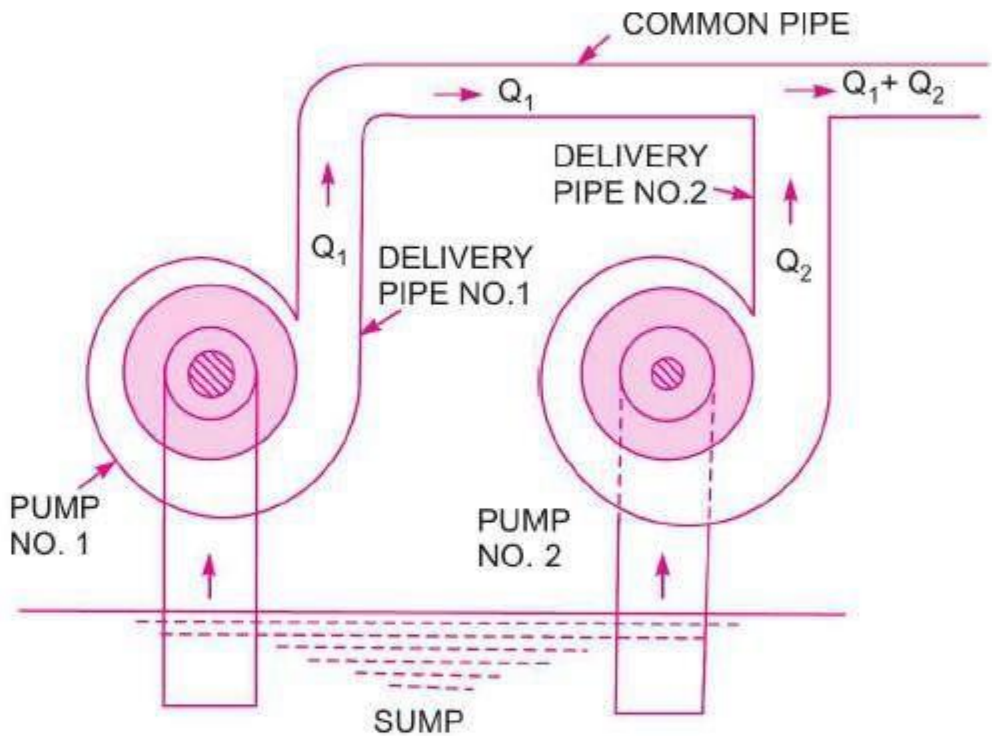


Fig. *Pumps in parallel.*

Let n = Number of identical pumps arranged in parallel.

Q = Discharge from one pump.

$\therefore$ Total discharge $= n \times Q$

PRIMING OF A CENTRIFUGAL PUMP

Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe upto the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped.

The work done by the impeller per unit weight of liquid per sec is known as the head generated by the pump. Equation gives the head generated by the pump as $= \frac{1}{g} V_{w_2} u_2$ metre. This equation is independent of the density of the liquid. This means that when pump is running in air, the head generated is in terms of metre of air. If the pump is primed with water, the head generated is same metre of water. But as the density of air is very low, the generated head of air in terms of equivalent metre of water head is negligible and hence the water may not be sucked from the pump. To avoid this difficulty, priming is necessary.

CAVITATION

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure and the sudden collapsing of these vapour bubbles in a region of higher pressure. When the vapour bubbles collapse, a very high pressure is created. The metallic surfaces, above which these vapour bubbles collapse, is subjected to these high pressures, which cause pitting action on the surface. Thus cavities are formed on the metallic surface and also considerable noise and vibrations are produced.

Cavitation includes formation of vapour bubbles of the flowing liquid and collapsing of the vapour bubbles. Formation of vapour bubbles of the flowing liquid take place only whenever the pressure in any region falls below vapour pressure. When the pressure of the flowing liquid is less than its vapour pressure, the liquid starts boiling and vapour bubbles are formed. These vapour bubbles are carried along with the flowing liquid to higher pressure zones where these vapours condense and bubbles collapse. Due to sudden collapsing of the bubbles on the metallic surface, high pressure is produced and metallic surfaces are subjected to high local stresses. Thus the surfaces are damaged.

Precaution Against Cavitation.

(*i*) The pressure of the flowing liquid in any part of the hydraulic system should not be allowed to fall below its vapour pressure. If the flowing liquid is water, then the absolute pressure head should not be below 2.5 m of water.

(*ii*) The special materials or coatings such as aluminium-bronze and stainless steel, which are cavitation resistant materials, should be used.

Effects of Cavitation.

(*i*) The metallic surfaces are damaged and cavities are formed on the surfaces.
(*ii*) Due to sudden collapse of vapour bubble, considerable noise and vibrations are produced.
(*iii*) The efficiency of a turbine decreases due to cavitation. Due to pitting action, the surface of the turbine blades becomes rough and the force exerted by water on the turbine blades decreases. Hence, the work done by water or output horse power becomes less and thus efficiency decreases.

Hydraulic Machines Subjected to Cavitation.

Cavitation in Turbines. In turbines, only reaction turbines are subjected to cavitation. In reaction turbines the cavitation may occur at the outlet of the runner or at the inlet of the draft-tube where the pressure is considerably reduced (*i.e.*, which may be below the vapour pressure of the liquid flowing through the turbine). Due to cavitation, the metal of the runner vanes and draft-tube is gradually eaten away, which results in lowering the efficiency of the turbine. Hence, the cavitation in a reaction turbine can be noted by a sudden drop in efficiency. In order to determine whether cavitation will occur in any portion of a reaction turbine, the critical value of Thoma's cavitation factor (σ, sigma) is calculated.

Thoma's Cavitation Factor for Reaction Turbines. Prof. D. Thoma suggested a dimensionless number, called after his name Thoma's cavitation factor σ (sigma), which can be used for determining the region where cavitation takes place in reaction turbines. The mathematical expression for the Thoma's cavitation factor is given by

$$\sigma = \frac{H_b - H_s}{H} = \frac{(H_{atm} - H_v) - H_s}{H} \quad \text{...(19.23)}$$

where H_b = Barometric pressure head in m of water,

H_{atm} = Atmospheric pressure head in m of water,

H_v = Vapour pressure head in m of water,

H_s = Suction pressure at the outlet of reaction turbine in m of water or height of turbine runner above the tail water surface,

H = Net head on the turbine in m.

Cavitation in Centrifugal Pumps.

Cavitation in Centrifugal Pumps. In centrifugal pumps the cavitation may occur at the ınlet of the impeller of the pump, or at the suction side of the pumps, where the pressure is considerably reduced. Hence if the pressure at the suction side of the pump drops below the vapour pressure of the liquid then the cavitation may occur. The cavitation in a pump can be noted by a sudden drop in efficiency and head. In order to determine whether cavitation will occur in any portion of the suction side of the pump, the critical value of Thoma's cavitation factor (σ) is calculated.

Thoma's Cavitation Factor for Centrifugal Pumps. The mathematical expression for Thoma's cavitation factor for centrifugal pump is given by

$$\sigma = \frac{(H_b) - H_S - h_{LS}}{H} = \frac{(H_{atm} - H_V) - H_S - h_{LS}}{H}$$

where H_{atm} = Atmospheric pressure head in m of water or absolute pressure head at the liquid surface in pump,

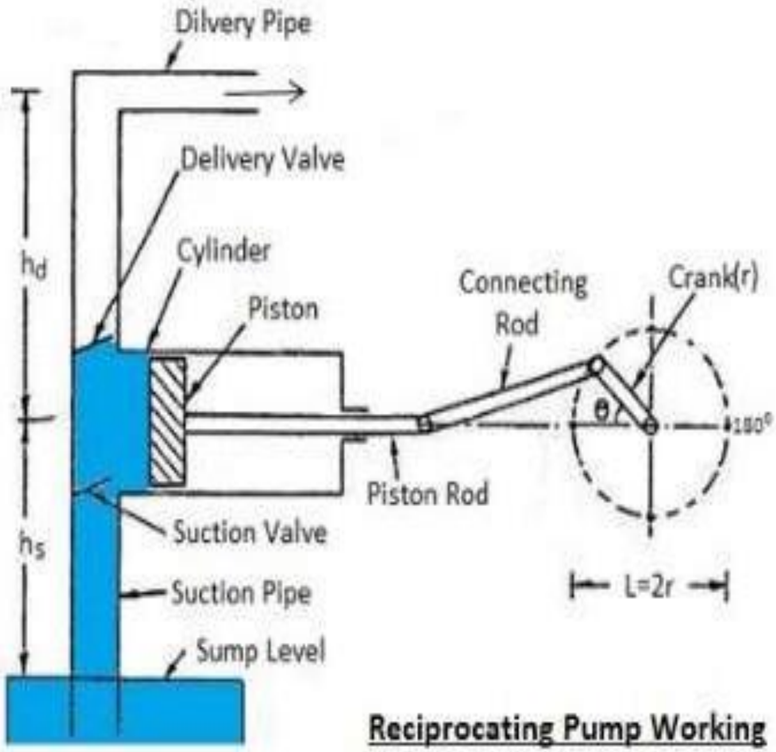
H_V = Vapour pressure head in m of water,

H_S = Suction pressure head in m of water,

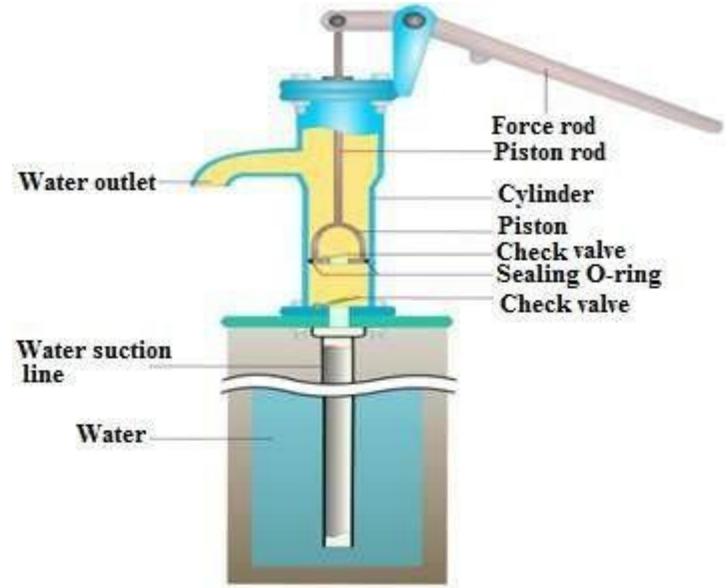
h_{LS} = Head lost due to friction in suction pipe, and

H = Head developed by the pump.

RECIPROCATING PUMP



Reciprocating Pump Working

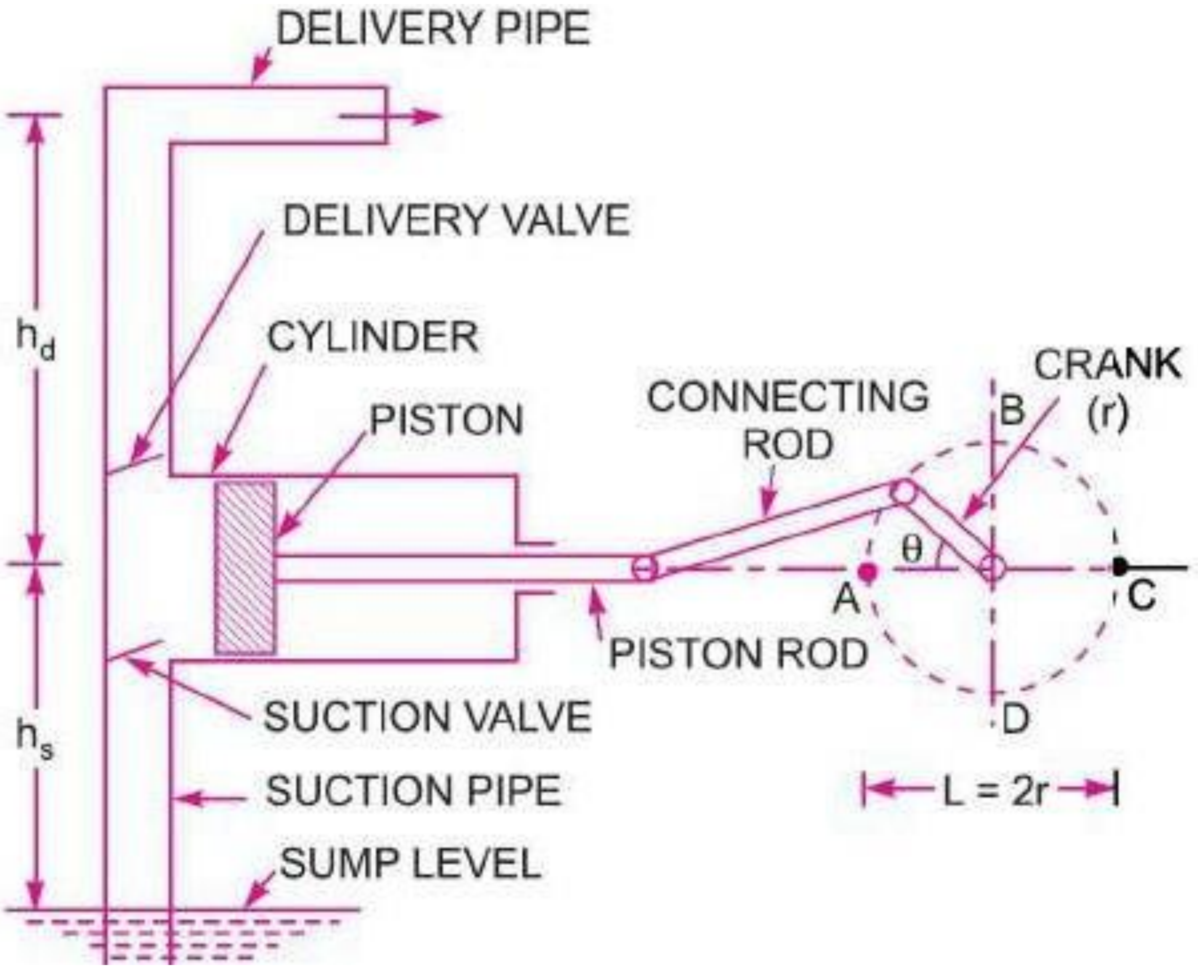


INTRODUCTION

In the last chapter, we have defined the pumps as the hydraulic machines which convert the mechanical energy into hydraulic energy which is mainly in the form of pressure energy. If the mechanical energy is converted into hydraulic energy, by means of centrifugal force acting on the liquid, the pump is known as centrifugal pump. But if the mechanical energy is converted into hydraulic energy (or pressure energy) by sucking the liquid into a cylinder in which a piston is reciprocating (moving backwards and forwards), which exerts the thrust on the liquid and increases its hydraulic energy (pressure energy), the pump is known as reciprocating pump.

MAIN PARTS OF RECIPROCATIMG PUMP

1. A cylinder with a piston, piston rod, connecting rod and a crank,
2. Suction pipe,
3. Delivery pipe,
4. Suction valve, and
5. Delivery valve.



WORKING OF SINGLE ACTING RECIPROCATING PUMP

Fig. : shows a single acting reciprocating pump, which consists of a piston which moves forwards and backwards in a close fitting cylinder. The movement of the piston is obtained by connecting the piston rod to crank by means of a connecting rod. The crank is rotated by means of an electric motor. Suction and delivery pipes with suction valve and delivery valve are connected to the cylinder. The suction and delivery valves are one way valves or non-return valves, which allow the water to flow in one direction only. Suction valve allows water from suction pipe to the cylinder which delivery valve allows water from cylinder to delivery pipe only.

When crank starts rotating, the piston moves to and fro in the cylinder. When crank is at *A*., the piston is at the extreme left position in the cylinder. As the crank is rotating from *A* to *C*, (*i.e.*, from $\theta = 0^o$ to $\theta = 180°$), the piston is moving towards right in the cylinder. The movement of the piston towards right creates a partial vacuum in the cylinder. But on the surface of the liquid in the sump atmospheric pressure is acting, which is more than the pressure inside the cylinder. Thus, the liquid is forced in the suction pipe from the sump. This liquid opens the suction valve and enters the cylinder.

When crank is rotating from *C* to *A* (*i.e.*, from $\theta = 180°$ to $\theta = 360°$), the piston from its extreme right position starts moving towards left in the cylinder. The movement of the piston towards left increases the pressure of the liquid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. The liquid is forced into the delivery pipe and is raised to a required height.

Discharge Through a Reciprocating Pump. Consider a single* acting reciprocating pump as shown in Fig. .

Let D = Diameter of the cylinder

A = Cross-sectional area of the piston or cylinder

$$= \frac{\pi}{4} D^2$$

r = Radius of crank

N = r.p.m. of the crank

L = Length of the stroke = $2 \times r$

h_s = Height of the axis of the cylinder from water surface in sump.

h_d = Height of delivery outlet above the cylinder axis (also called delivery head)

Volume of water delivered in one revolution or discharge of water in one revolution

$$= \text{Area} \times \text{Length of stroke} = A \times L$$

Number of revolution per second, $= \dfrac{N}{60}$

$\therefore$ Discharge of the pump per second,

$$Q = \text{Discharge in one revolution} \times \text{No. of revolution per second}$$

$$= A \times L \times \frac{N}{60} = \frac{ALN}{60}$$

Weight of water delivered per second,

$$W = \rho \times g \times Q = \frac{\rho g ALN}{60}.$$

Work done by Reciprocating Pump. Work done by the reciprocating pump per second is given by the reaction as

Work done per second = Weight of water lifted per second × Total height through which water is lifted

$$= W \times (h_s + h_d) \quad \ldots(i)$$

where $(h_s + h_d)$ = Total height through which water is lifted.

From equation Weight, W, is given by

$$W = \frac{\rho g \times ALN}{60}.$$

Substituting the value of W in equation (i), we get

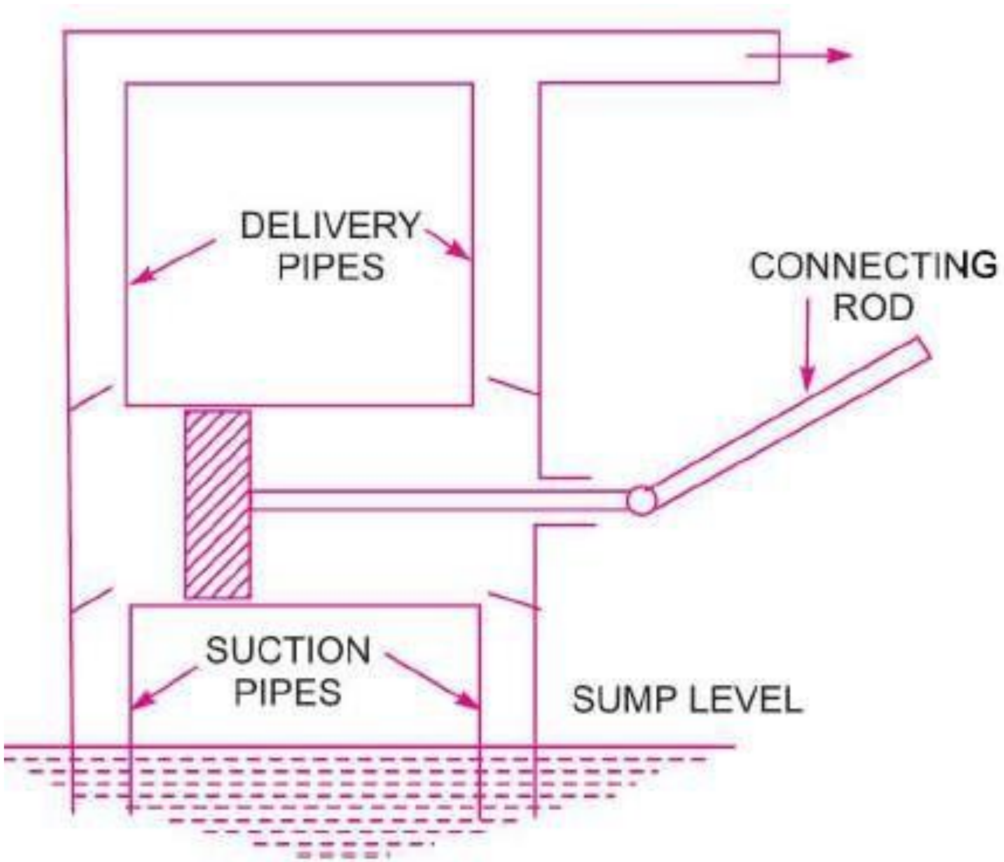
$$\text{Work done per second} = \frac{\rho g \times ALN}{60} \times (h_s + h_d)$$

$\therefore$ Power required to drive the pump, in kW

$$P = \frac{\text{Work done per second}}{1000} = \frac{\rho g \times ALN \times (h_s + h_d)}{60 \times 1000}$$

$$= \frac{\rho g \times ALN \times (h_s + h_d)}{60{,}000} \text{ kW}$$

DOUBLE ACTING RECIPROCATING PUMP



Discharge, Work done and Power Required to Drive a Double-acting Pump.

In case of double-acting pump, the water is acting on both sides of the piston as shown in Fig. Thus, we require two suction pipes and two delivery pipes for double-acting pump. When there is a suction stroke on one side of the piston, there is at the same time a delivery stroke on the other side of the piston. Thus for one complete revolution of the crank there are two delivery strokes and water is delivered to the pipes by the pump during these two delivery strokes.

Let D = Diameter of the piston,

d = Diameter of the piston rod

$\therefore$ Area on one side of the piston,

$$A = \frac{\pi}{4} D^2$$

Area on the other side of the piston, where piston rod is connected to the piston,

$$A_1 = \frac{\pi}{4} D^2 - \frac{\pi}{4} d^2 = \frac{\pi}{4} (D^2 - d^2).$$

$\therefore$ Volume of water delivered in one revolution of crank

$$= A \times \text{Length of stroke} + A_1 \times \text{Length of stroke}$$

$$= AL + A_1 L = (A + A_1)L = \left[\frac{\pi}{4}D^2 + \frac{\pi}{4}\left(D^2 - d^2\right)\right] \times L$$

$\therefore$ Discharge of pump per second

$$= \text{Volume of water delivered in one revolution} \times \text{No. of revolution per second}$$

$$= \left[\frac{\pi}{4}D^2 + \frac{\pi}{4}\left(D^2 - d^2\right)\right] \times L \times \frac{N}{60}$$

If 'd' the diameter of the piston rod is very small as compared to the diameter of the piston, then it can be neglected and discharge of pump per second,

$$Q = \left(\frac{\pi}{4}D^2 + \frac{\pi}{4}D^2\right) \times \frac{L \times N}{60} = 2 \times \frac{\pi}{4}D^2 \times \frac{L \times N}{60} = \frac{2ALN}{60} \ldots$$

Equation gives the discharge of a double-acting reciprocating pump. This discharge is two times the discharge of a single-acting pump.

Work done by double-acting reciprocating pump

Work done per second = Weight of water delivered × Total height

$$= \rho g \times \text{Discharge per second} \times \text{Total height}$$

$$= \rho g \times \frac{2ALN}{60} \times (h_s + h_d) = 2\rho g \times \frac{ALN}{60} \times (h_s + h_d)$$

∴ Power required to drive the double-acting pump in kW,

$$P = \frac{\text{Work done per second}}{1000} = 2\rho g \times \frac{ALN}{60} \times \frac{(h_s + h_d)}{1000}$$

$$= \frac{2\rho g \times ALN \times (h_s + h_d)}{60{,}000}$$

SLIP Of Reciprocating Pump

Slip of a pump is defined as the difference between the theoretical discharge and actual discharge of the pump. The discharge of a single-acting pump given by equation (20.1) and of a double-acting pump given by equation (20.5) are theoretical discharge. The actual discharge of a pump is less than the theoretical discharge due to leakage. The difference of the theoretical discharge and actual discharge is known as slip of the pump. Hence, mathematically.

$$\text{Slip} = Q_{th} - Q_{act}$$

But slip is mostly expressed as percentage slip which is given by,

$$\text{Percentage slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100 = \left(1 - \frac{Q_{act}}{Q_{th}}\right) \times 100$$

$$= (1 - C_d) \times 100 \qquad \left(\because \frac{Q_{act}}{Q_{th}} = C_d\right)$$

where C_d = Co-efficient of discharge.

Negative Slip of the Reciprocating Pump. Slip is equal to the difference of theoretical discharge and actual discharge. If actual discharge is more than the theoretical discharge, the slip of the pump will become –ve. In that case, the slip of the pump is known as negative slip.

Negative slip occurs when delivery pipe is short, suction pipe is long and pump is running at high speed.

Difference between Centrifugal pump and Reciprocating pump

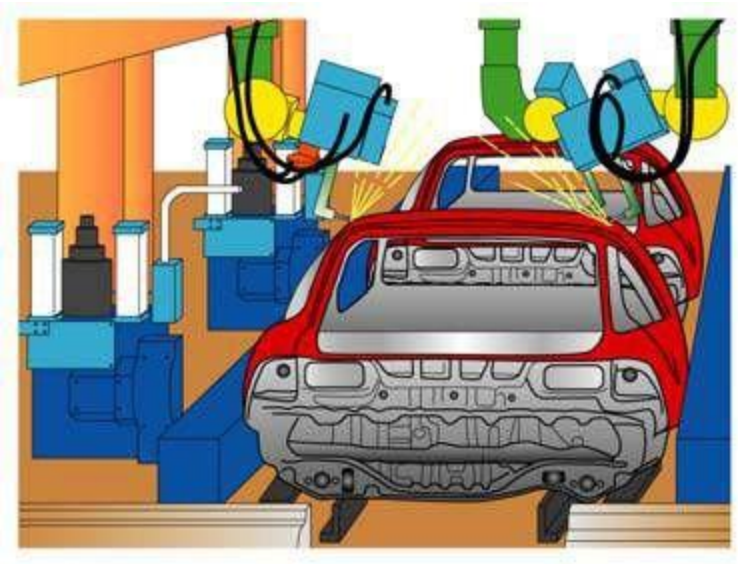
Centrifugal pump is a rotodynamic pump that uses kinetic energy to transfer fluid from low pressure to high pressure while the reciprocating pump uses a piston (suction and discharge stroke) to transfer fluid. Centrifugal pump is the most popular pump as compared to the reciprocating pump. There are many Differences between the Centrifugal pump and the reciprocating pump.

1. Centrifugal pump is a rotary pump uses the kinetic energy of impeller to transfer liquid.
A reciprocating pump is a positive displacement type pump which is forced through the piston.
2. Centrifugal pump provides a steady flow (continuous discharge).
The reciprocating pump provides pulsating flow.
3. Centrifugal pump uses uniform torque.
Reciprocating pump torque is not uniform.
4. Centrifugal pump discharge is inversely proportional to the viscosity of working fluid.
In Reciprocating pump viscosity of working fluid does not affect the pump discharge rate.

Pneumatic

Systems

- Pneumatic technology deals with the study of behaviour and applications of compressed air in our daily life in general and manufacturing automation in particular. Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.
- A pneumatic system is a system that uses compressed air to transmit and control energy.
- Pneumatic systems are used in controlling train doors, automatic production lines, mechanical clamps, etc (Fig. 1).



(a) Automobile production lines

(b) Pneumatic system of an automatic machine

Fig. 1 Common pneumatic systems used in the industrial sector

1. Basic Components of Pneumatic System

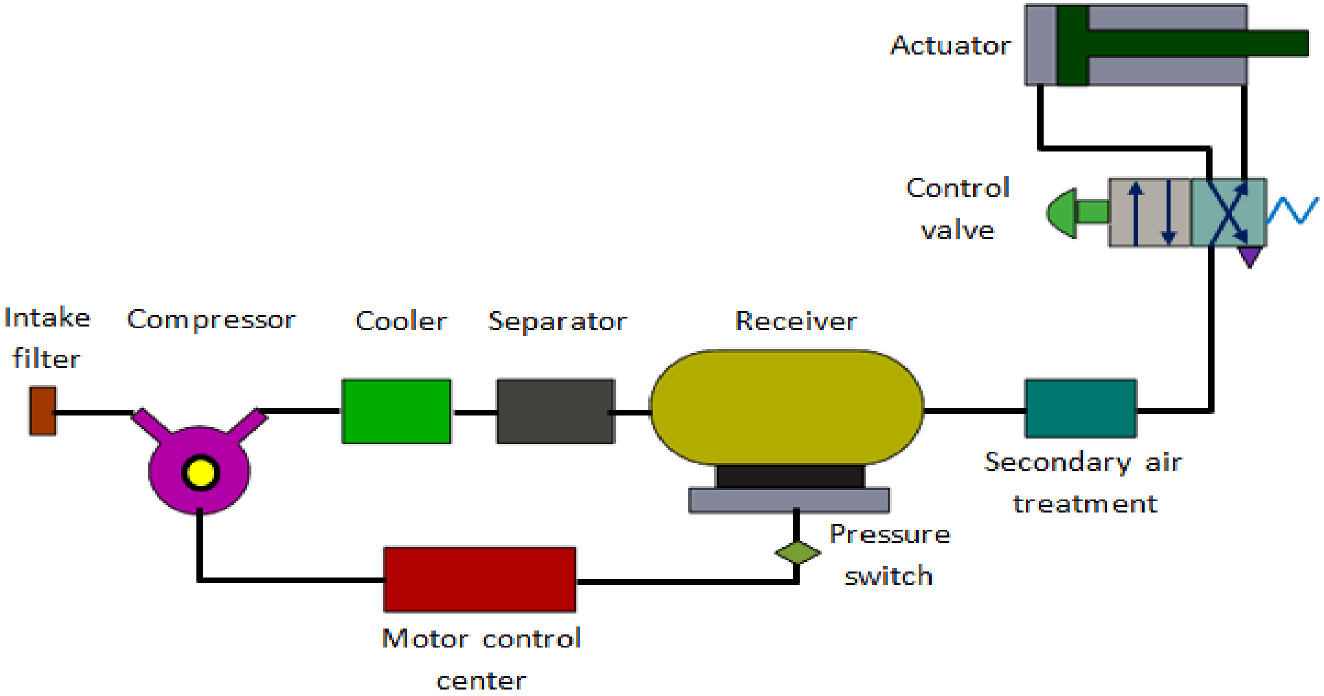


Fig 2: . *Basic Components of Pneumatic System*

a) Air filters: These are used to filter out the contaminants from the air.

b) Compressor: Compressed air is generated by using air compressors. Air compressors are either diesel or electrically operated. Based on the requirement of compressed air, suitable capacity compressors may be used.

c) Air cooler: During compression operation, air temperature increases. Therefore coolers are used to reduce the temperature of the compressed air.

d) Dryer: The water vapour or moisture in the air is separated from the air by using a dryer.

e) Control Valves: Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.

f) Air Actuator: Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system.

g) Electric Motor: Transforms electrical energy into mechanical energy. It is used to drive the compressor.

h) Receiver tank*:* The compressed air coming from the compressor is stored in the air receiver.

2. Receiver tank

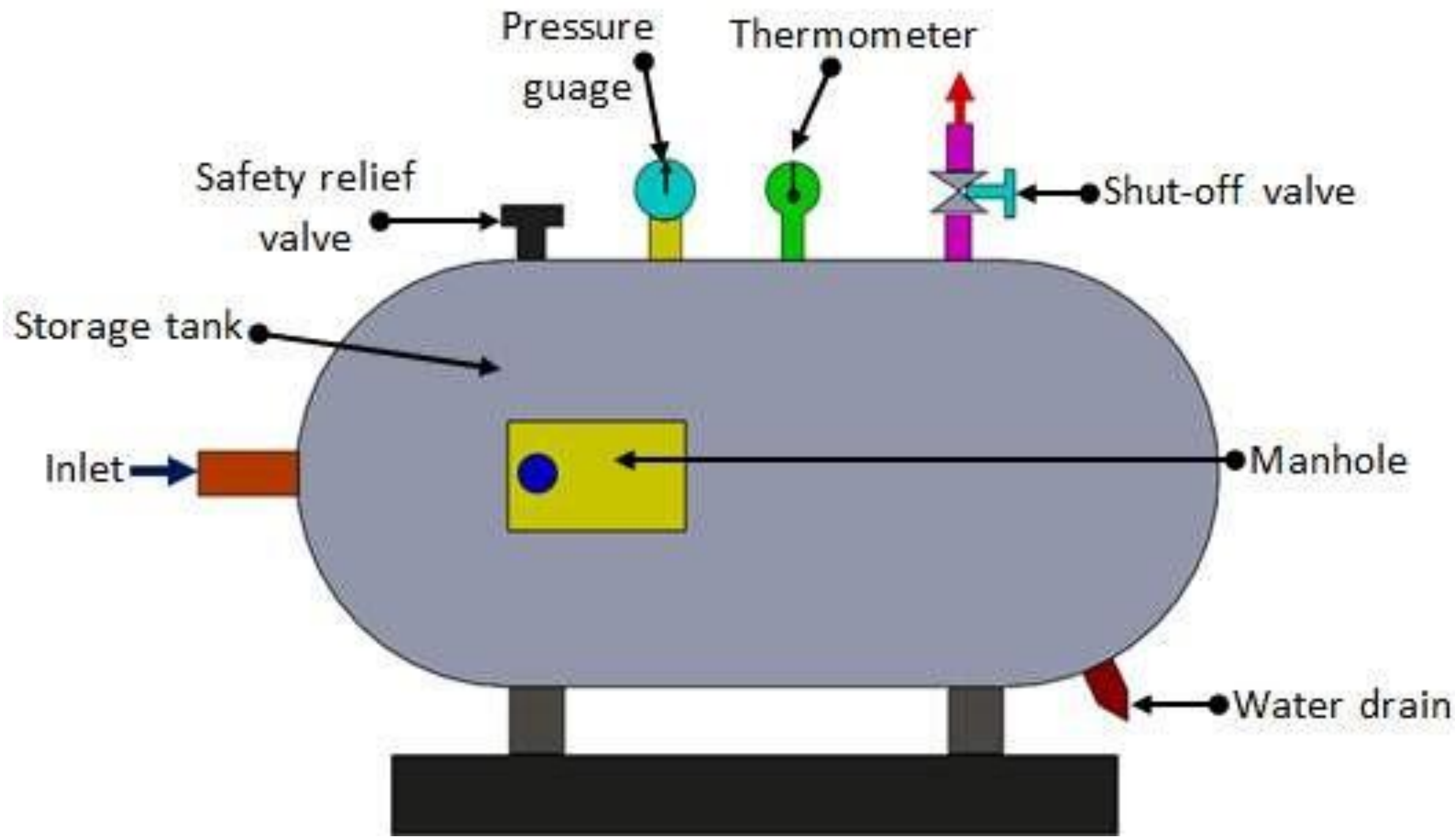


Fig 3 . Receiver tank

The air is compressed slowly in the compressor. But since the pneumatic system needs continuous supply of air, this compressed air has to be stored. The compressed air is stored in an air receiver as shown in Figure 3. It also helps the air to cool and condense the moisture present. The air receiver should be large enough to hold all the air delivered by the compressor. The pressure in the receiver is held higher than the system operating pressure to compensate pressure loss in the pipes. Also the large surface area of the receiver helps in dissipating the heat from the compressed air. Generally the size of receiver depends on,

- Delivery volume of compressor.
- Air consumption.
- Pipeline network
- Type and nature of on-off regulation
- Permissible pressure difference in the pipelines

Main pneumatic components

Pneumatic components can be divided into two categories:

1. Components that produce and transport compressed air.

2. Components that consume compressed air.

1.The production and transportation of compressed air

Examples of components that produce and transport compressed air include compressors and pressure regulating components.

(a) Compressor

It is a mechanical device which converts mechanical energy into fluid energy. The compressor increases the air pressure by reducing its volume which also increases the temperature of the compressed air. The compressor is selected based on the pressure it needs to operate and the delivery volume.

The compressor can be classified into two main types

a. Positive displacement compressors and

b. Dynamic displacement compressor

Positive displacement compressors include piston type, vane type, diaphragm type and screw type.

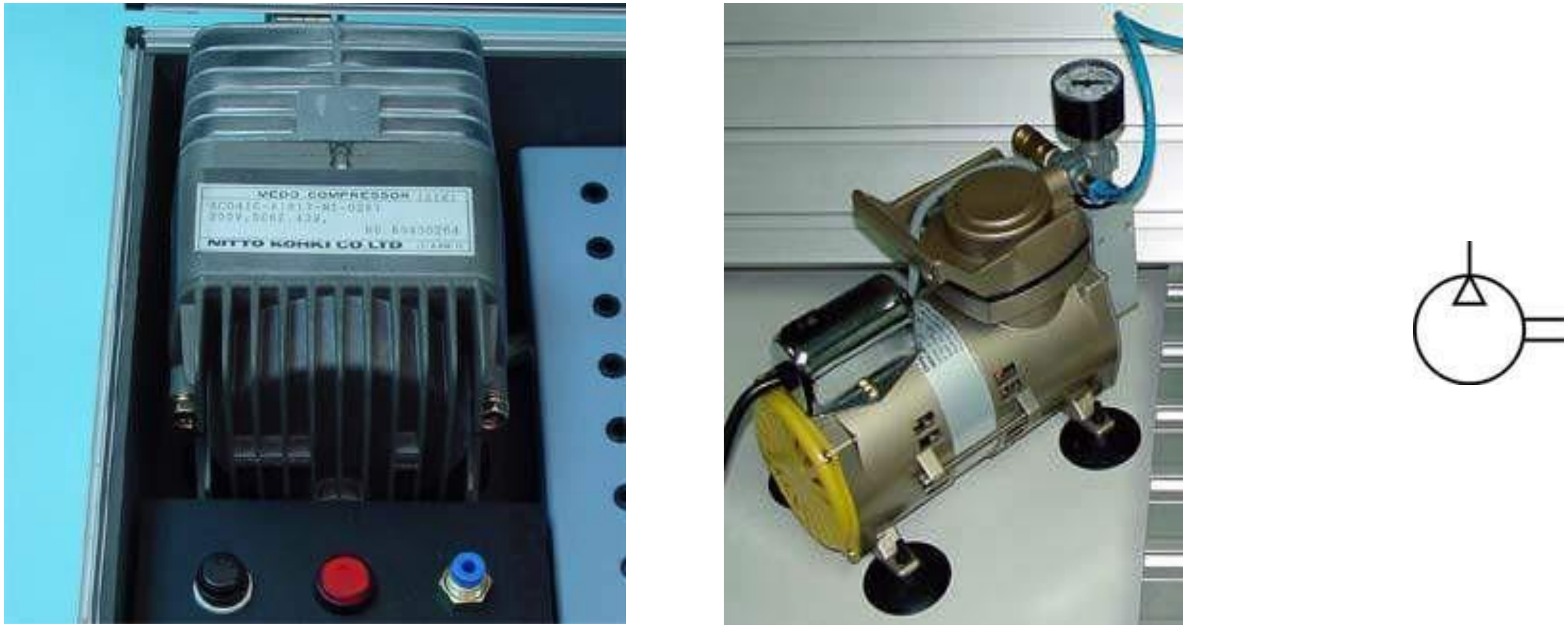


Fig 4 (a) Compressor used in schools (b) Compressor used in laboratories (c) Pneumatic symbol of compressor

Piston compressors

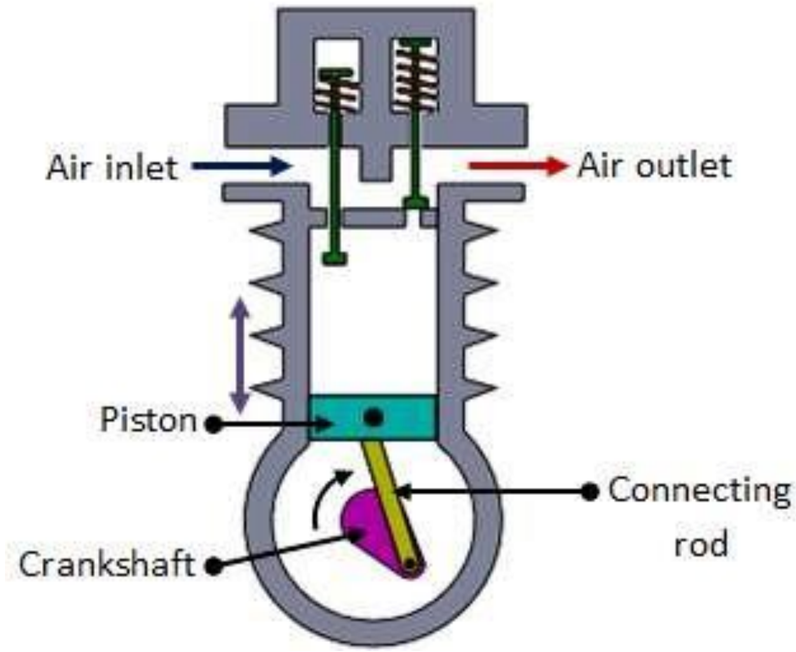


Fig 5 piston compressor

Piston compressors are commonly used in pneumatic systems. The simplest form is single cylinder compressor (Fig.5). It produces one pulse of air per piston stroke. As the piston moves down during the inlet stroke the inlet valve opens and air is drawn into the cylinder. As the piston moves up the inlet valve closes and the exhaust valve opens which allows the air to be expelled. The valves are spring loaded. The single cylinder compressor gives significant amount of pressure pulses at the outlet port. The pressure developed is about 3-40 bar.

Double acting compressor

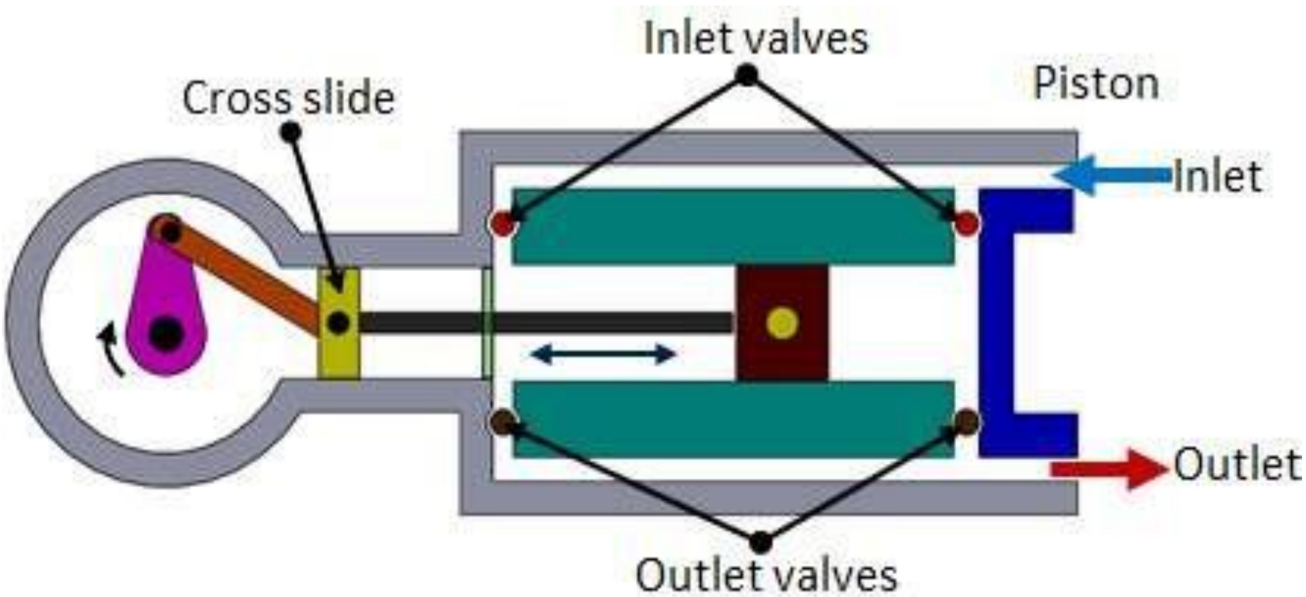


Fig 6 double acting piston compressor

The pulsation of air can be reduced by using double acting compressor as shown in Figure 6 It has two sets of valves and a crosshead. As the piston moves, the air is compressed on one side whilst on the other side of the piston, the air is sucked in. Due to the reciprocating action of the piston, the air is compressed and delivered twice in one piston stroke. Pressure higher than 30bar can be produced.

Multistage compressor

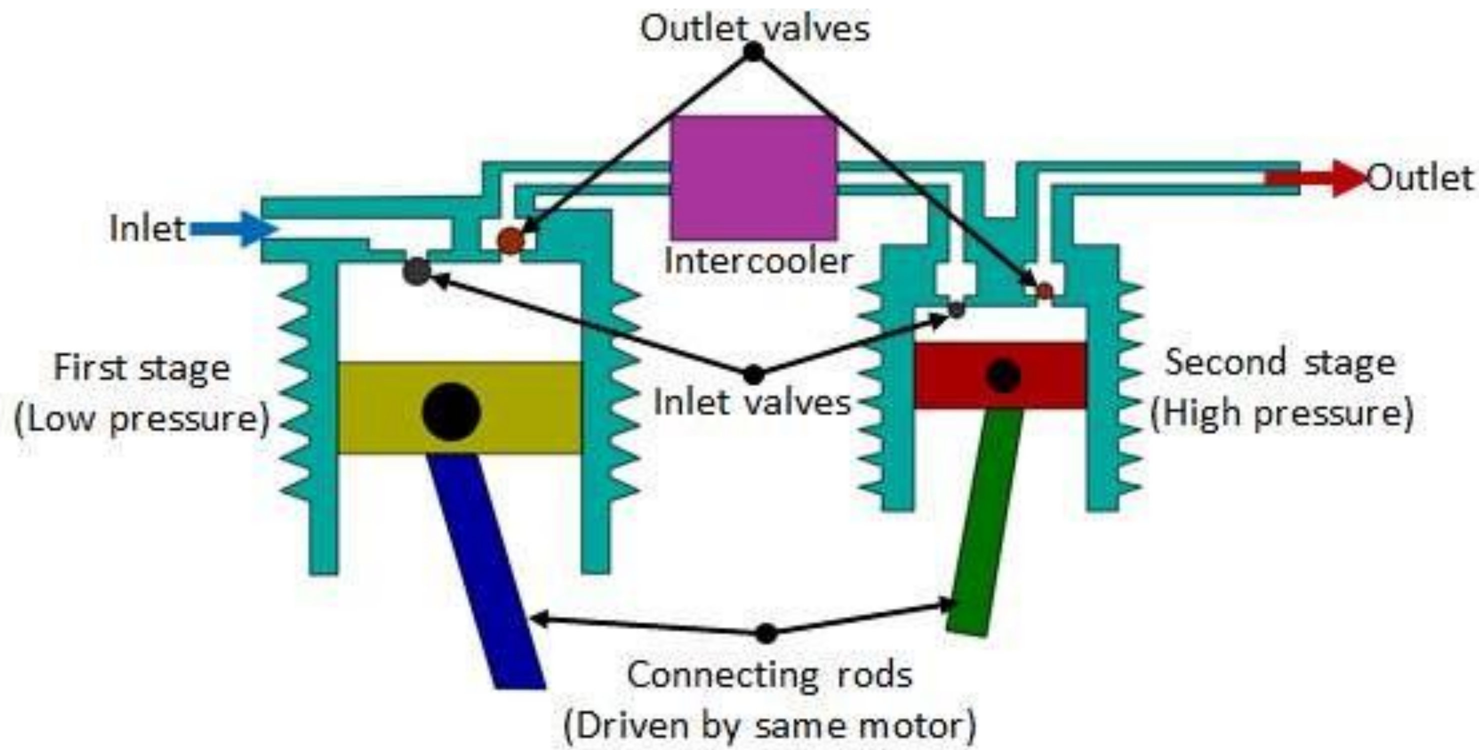


Fig 7 multistage compreressor

As the pressure of the air increases, its temperature rises. It is essential to reduce the air temperature to avoid damage of compressor and other mechanical elements. The multistage compressor with intercooler in-between is shown in Figure 7. It is used to reduce the temperature of compressed air during the compression stages. The inter-cooling reduces the volume of air which used to increase due to heat. The compressed air from the first stage enters the intercooler where it is cooled. This air is given as input to the second stage where it is compressed again. The multistage compressor can develop a pressure of around 50bar.

Rotary vane compressors

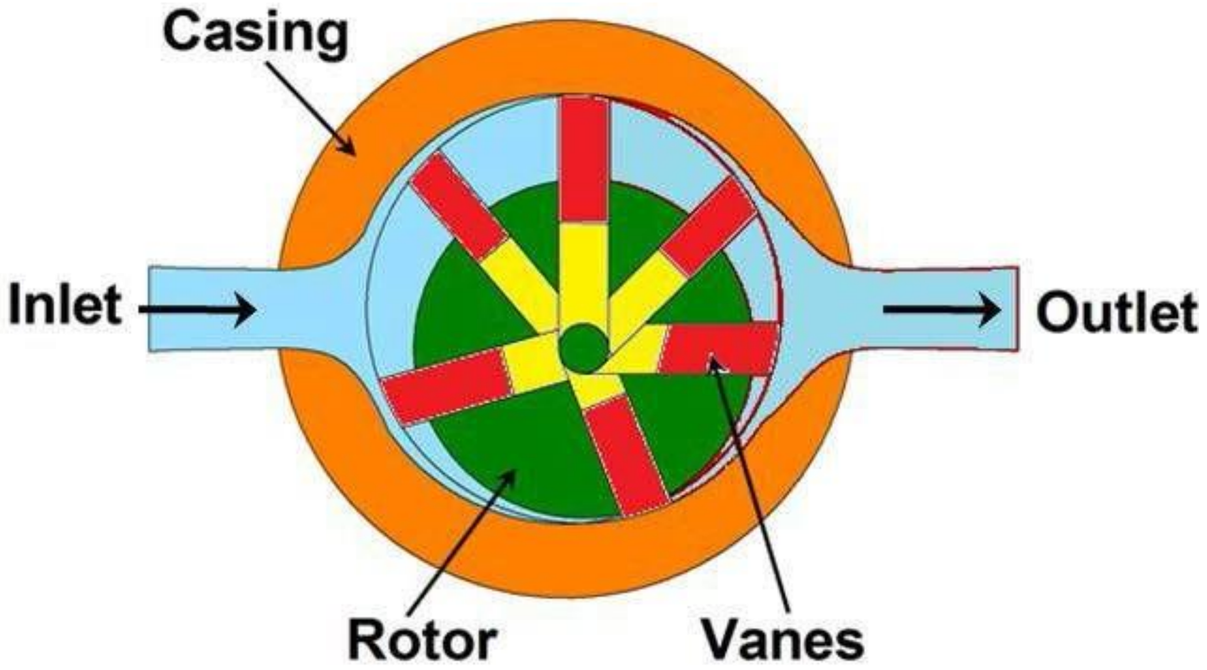


Fig 8 vane compressor

The principle of operation of vane compressor is similar to the hydraulic vane pump. Figure 8 shows the working principle of Rotary vane compressor. The unbalanced vane compressor consists of spring loaded vanes seating in the slots of the rotor. The pumping action occurs due to movement of the vanes along a cam ring. The rotor is eccentric to the cam ring. As the rotor rotates, the vanes follow the inner surface of the cam ring. The space between the vanes decreases near the outlet due to the eccentricity. This causes compression of the air. These compressors are free from pulsation. If the eccentricity is zero no flow takes place

Lobe compressor

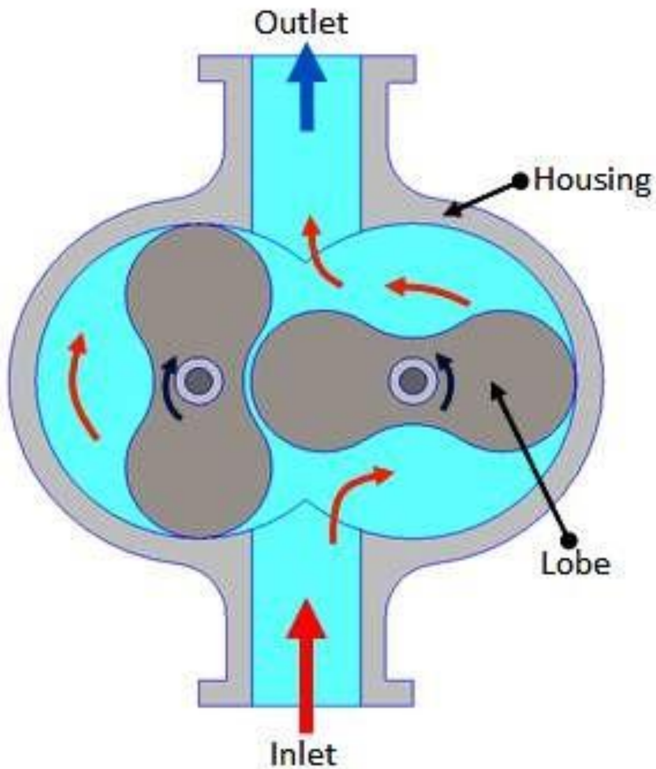
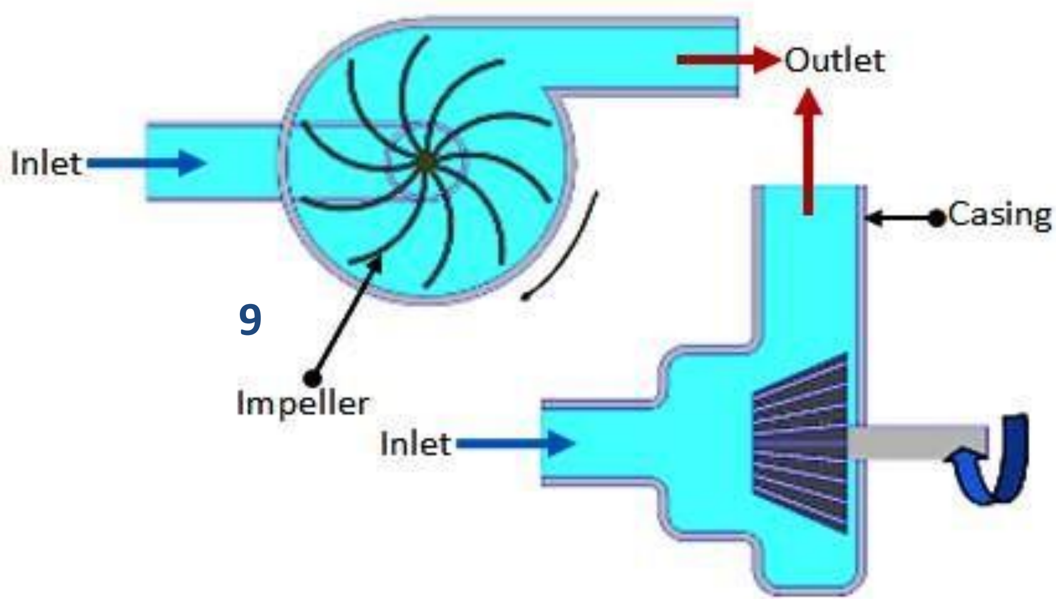


Fig 9 lobe compressor

The lobe compressor is used when high delivery volume but low pressure is needed. It consists of two lobes with one being driven and the other driving. Figure 9 shows the construction and working of Lobe compressor. It is similar to the Lobe pump used in hydraulic systems. The operating pressure is limited by leakage between rotors and housing. As the wear increases during the operation, the efficiency falls rapidly.

5. Dynamic compressors



9

Fig 10 lobe compressor

Blower (Centrifugal type)

When very large volume of compressed air is required in applications such as ventilators, combustion system and pneumatic powder blower conveyors, the dynamic compressor can be used. The pressure needed is very low in such applications. Figure 10. shows a typical Centrifugal type blower. The impeller rotates at a high speed. Large volume of low pressure air can be provided by blowers. The blowers draw the air in and the impeller flings it out due to centrifugal force.

Air Treatment

And

Pressure Regulation

1. Air treatment stages

For satisfactory operation of the pneumatic system the compressed air needs to be cleaned and dried. Atmospheric air is contaminated with dust, smoke and is humid. These particles can cause wear of the system components and presence of moisture may cause corrosion. Hence it is essential to treat the air to get rid of these impurities. The air treatment can be divided into three stages as shown in Figure .11

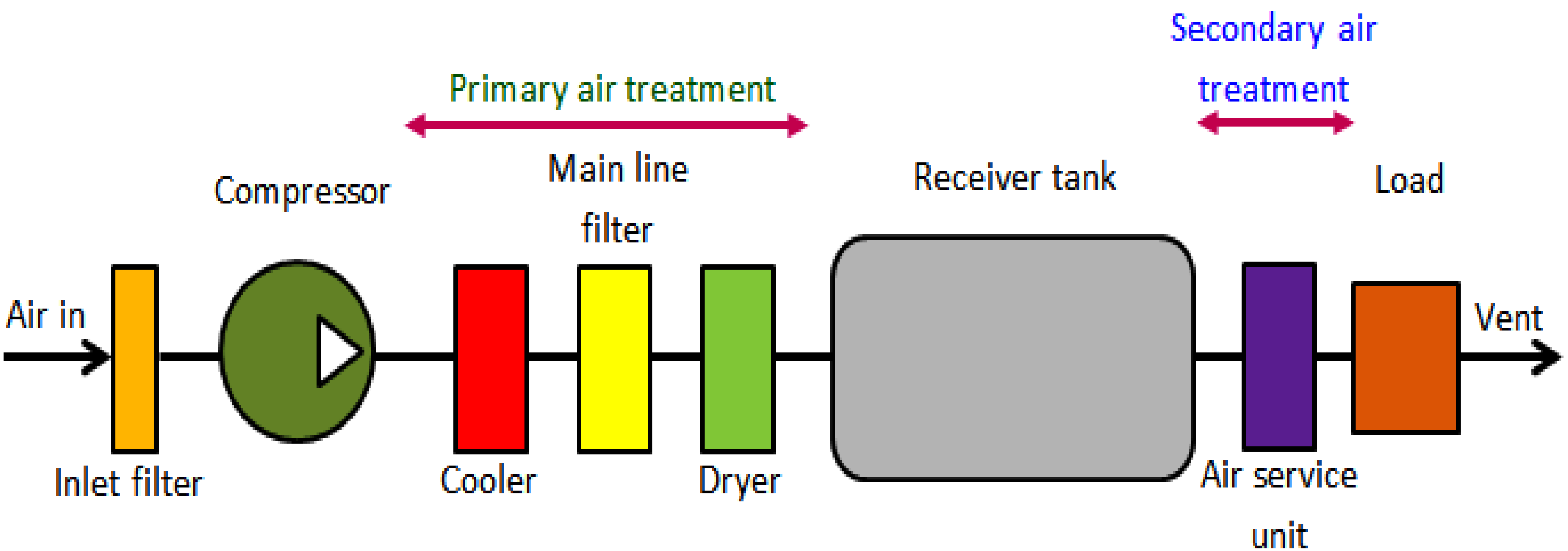


Figure .11

- **In the first stage, the large sized particles are prevented from entering the compressor by an intake filter. The air leaving the compressor may be humid and may be at high temperature.**

- **The air from the compressor is treated in the second stage. In this stage temperature of the compressed air is lowered using a cooler and the air is dried using a dryer. Also an inline filter is provided to remove any contaminant particles present. This treatment is called primary air treatment.**

- **In the third stage which is the secondary air treatment process, further filtering is carried out. A lubricator introduces a fine mist of oil into the compressed air. This will help in lubrication of the moving components of the system to which the compressed air will be applied.**

Filters

To prevent any damage to the compressor, the contaminants present in the air need to be filtered out. This is done by using inlet filters. These can be dry or wet filters. Dry filters use disposable cartridges. In the wet filter, the incoming air is passed through an oil bath and then through a fine wire mesh filter. Dirt particles cling to the oil drops during bubbling and are removed by wire mesh as they pass through it. In the dry filter the cartridges are replaced during servicing. The wet filters are cleaned using detergent solution.

Cooler

As the air is compressed, the temperature of the air increases. Therefore the air needs to be cooled. This is done by using a cooler. It is a type of heat exchanger. There are two types of coolers commonly employed viz. air cooled and water cooled. In the air cooled type, ambient air is used to cool the high temperature compressed air, whereas in the water cooled type, water is used as cooling medium. These are counter flow type coolers where the cooling medium flows in the direction opposite to the compressed air. During cooling, the water vapour present will condense which can be drained away later.

2. Main line filter

These filters are used to remove the water vapors or solid contaminants present in the pneumatic systems main lines. These filters are discussed in detail as follows.

Air filter and water trap

Air filter and water trap is used to

- **prevent any solid contaminants from entering in the system.**
- **condense and remove water vapor that is present in the compressed air.**

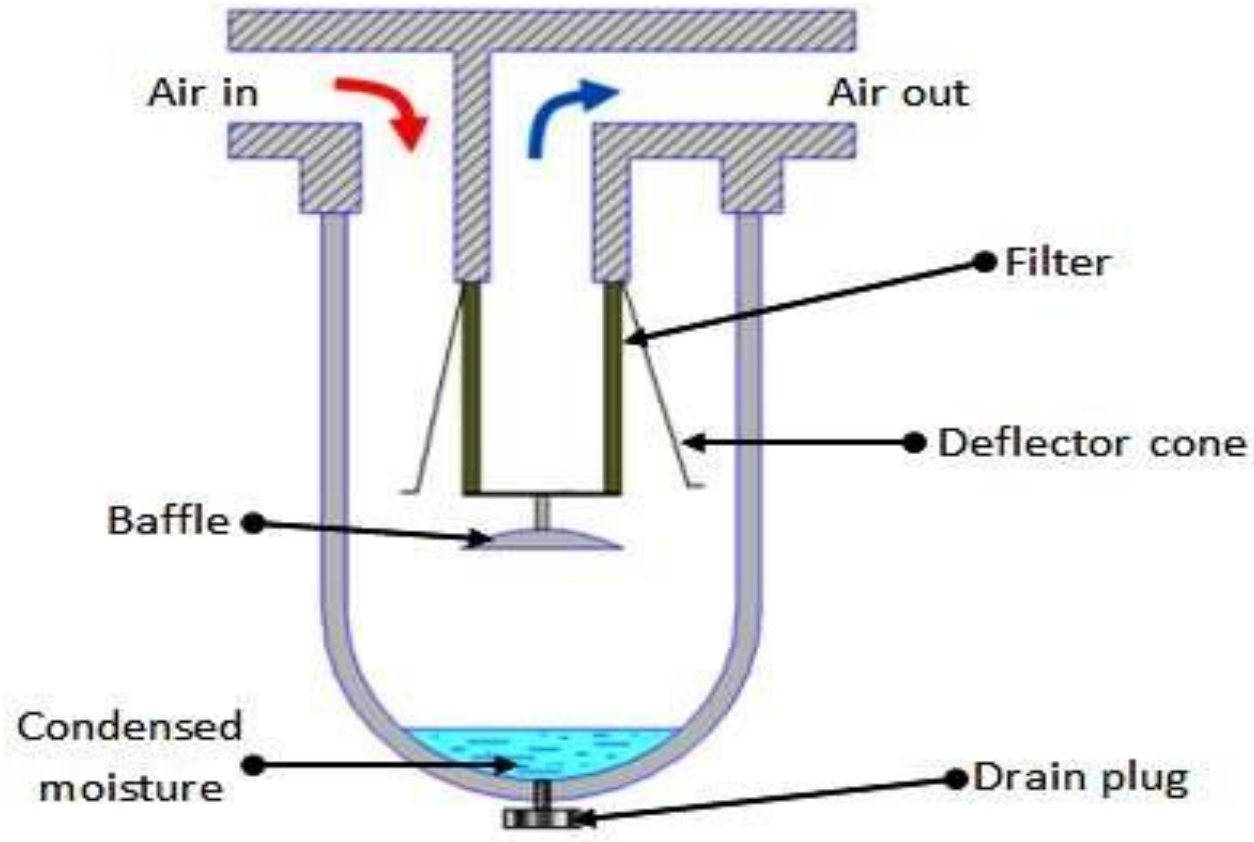


Fig 12 Air filter and water trap

The filter cartridge is made of sintered brass. The schematic of the filter is shown in Fig. 12 . The thickness of sintered cartridge provides random zigzag passage for the air to flow-in which helps in arresting the solid particles. The air entering the filter swirls around due to the deflector cone. The centrifugal action causes the large contaminants and water vapour to be flung out, which hit the glass bowl and get collected at the bottom. A baffle plate is provided to prevent the turbulent air from splashing the water into the filter cartridge. At the bottom of the filter bowl there is a drain plug which can be opened manually to drain off the settled water and solid particles.

Refrigerated dryers

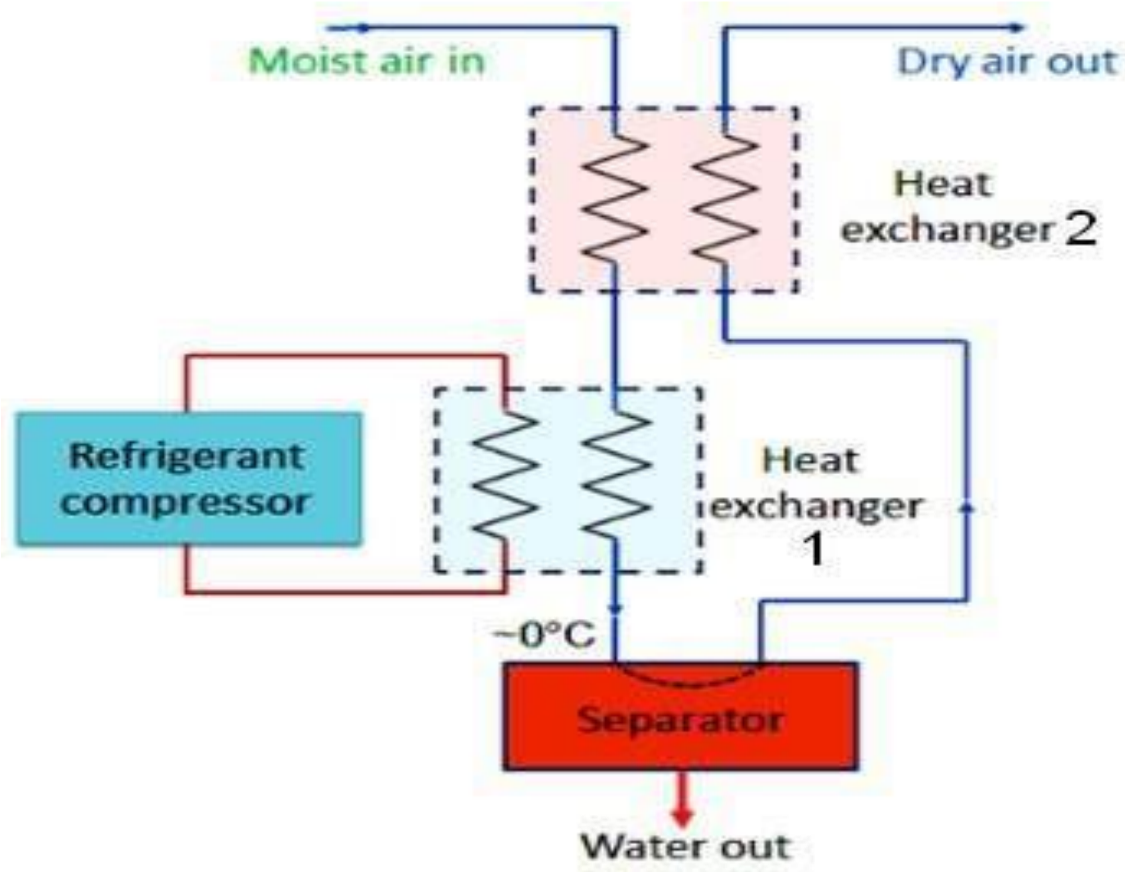


Fig 13 refrigerated dryer

It **consists of two heat exchangers, refrigerant compressor and a separator. The system circuitry is shown in Figure 12. The dryer chills the air just above 0 °C which condenses the water vapour.**

The condensate is collected by the separator. However such low temperature air may not be needed at the application. Therefore this chilled air is used to cool the high temperature air coming out from the compressor at heat exchanger 2.

The moderate temperature dry air coming out from the heat exchanger 2 is then used for actual application; whilst the reduced temperature air from compressor will further be cooled at heat exchanger 1. Thus, the efficiency of the system is increased by employing a second heat exchanger.

3.Lubricators

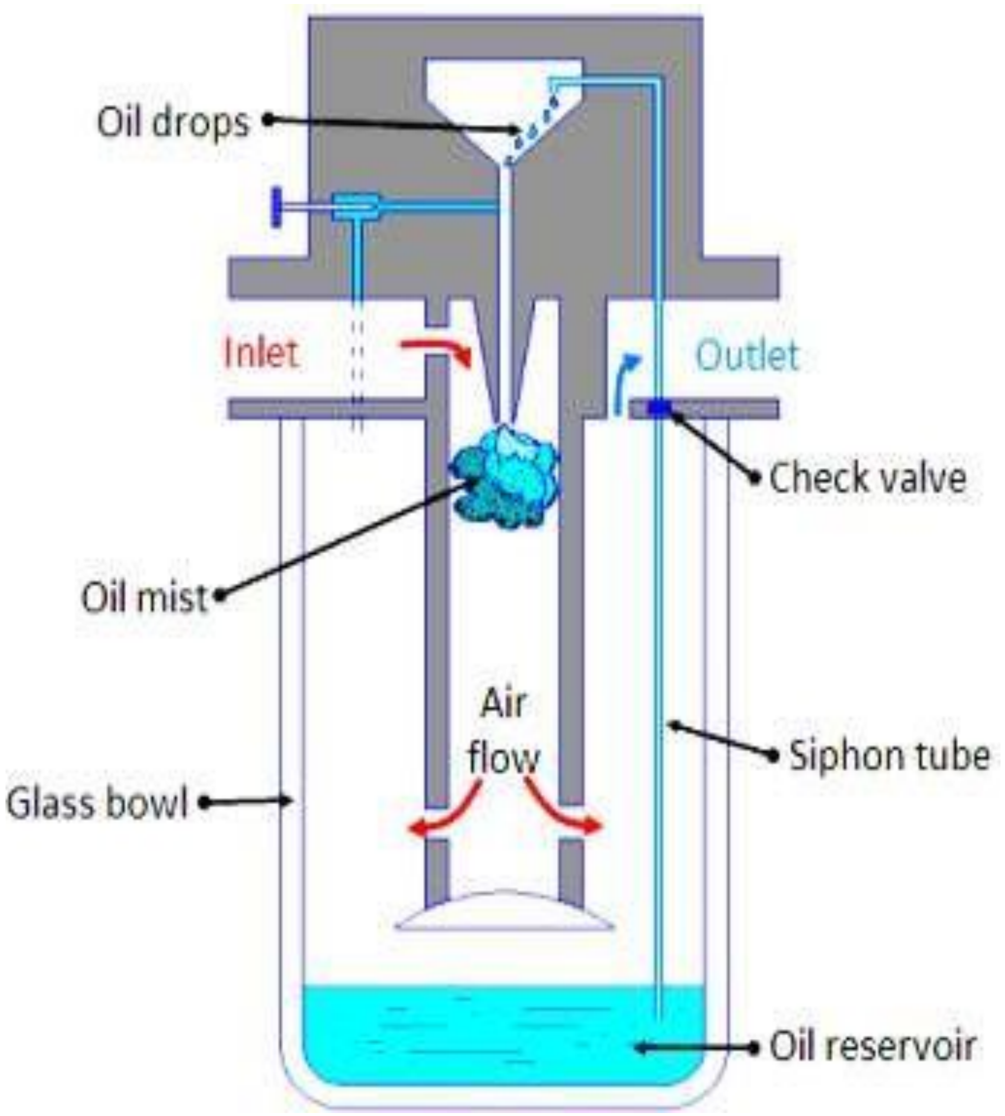


Fig 14 lubricator

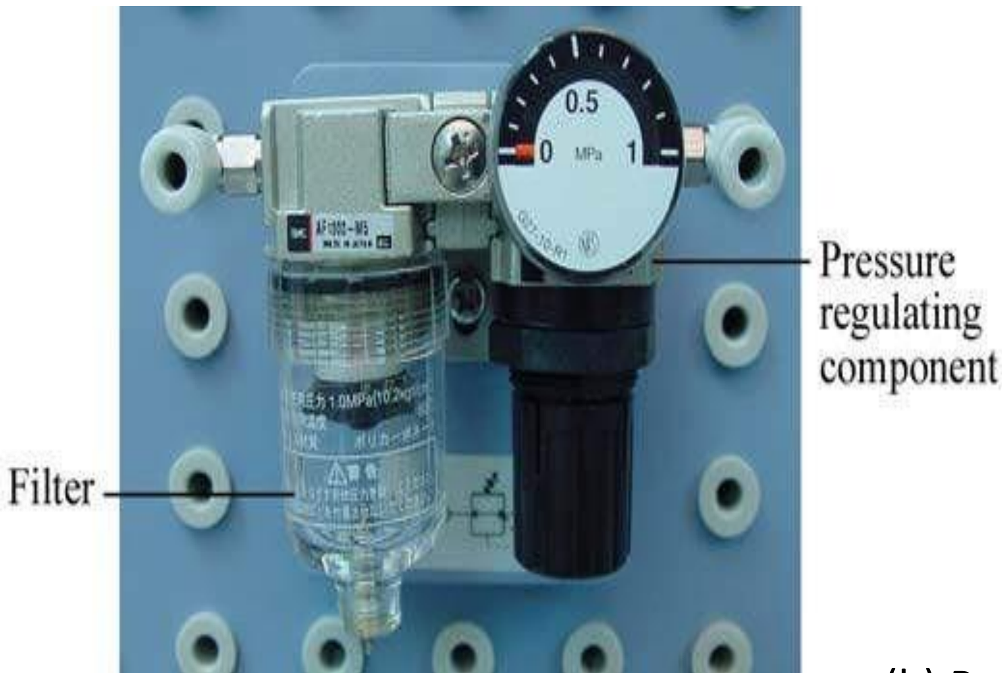
The compressed air is first filtered and then passed through a lubricator in order to form a mist of oil and air to provide lubrication to the mating components.
Figure 14 shows the schematic of a typical lubricator.

The principle of working of venturimeter is followed in the operation of lubricator. The compressed air from the dryer enters in the lubricator. Its velocity increases due to a pressure differential between the upper and lower changer (oil reservoir). Due to the low pressure in the upper chamber the oil is pushed into the upper chamber from the oil reservoir through a siphon tube with check valve.

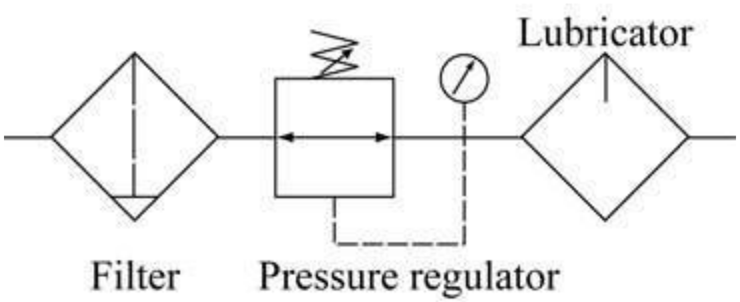
The main function of the valve is to control the amount of oil passing through it. The oil drops inside the throttled zone where the velocity of air is much higher and this high velocity air breaks the oil drops into tiny particles.

Thus a mist of air and oil is generated. The pressure differential across chambers is adjusted by a needle valve. It is difficult to hold an oil mixed air in the air receiver as oil may settle down. Thus air is lubricated during secondary air treatment process. Low viscosity oil forms better mist than high viscosity oil and hence ensures that oil is always present in the air.

4. Pressure regulation



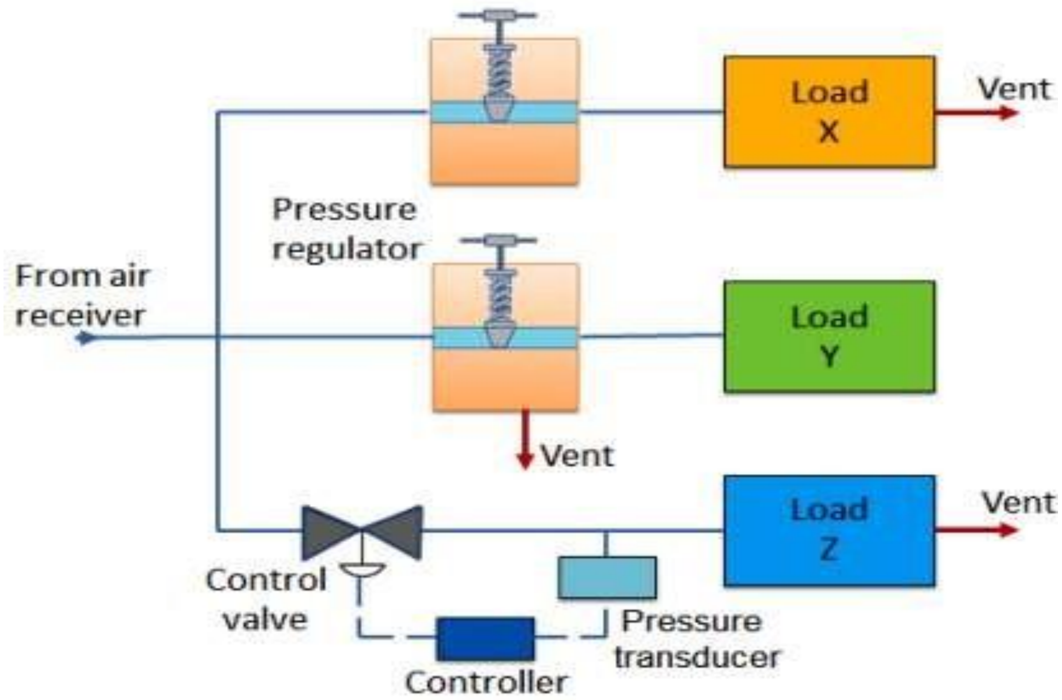
(a) Pressure regulating component



(b) Pneumatic symbols of the pneumatic components within a pressure regulating component

Pressure regulation

In pneumatic systems, during high velocity compressed air flow, there is flow-dependent pressure drop between the receiver and load (application). Therefore the pressure in the receiver is always kept higher than the system pressure. At the application site, the pressure is regulated to keep it constant. There are three ways to control the local pressure, these are shown in Figure

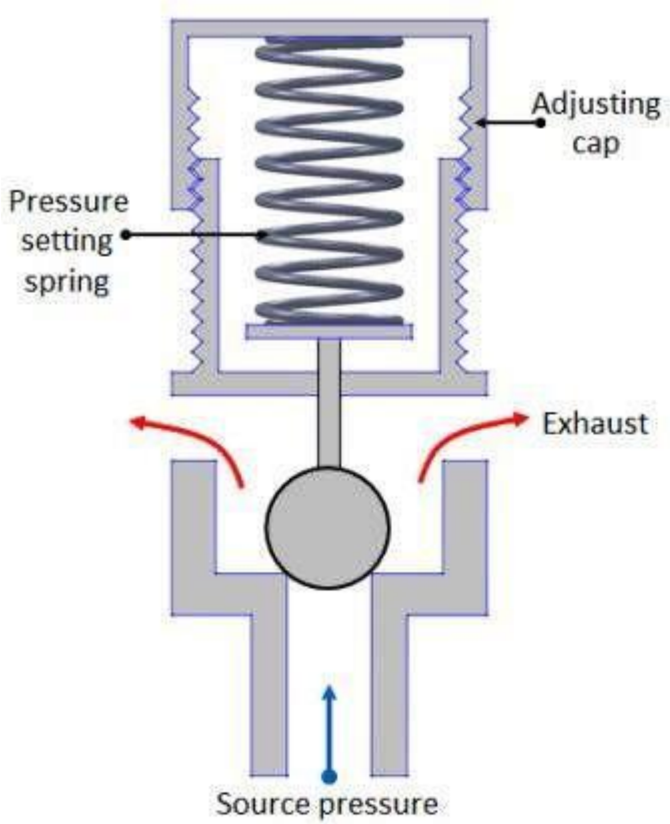


- **In the first method, load X vents the air into atmosphere continuously. The pressure regulator restricts the air flow to the load, thus controlling the air pressure. In this type of pressure regulation, some minimum flow is required to operate the regulator. If the load is a dead end type which draws no air, the pressure in the receiver will rise to the manifold pressure. These type of regulators are called as ‘non-relieving regulators’, since the air must pass through the load.**

- **• In the second type, load Y is a dead end load. However the regulator vents the air into atmosphere to reduce the pressure. This type of regulator is called as ‘relieving regulator’.**

- **• The third type of regulator has a very large load Z. Therefore its requirement of air volume is very high and can’t be fulfilled by using a simple regulator. In such cases, a control loop comprising of pressure transducer, controller and vent valve is used. Due to large load the system pressure may rise above its critical value. It is detected by a transducer. Then the signal will be processed by the controller which will direct the valve to be opened to vent out the air. This technique can be also be used when it is difficult to mount the pressure regulating valve close to the point where pressure regulation is needed.**

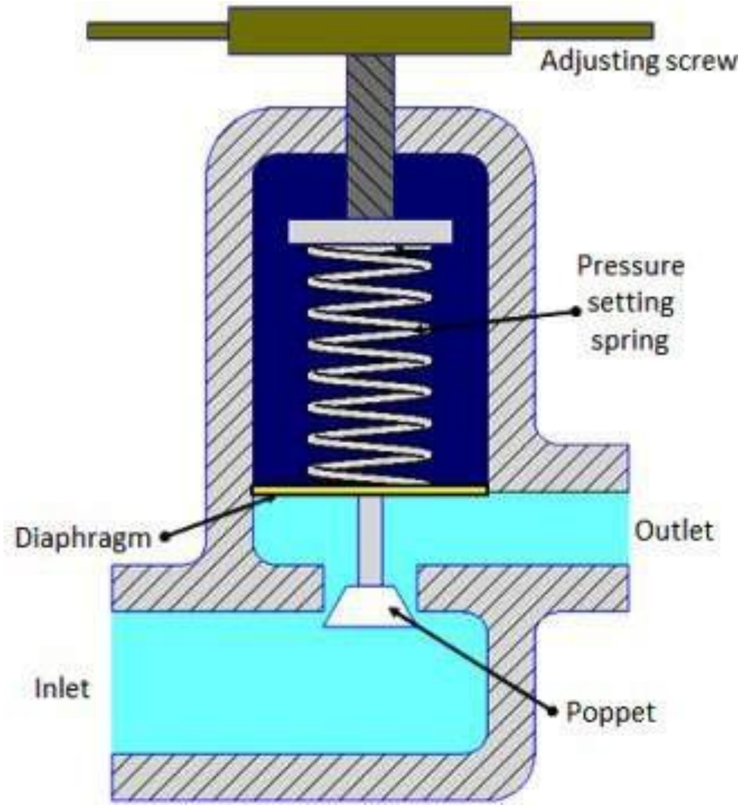
5. Relief valve



Relief valve

- **Relief valve is the simplest type of pressure regulating device. The schematic of its construction and working is shown in the Figure**
- **It is used as a backup device if the main pressure control fails. It consists of ball type valve held on to the valve seat by a spring in tension. The spring tension can be adjusted by using the adjusting cap.**
- **When the air pressure exceeds the spring tension pressure the ball is displaced from its seat, thus releasing the air and reducing the pressure.**
- **A relief is specified by its span of pressure between the cracking and full flow, pressure range and flow rate. Once the valve opens (cracking pressure), flow rate depends on the excess pressure. Once the pressure falls below the cracking pressure, the valve seals itself.**

6. Non-relieving pressure regulator

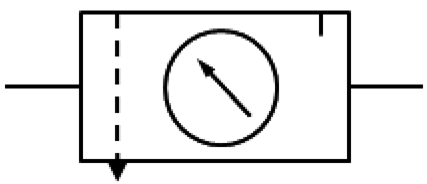


- **In a non-relieving pressure regulator the outlet pressure is sensed by a diaphragm which is preloaded by a pressure setting spring.**
- **If outlet pressure is too low, the spring forces the diaphragm and poppet to move down thus opening the valve to admit more air and raise outlet pressure.**
- **If the outlet pressure is too high the air pressure forces the diaphragm up hence reduces the air flow and causing a reduction in air pressure.**
- **The air vents away through the load. At steady state condition the valve will balance the force on the diaphragm from the outlet pressure with the present force on the spring**

7. Service units

During the preparation of compressed air, various processes such as filtration, regulation and lubrication are carried out by individual components. The individual components are: separator/filter, pressure regulator and lubricator.

Preparatory functions can be combined into one unit which is called as 'service unit'. Figure symbolic representation of various processes involved in air preparation and the service unit.



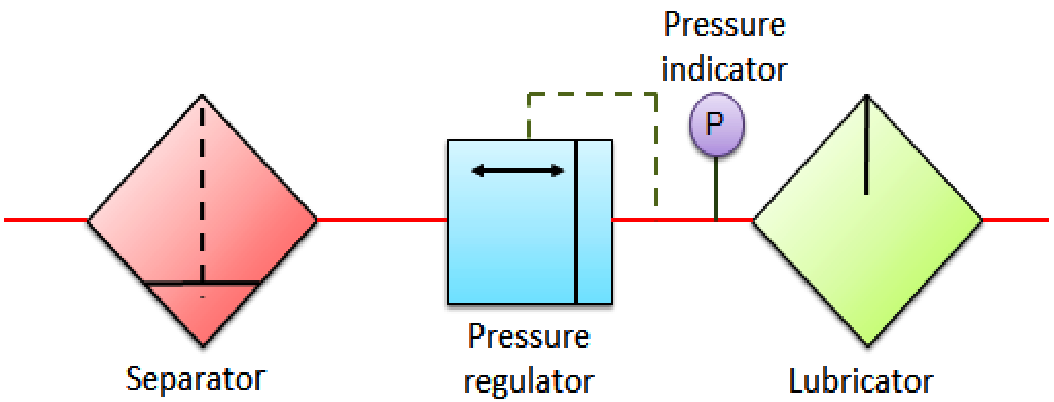


Fig. (a) Service unit components (b) Service unit symbol

Pneumatic Systems

Actuators

The consumption of compressed air

Examples of components that consume compressed air include execution components (cylinders), directional control valves and assistant valves.

(a) Execution component

Actuators

Actuators are output devices which convert energy from pressurized hydraulic oil or compressed air into the required type of action or motion. In general, hydraulic or pneumatic systems are used for gripping and/or moving operations in industry. These operations are carried out by using actuators.

Actuators can be classified into three types.

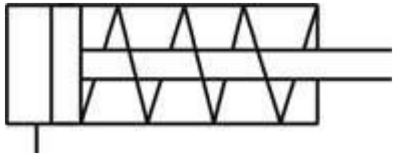
1. **Linear actuators: These devices convert hydraulic/pneumatic energy into linear motion.**
2. **Rotary actuators: These devices convert hydraulic/pneumatic energy into rotary motion.**

3. Actuators to operate flow control valves: these are used to control the flow and pressure of fluids such as gases, steam or liquid.

The construction of hydraulic and pneumatic linear actuators is similar. However they differ at their operating pressure ranges. Typical pressure of hydraulic cylinders is about 100 bar and of pneumatic system is around 10 bar.

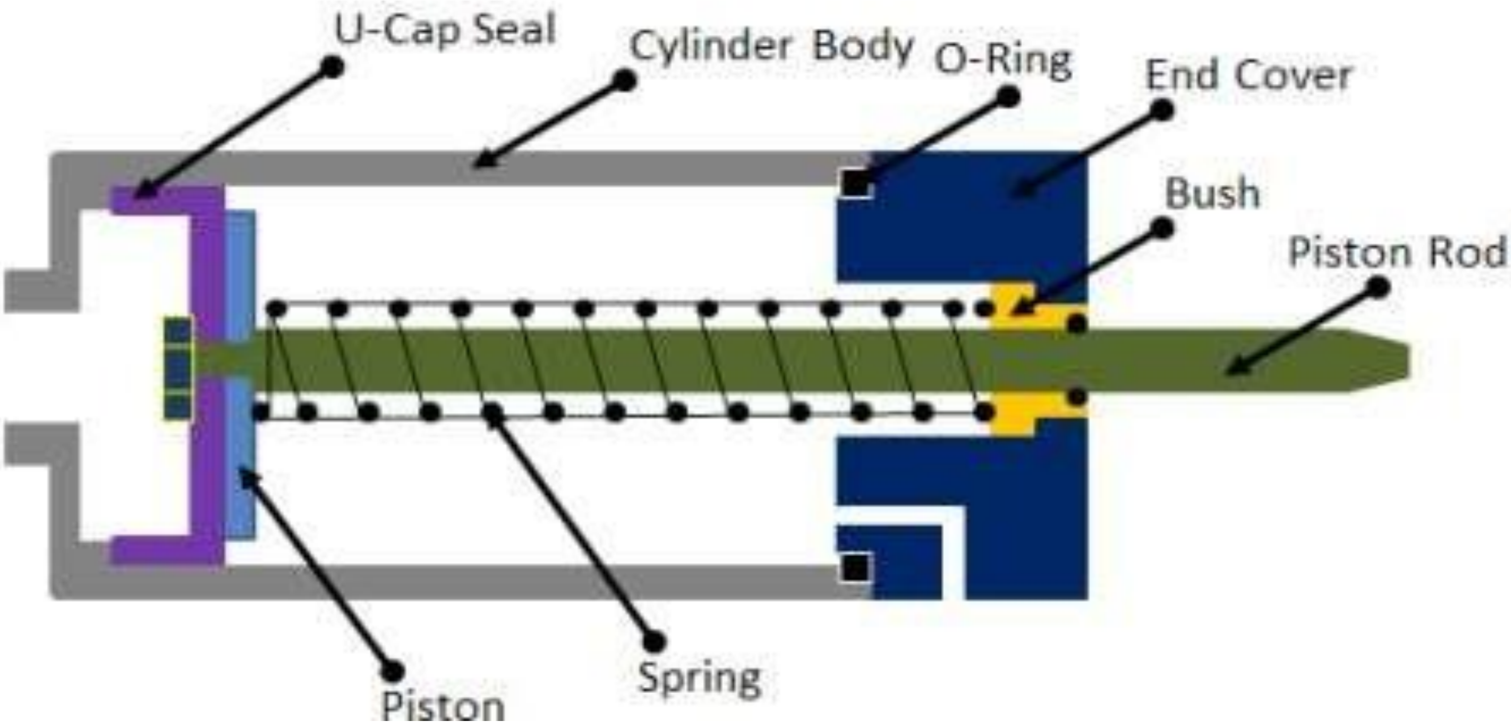
1. Single acting cylinder

(a) Single acting cylinder



(b) Pneumatic symbol of a single acting cylinder

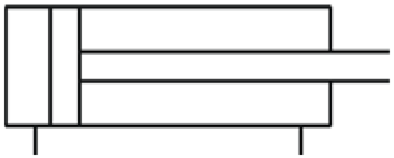
Single acting cylinder



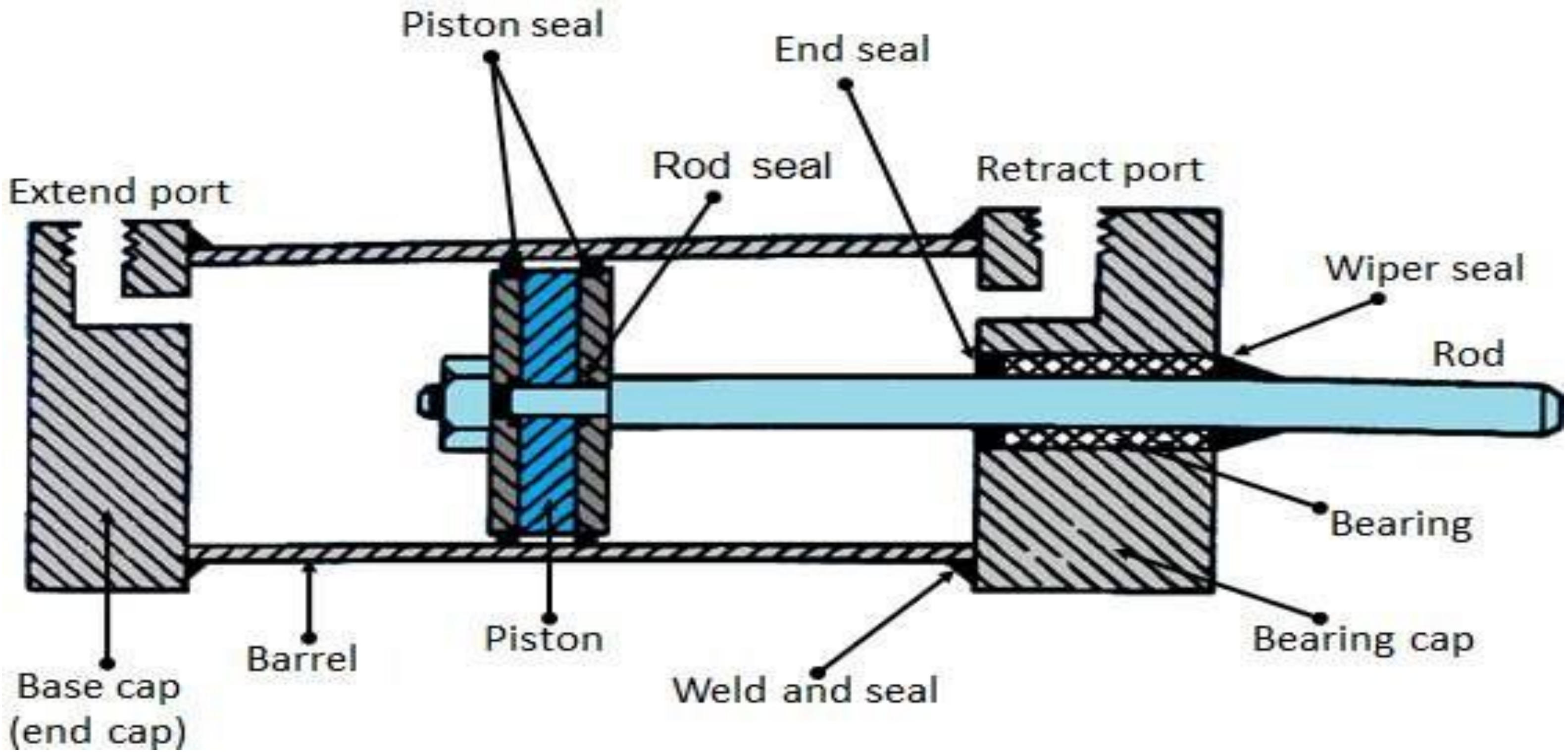
These cylinders produce work in one direction of motion hence they are named as single acting cylinders. Figure shows the construction of a single acting cylinder. The compressed air pushes the piston located in the cylindrical barrel causing the desired motion. The return stroke takes place by the action of a spring. Generally the spring is provided on the rod side of the cylinder.

2. Double acting cylinder

a) Double acting cylinder



(b) Pneumatic symbol of a double acting cylinder



Double acting cylinder

- The main parts of a hydraulic double acting cylinder are: piston, piston rod, cylinder tube, and end caps.

- These are shown in Figure The piston rod is connected to piston head and the other end extends out of the cylinder.

- The piston divides the cylinder into two chambers namely the rod end side and piston end side. The seals prevent the leakage of oil between these two chambers. The cylindrical tube is fitted with end caps. The pressurized oil, air enters the cylinder chamber through the ports provided. In the rod end cover plate, a wiper seal is provided to prevent the leakage of oil and entry of the contaminants into the cylinder.

- The combination of wiper seal, bearing and sealing ring is called as cartridge assembly. The end caps may be attached to the tube by threaded connection, welded connection or tie rod connection. The piston seal prevents metal to metal contact and wear of piston head and the tube. These seals are replaceable. End cushioning is also provided to prevent the impact with end caps.

(b) Directional control valve

Directional control valves ensure the flow of air between air ports by opening, closing and switching their internal connections.
Their classification is determined by the number of ports, the number of switching positions, the normal position of the valve and its method of operation.

Common types of directional control valves include 2/2, 3/2, 5/2, etc. The first number represents the number of ports; the second number represents the number of positions.

A directional control valve that has five ports and two positions can be represented by the drawing in Fig. 8, as well as its own unique pneumatic symbol.

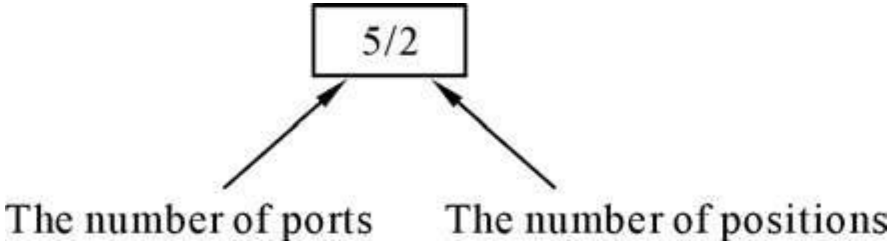
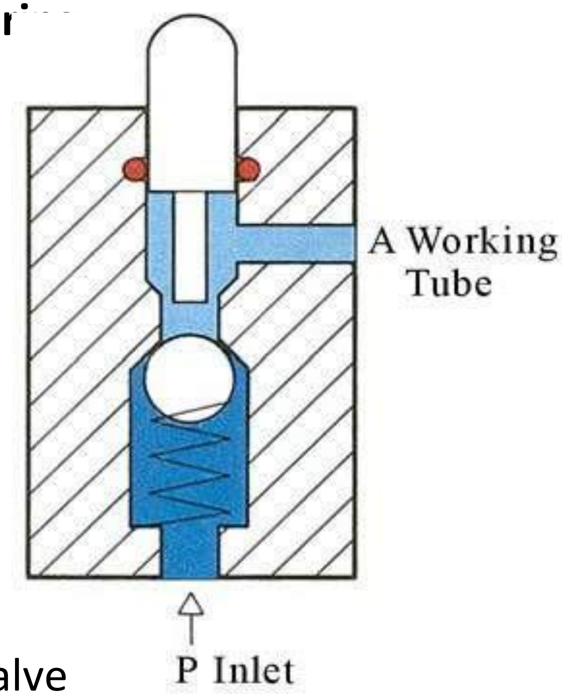


Fig. 8 Describing a 5/2 directional control valve

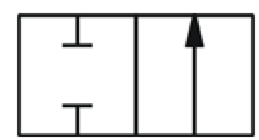
(i) 2/2 Directional control valve

The 2/2 way valves has two ports and two position (open ,closed).The structure of a 2/2 directional control valve is very simple. It uses the thrust from the spring to open and close the valve, stopping compressed air from flowing towards working tube 'A' from air inlet 'P'. When a force is applied to the control axis, the valve will be pushed open, connecting 'P' with 'A' (Fig.). The force applied to the control axis has to overcome both air pressure and the repulsive force of the spring. The control valve can be driven manually or mechanically, and restored to its original position by the spr

(a) 2/2 directional control valve



(b) Cross section



(c) Pneumatic symbol of a 2/2 directional control valve

(ii) 3/2 Directional control valve

A 3/2 directional control valve can be used to control a single acting cylinder (Fig. 10). The open valves in the middle will close until ‘P’ and ‘A’ are connected together. Then another valve will open the sealed base between ‘A’ and ‘R’ (exhaust). The valves can be driven manually, mechanically, electrically or pneumatically. 3/2 directional control valves can further be divided into two classes: Normally open type (N.O.) and normally closed type (N.C.) (Fig. 11).

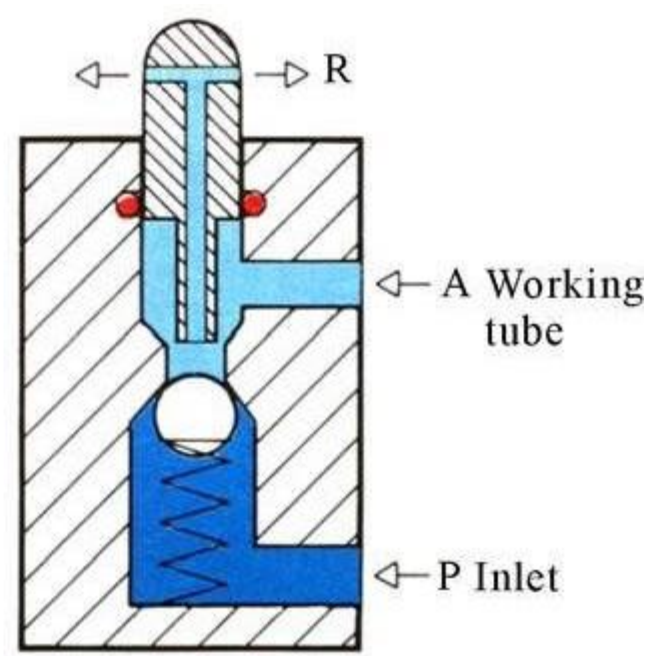


Fig. 10 (a) 3/2 directional control valve (b) Cross section

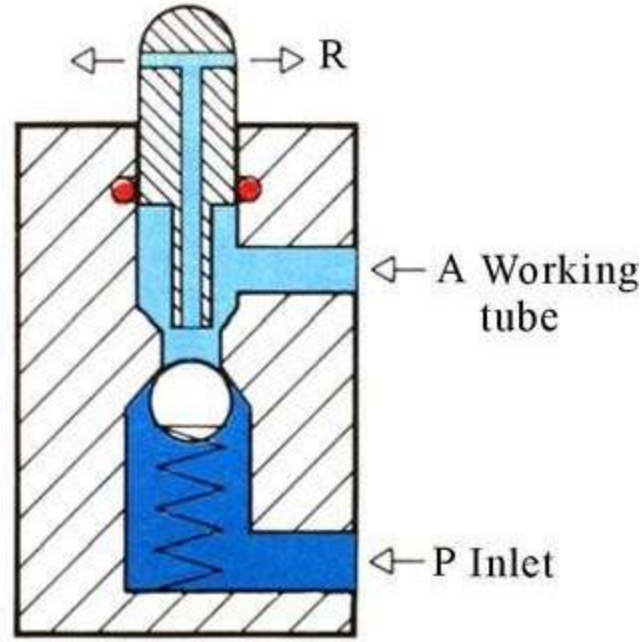
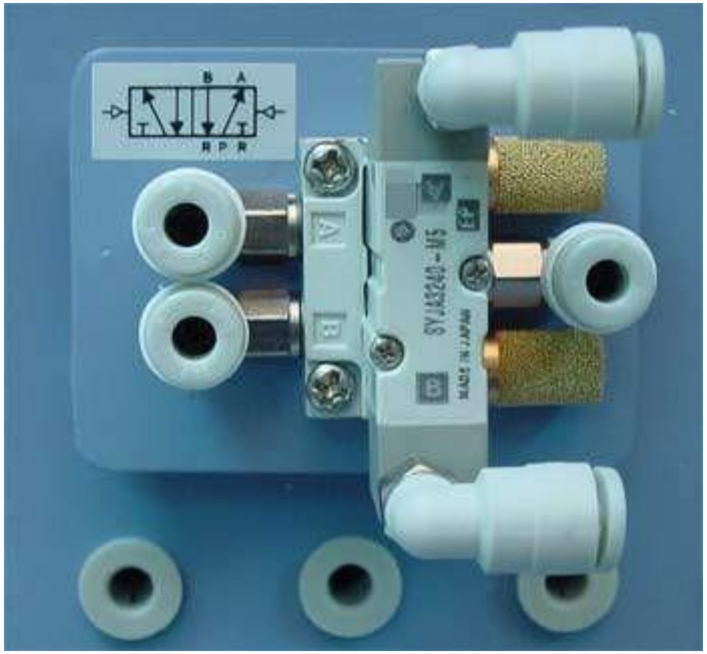
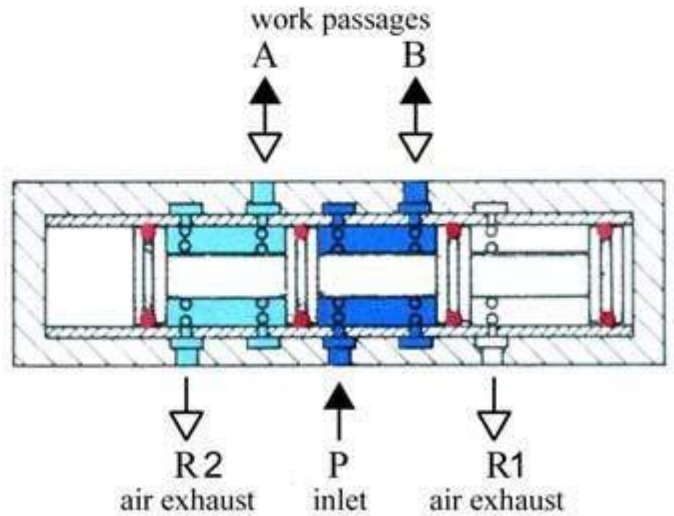


Fig. 11 Pneumatic symbols

(iii) 5/2 Directional control valve





(a) 5/2 directional control valve b) Cross section (c) Pneumatic symbol

When a pressure pulse is input into the pressure control port ‘P’, the spool will move to the left, connecting inlet ‘P’ and work passage ‘B’. Work passage ‘A’ will then make a release of air through ‘R1’ and ‘R2’. The directional valves will remain in this operational position until signals of the contrary are received. Therefore, this type of directional control valves is said to have the function of ‘memory’.

(c) Control valve

A control valve is a valve that controls the flow of air. Examples include non-return valves, flow control valves, shuttle valves, etc.

(i) Non-return valve

A non-return valve allows air to flow in one direction only. When air flows in the opposite direction, the valve will close. Another name for non-return valve is poppet valve (Fig. 13).

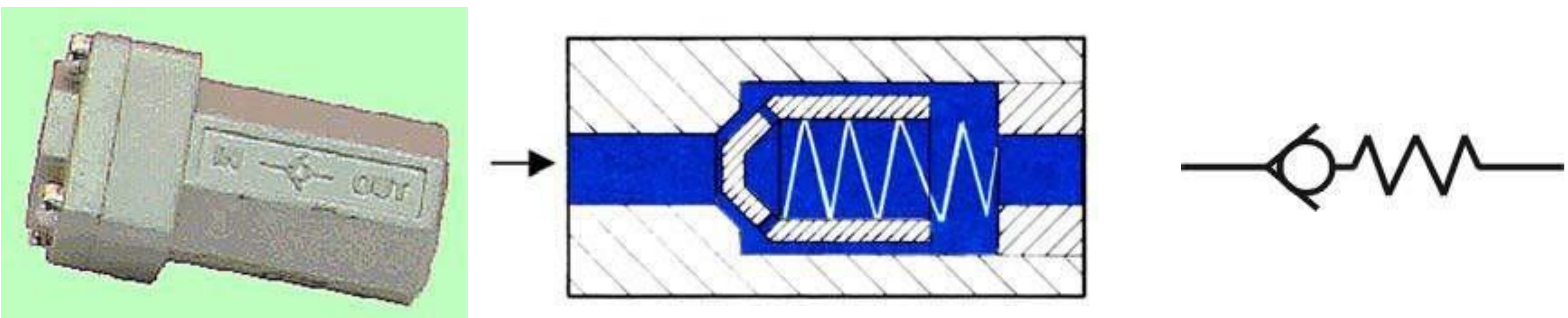


Fig. 13 (a) Non-return valve (b) Cross section (c) Pneumatic symbol

(ii) Flow control valve

A flow control valve is formed by a non-return valve and a variable throttle (Fig. 14).

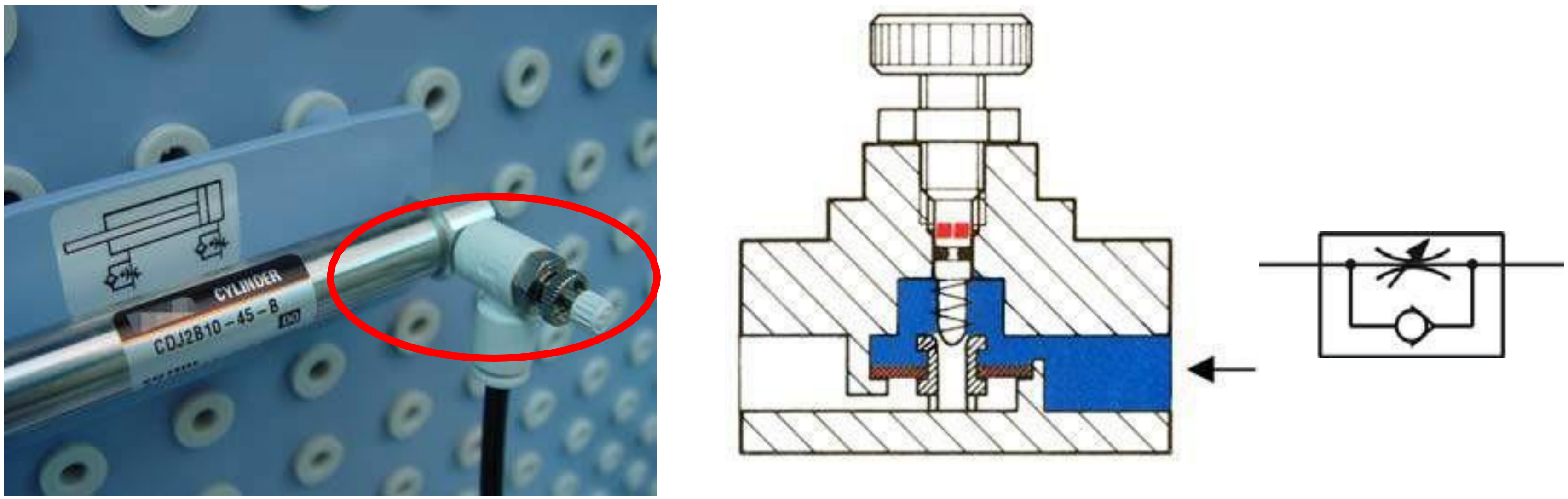


Fig. 14 (a) Flow control valve(b) Cross section (c) Pneumatic symbol

(iii) Shuttle valve

Shuttle valves are also known as double control or single control non-return valves. A shuttle valve has two air inlets ‘P1’ and ‘P2’ and one air outlet ‘A’. When compressed air enters through ‘P1’, the sphere will seal and block the other inlet ‘P2’. Air can then flow from ‘P1’ to ‘A’. When the contrary happens, the sphere will block inlet ‘P1’, allowing air to flow from ‘P2’ to ‘A’ only.

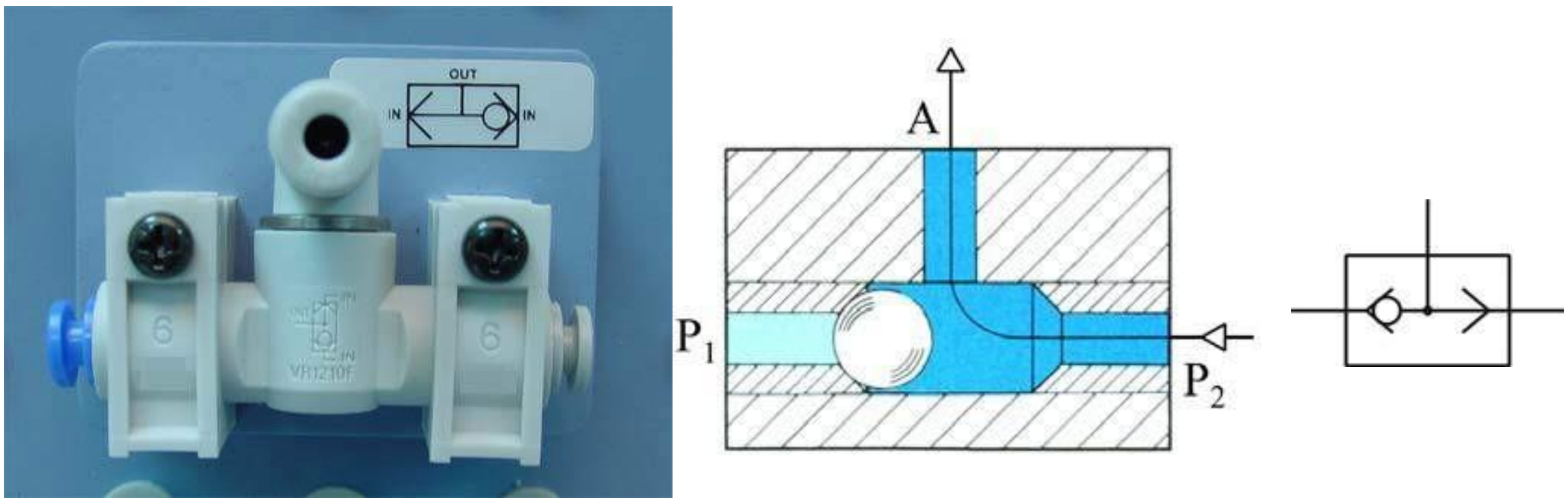
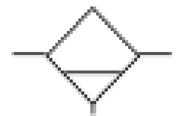


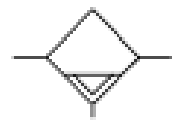
Fig. 15 (a) Shuttle valve (b) Cross section (c) Pneumatic symbol

Conditioners

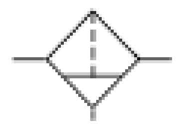
- Water separator with manual drain



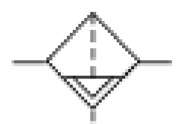
- Water separator with automatic drain



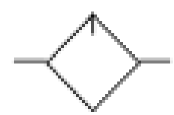
- Filter with manual drain



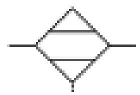
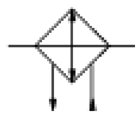
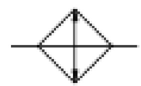
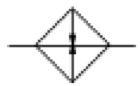
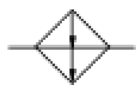
- Filter with automatic drain



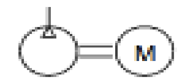
- Lubricator

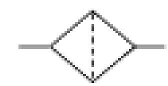


Conditioners

- Dryer 
- Cooler with and without coolant flow lines  
- Heater 
- Combined heater / cooler 

Plant

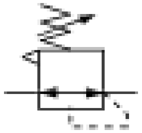
- Compressor and electric motor 

- Air receiver 
- Isolating valve 
- Air inlet filter 

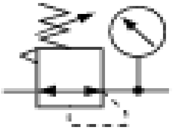
Pressure regulators

- A pressure regulator symbol represents a normal state with the spring holding the regulator valve open to connect the supply to the outlet.
- The dotted line represents the feedback, this opposes the spring and can vary the flow through the valve from full flow, through shut off, to exhaust. The symbol is usually drawn in only this one state. The flow path can be imagined to hinge at the right hand end to first shut off the supply then connect to the exhaust.

- Adjustable Regulator simplified

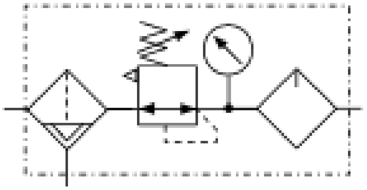


- Adjustable Regulator with pressure gauge simplified

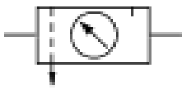


Filter Regulator Lubricator

- **FRL Combined unit**



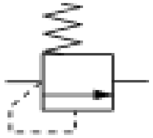
- **FRL Simplified symbol**



Pressure relief valves

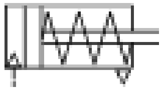
- A pressure relief valve symbol represents a normal state with the spring holding the valve closed.
- The dotted line represents feed-forward, this opposes the spring and can be imagined to lift the flow path. When the pressure reaches an excess value the flow path will line up with the ports and flow air to relief.
- Adjustable relief valve simplified

- Preset relief valve simplified

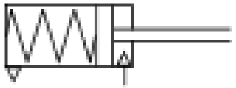


Single acting

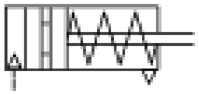
- Single acting sprung instroked



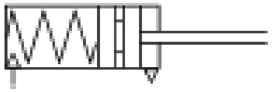
- Single acting sprung outstroked



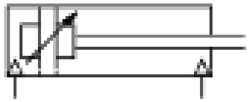
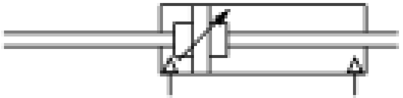
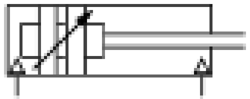
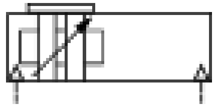
- Single acting sprung instroked magnetic *



- Single acting sprung outstroked magnetic *

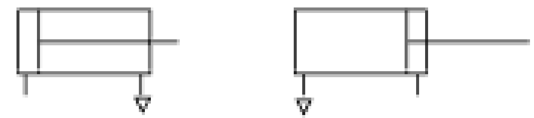


Double acting

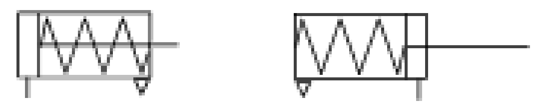
- Double acting adjustable cushions 
- Double acting through rod 
- Double acting magnetic * 
- Double acting rodless * 

Simplified cylinder symbols

- Single acting load returns

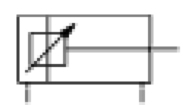


- Single acting spring returns

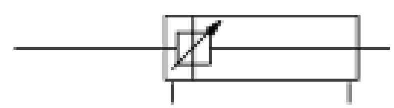


- Double acting non cushioned

- Double acting adjustable cushions



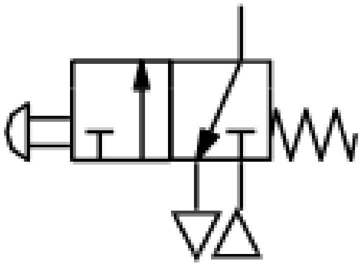
- Double acting through rod



Valve symbol structure

- **The operator for a particular state is illustrated against that state**

Operated state
produced by
pushing a button



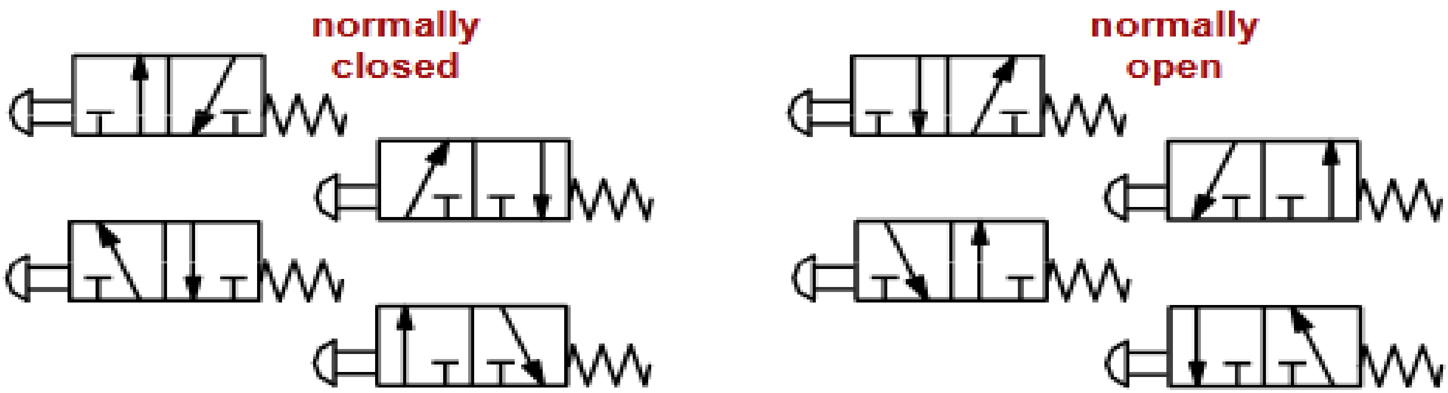
Normal state
produced by
a spring

Valve symbol structure

- A 5/2 valve symbol is constructed in a similar way. A picture of the valve flow paths for each of the two states is shown by the two boxes. The 5 ports are normally an inlet, 2 outlets and 2 exhausts

Valve symbol structure

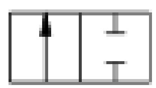
- The boxes can be joined at either end but the operator must be drawn against the state that it produces. The boxes can also be flipped
- A variety of symbol patterns are possible



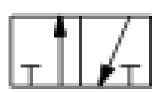
Valve functions

Basic valves before operators are added

Function 2/2

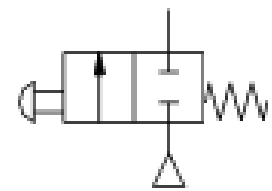


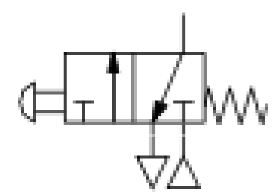
Function 3/2



Examples, push button operated with spring return

Normal position

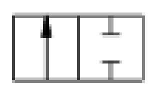




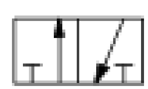
Valve functions

Basic valves before operators are added

Function 2/2

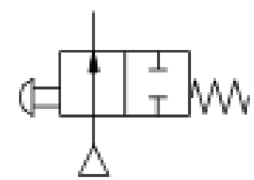


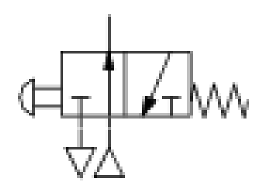
Function 3/2



Examples, push button operated with spring return

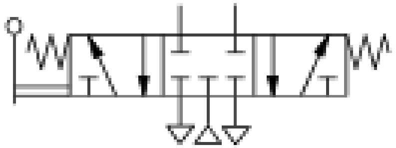
Operated position



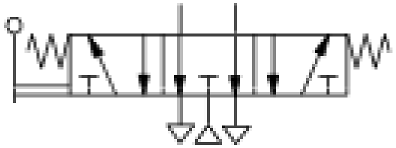


Valves 5/3

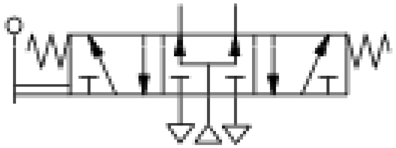
- All valves types shown in the normal position
- Type 1. All ports sealed



- Type 2. Outlets to exhaust

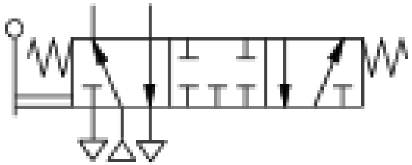


- Type 3. Supply to outlets

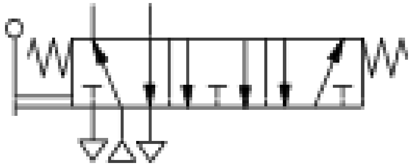


Valves 5/3

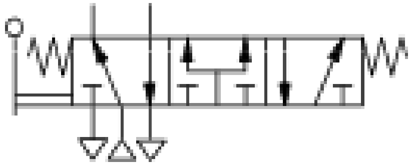
- All valves types shown in the first operated position
- Type 1. All ports sealed



- Type 2. Outlets to exhaust

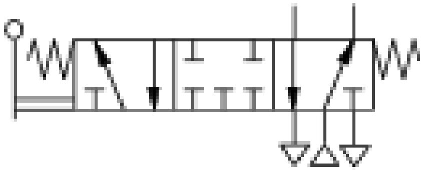


- Type 3. Supply to outlets

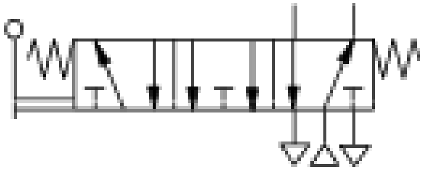


Valves 5/3

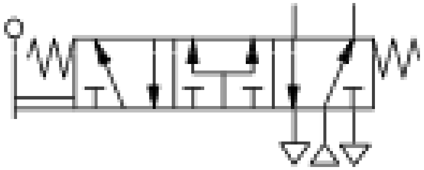
- All valves types shown in the second operated position
- Type 1. All ports sealed



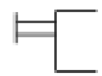
- Type 2. Outlets to exhaust

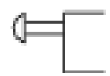


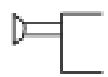
- Type 3. Supply to outlets

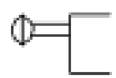


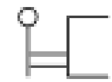
Manual

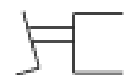
General manual 

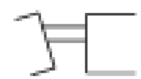
Push button 

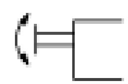
Pull button 

Push/pull button 

Lever 

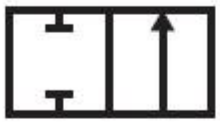
Pedal 

Treadle 

Rotary knob 

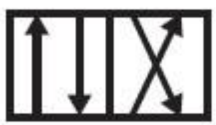
Valve Symbols, Flow Paths and Ports

2 position, 2 way, 2 ported



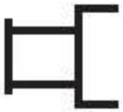
2 position, 3 way, 3 ported

2 position, 4 way, 4 ported

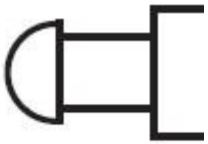


Actuator Symbols

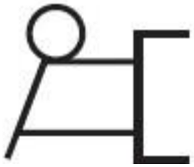
Manual



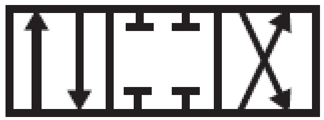
Push Button



Lever

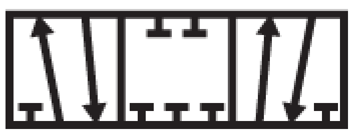


3 position, 4 way, 4 ported, Center Closed

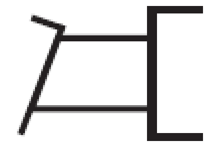


2 position, 4 way, 5 ported

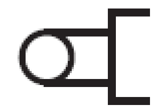
3 position, 4 way, 5 ported



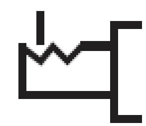
Foot Operated



Mechanical



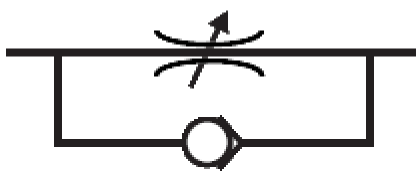
Detent



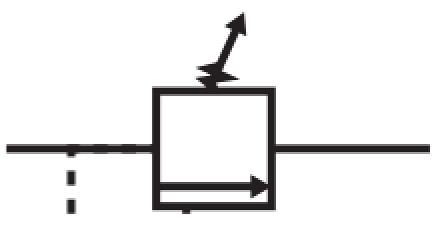
Simple Pneumatic Valves

Check Valve

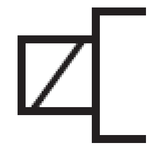
Flow Control, 1 direction



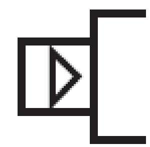
Relief Valve



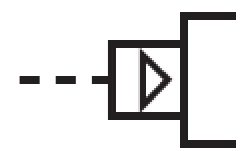
Solenoid



Internal Pilot



External Pilot

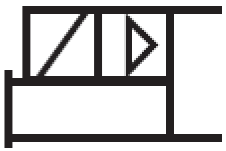


Lines

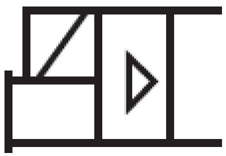
Main Line

Pilot Line

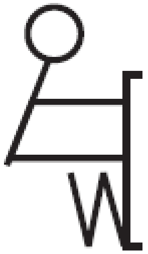
Piloted Solenoid *with* Manual Override



Piloted Solenoid *and* Manual Override

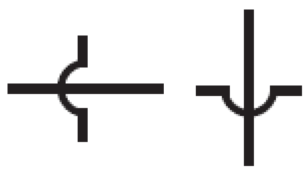


Lever with Spring

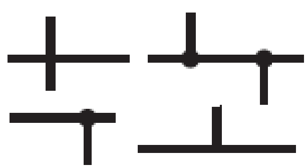


Exhaust Line
or Control Line

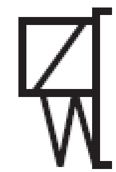
Lines Crossing



Lines
Connecting



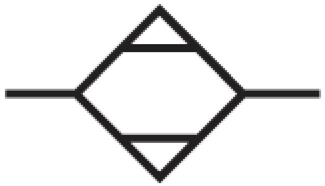
Solenoid with
Spring Return



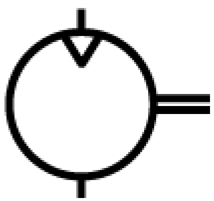
Miscellaneous

Accumulator

Air Dryer



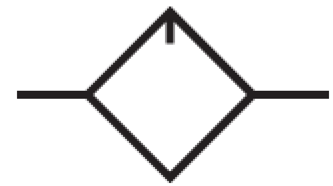
Air Motor (One Direction Flow)



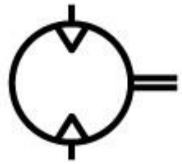
Differential Pressure

Direction of Flow

Lubricator

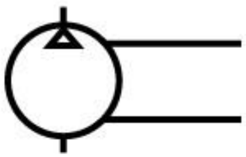


Air Motor (Two Direction Flow)



Check Valve (Spring Loaded)

Compressor



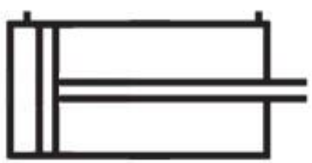
Filter

Filter (Automatic Drain)

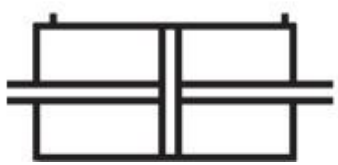
Filter (Manual Drain)

Cylinder (Spring Return)

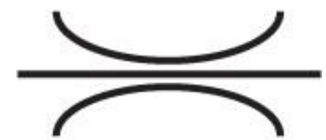
Cylinder Double Acting



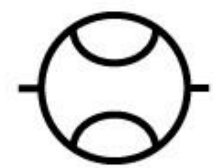
Cylinder Double Acting (Double Rod)



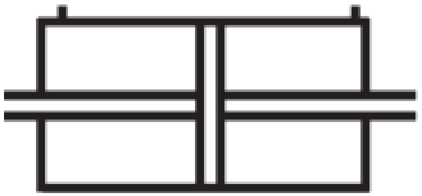
Fixed Restriction



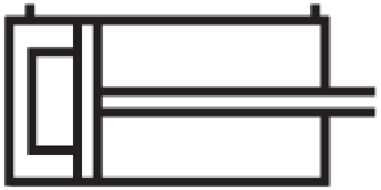
Flow Meter



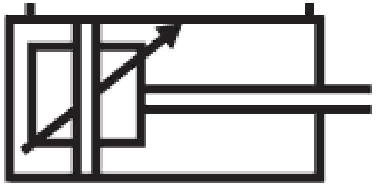
Cylinder
Double Acting
(Double Rod)



Cylinder
Double Acting
(Single Fixed
Cushion)



Cylinder
Double Acting
(Two
Adjustable
Cushions)



4 Principles of pneumatic control

(a) Pneumatic circuit

Pneumatic control systems can be designed in the form of pneumatic circuits. A pneumatic circuit is formed by various pneumatic components, such as cylinders, directional control valves, flow control valves, etc. Pneumatic circuits have the following functions:

1. To control the injection and release of compressed air in the cylinders.

2. To use one valve to control another valve.

(b) Pneumatic circuit diagram

A pneumatic circuit diagram uses pneumatic symbols to describe its design. Some basic rules must be followed when drawing pneumatic diagrams

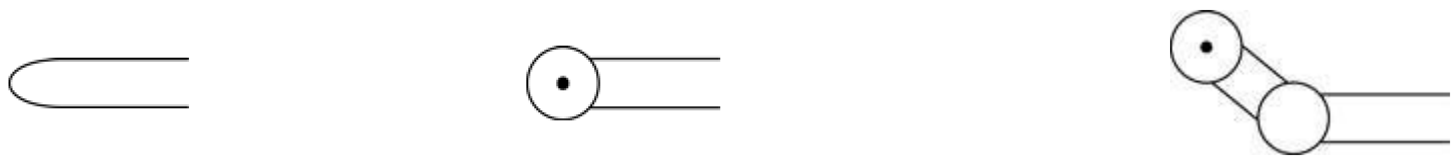
(i) Basic rules

1. A pneumatic circuit diagram represents the circuit in static form and assumes there is no supply of pressure. The placement of the pneumatic components on the circuit also follows this assumption.
2. The pneumatic symbol of a directional control valve is formed by one or more squares. The inlet and exhaust are drawn underneath the square, while the outlet is drawn on the top. Each function of the valve (the position of the valve) shall be represented by a square. If there are two or more functions, the squares should be arranged horizontally (Fig. 16).

Fig 17 3/2 directional control valve (normally closed type)

3. Arrows "↓↖" are used to indicate the flow direction of air current. If the external port is not connected to the internal parts, the symbol "⊤ " is used. The symbol "⊙" underneath the square represents the air input, while the symbol "∇" represents the exhaust. Fig. 17 shows an example of a typical pneumatic valve.

The pneumatic symbols of operational components should be drawn on the outside of the squares. They can be divided into two classes: mechanical and manual (Fig. 18 and 19).



(a) Vertical piston lever (b) Pulley lever (c) Unilateral pulley lever

Fig. 18 Mechanically operated pneumatic components

(a) Standard (b) Lever (c) Button (d) Pull & push

Fig. 19 Manually operated pneumatic components

5. Pneumatic operation signal pressure lines should be drawn on one side of the squares, while triangles are used to represent the direction of air flow (Fig. 20).

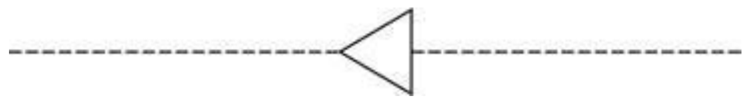
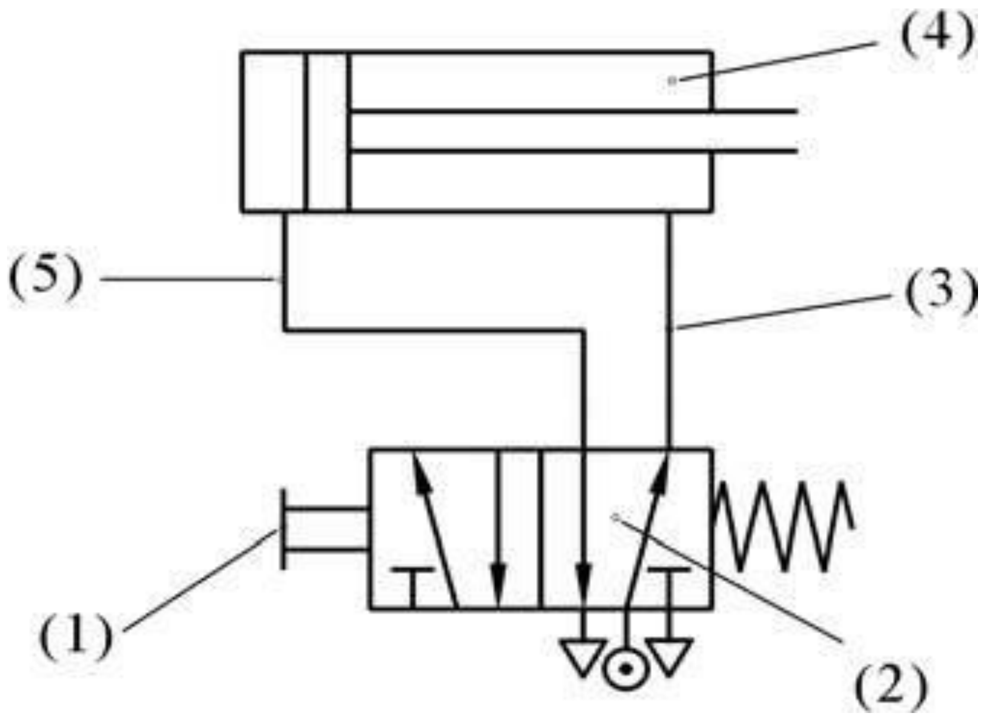


Fig. 20 Pneumatic operation signal pressure line

(ii) Basic principles

Fig. 21 shows some of the basic principles of drawing pneumatic circuit diagrams, the numbers in the diagram correspond to the following points:



**1. When the manual switch is not operated, the spring will restore the valve to its original
position.**

2. From the position of the spring, one can deduce that the block is operating. The other block will not operate until the switch is pushed.

3. Air pressure exists along this line because it is connected to the source of compressed air.

4. As this cylinder cavity and piston rod are under the influence of pressure, the piston rod is in its restored position.

5. The rear cylinder cavity and this line are connected to the exhaust, where air is release

(iii) The setting of circuit diagrams

When drawing a complete circuit diagram, one should place the pneumatic components on different levels and positions, so the relations between the components can be expressed clearly. This is called the setting of circuit diagrams.
A circuit diagram is usually divided into three levels:
power level, logic level and signal input level (Fig. 22).

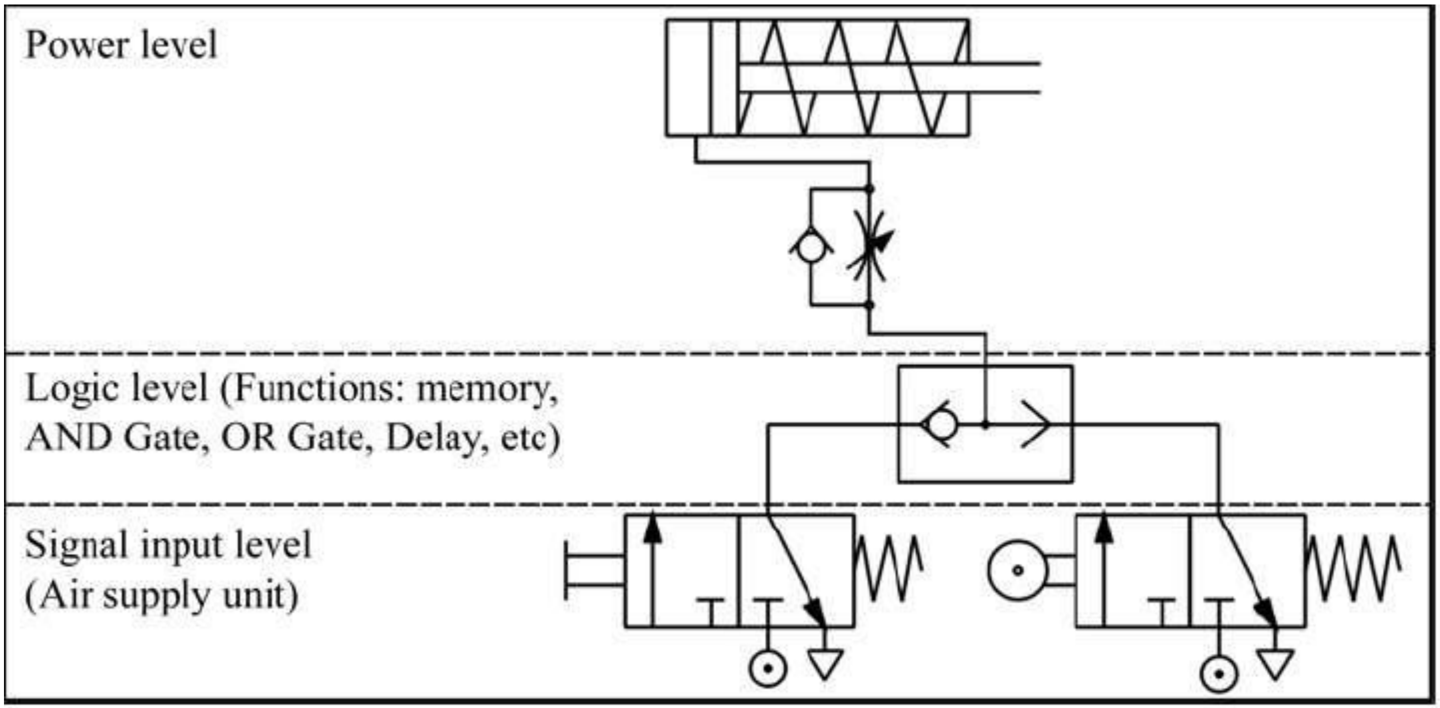
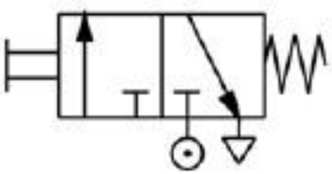


Fig. 22 Power level, logic level and signal input level

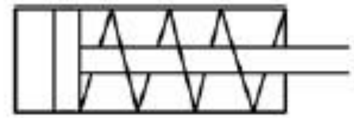
The basic rules of circuit diagram setting are as follows:

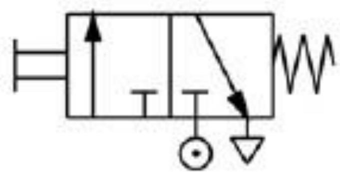
1.



In a pneumatic circuit, the flow of energy is from the bottom to the top. Therefore, the air supply unit should be put at the bottom left corner.

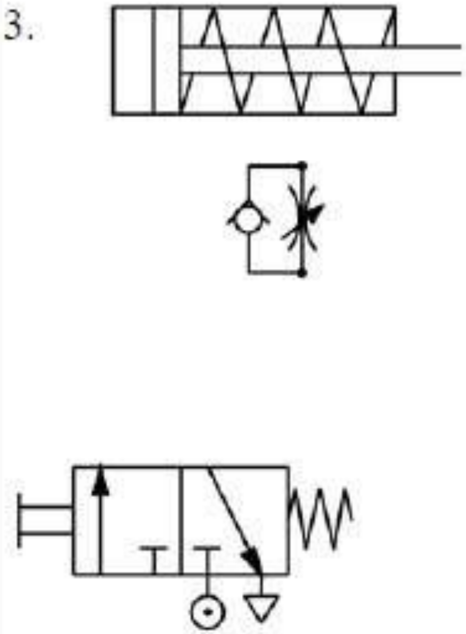
2.





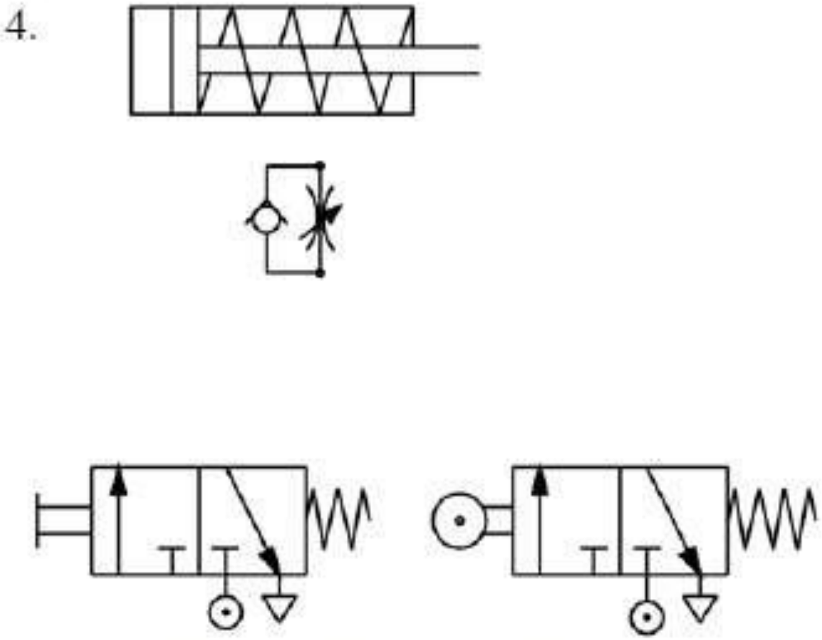
The work cycle should be drawn from left to right. The first operating cylinder should be placed at the upper left corner.

3.



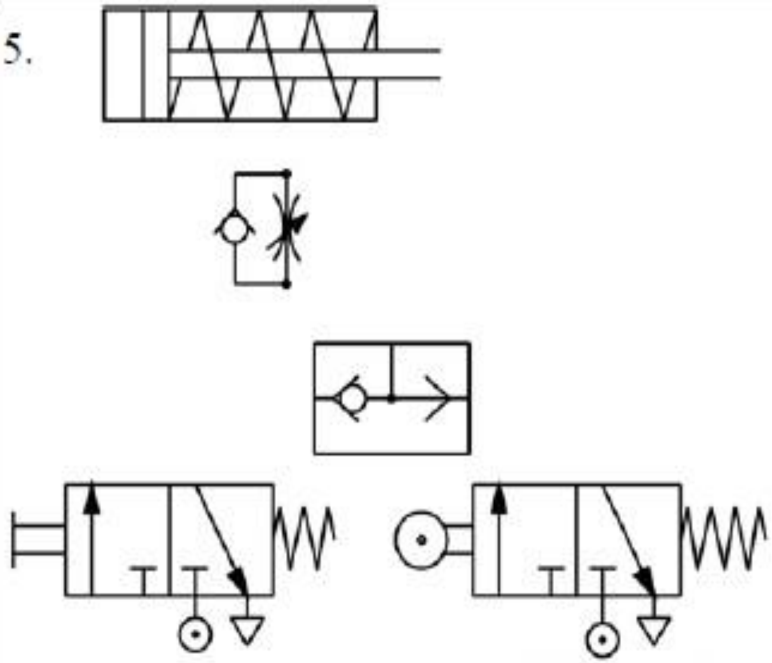
Power control valves should be drawn directly under the cylinder controlled by them, forming a power unit.

4.



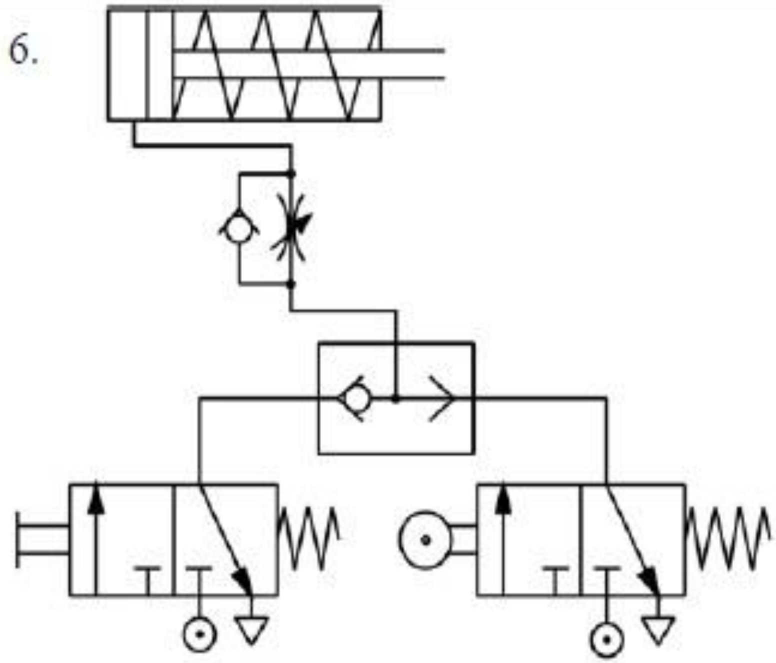
Control cylinders and operational valves (signal components) driven by power control valves should be placed at the lower levels of the diagram.

5.



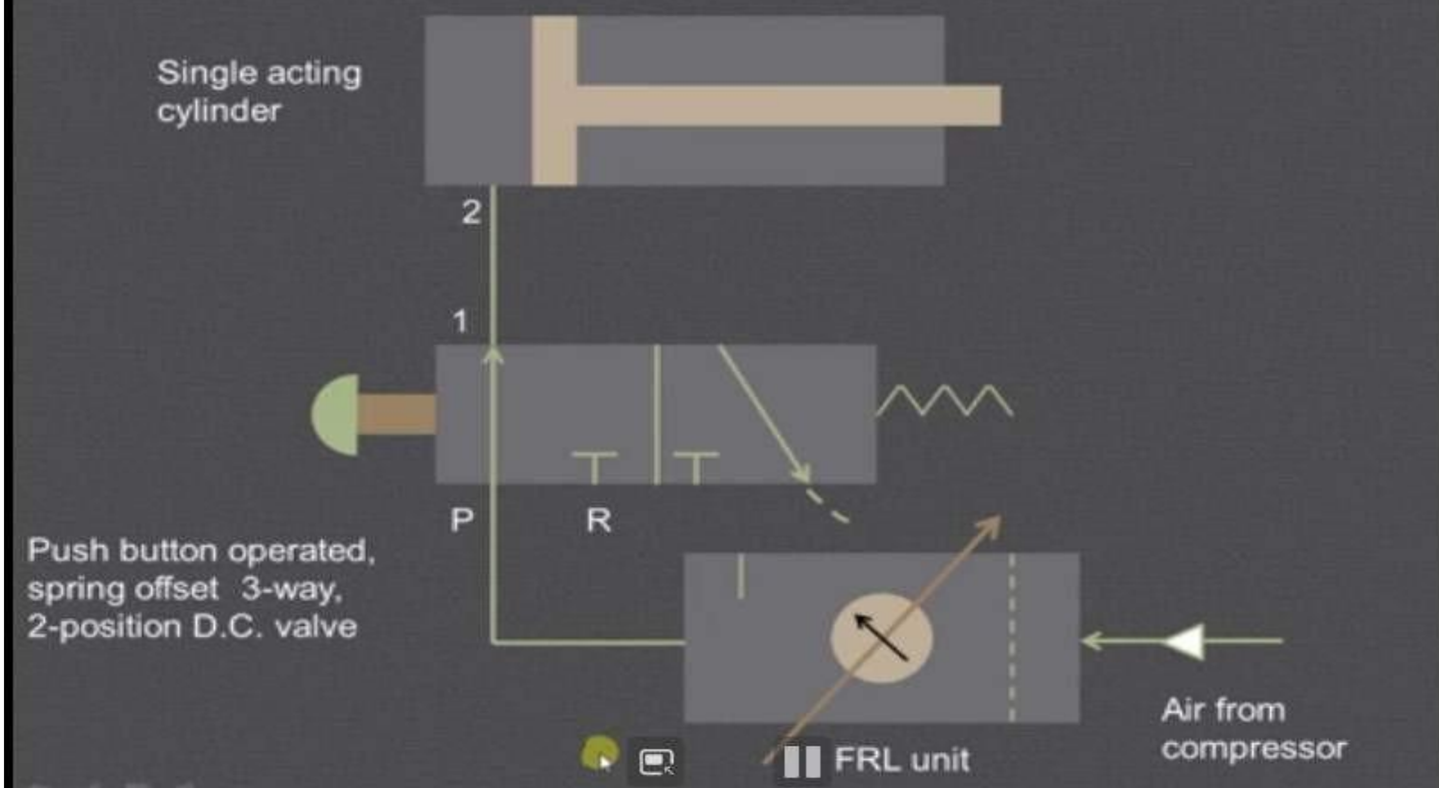
Assistance valves, such as those with logic functions (for example, memory, 'AND', 'OR', 'NOT', delay, etc), can be put between the pneumatic components and the power control valves.

6.



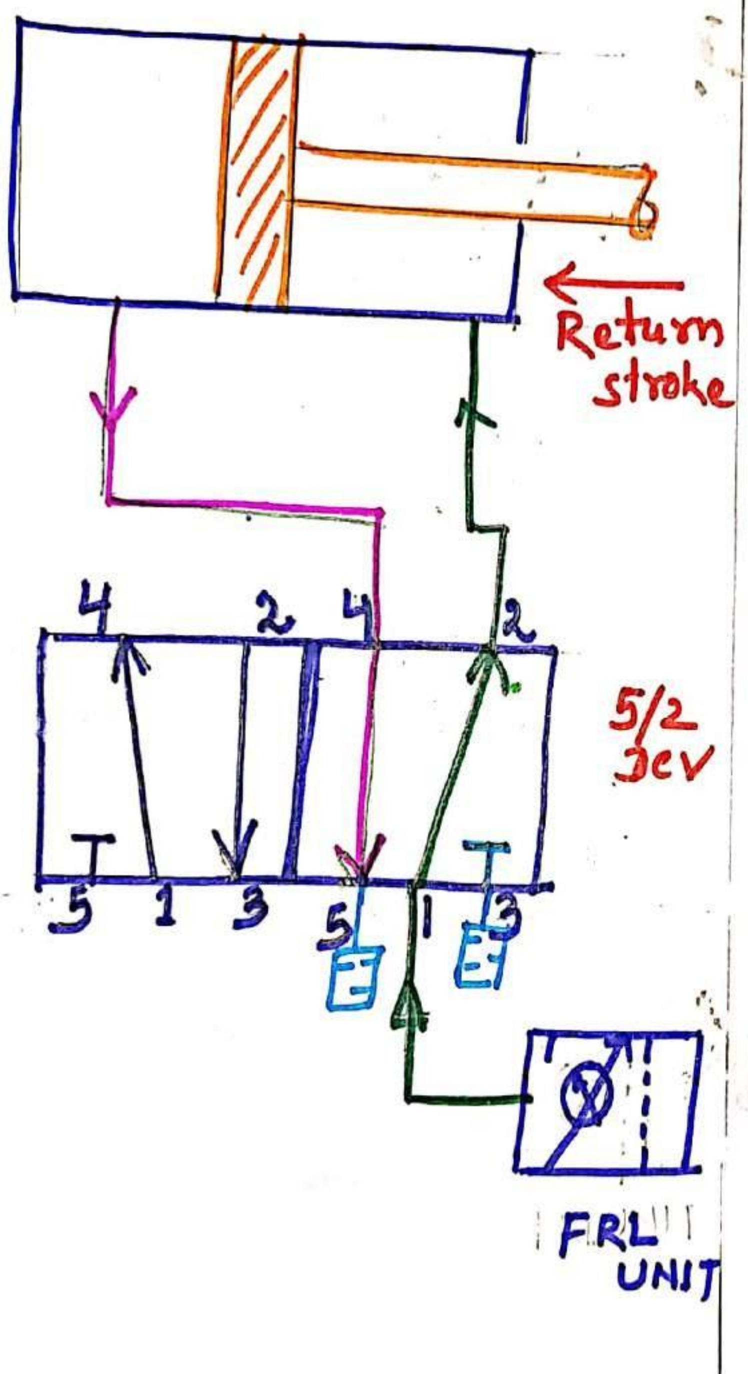
Use the line which represents the connecting pipe to connect all the air supply unit and the pneumatic components to complete the pneumatic circuit. Check carefully the circuit and the logic of the operation before use to avoid any accident.

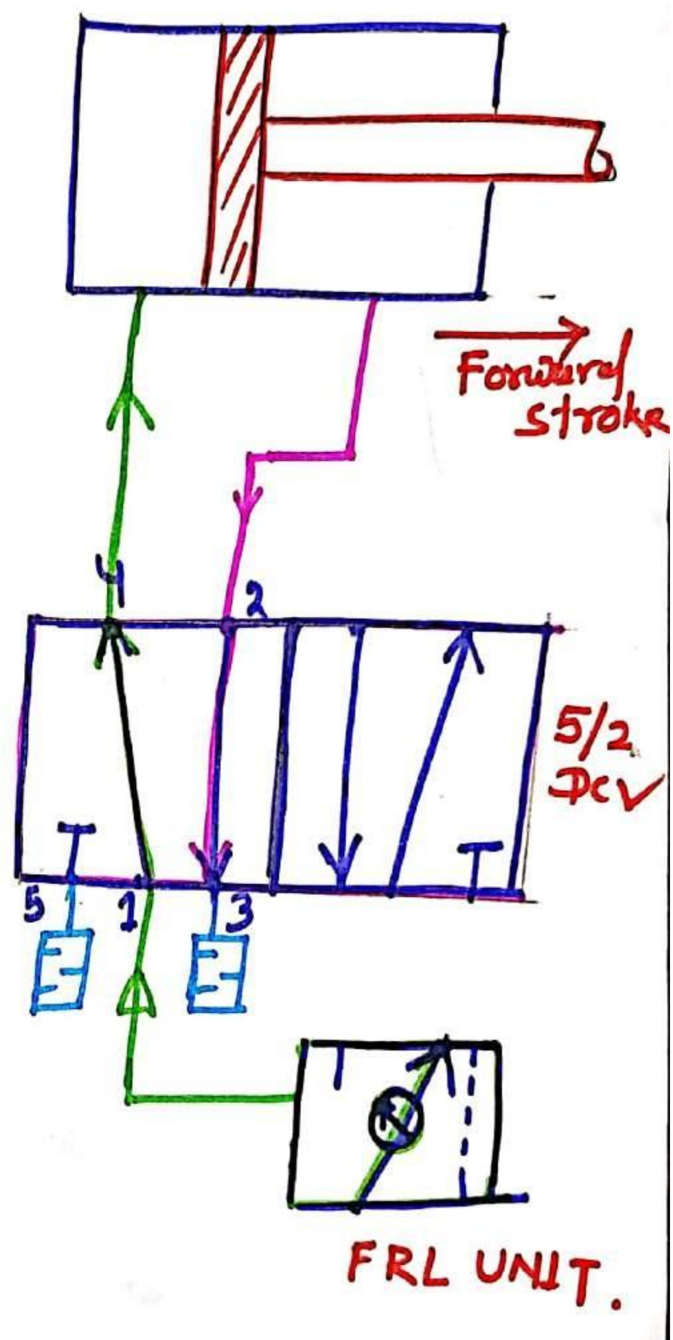
Pneumatic circuit to operate single acting cylinder :



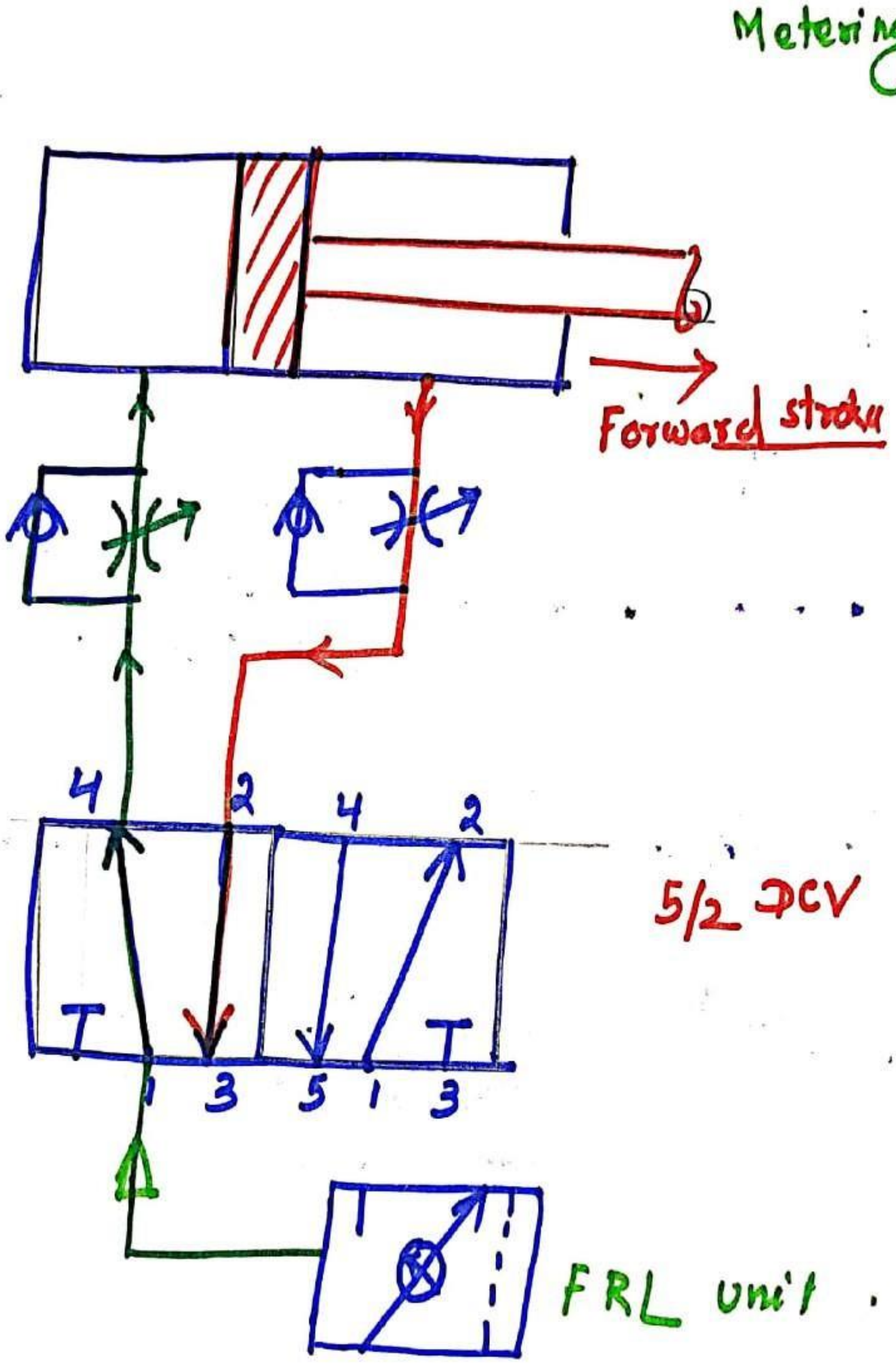
PNUEMATIC CIRCUIT

DIRECT CONTROL OF DOUBLE ACTING CYLINDER



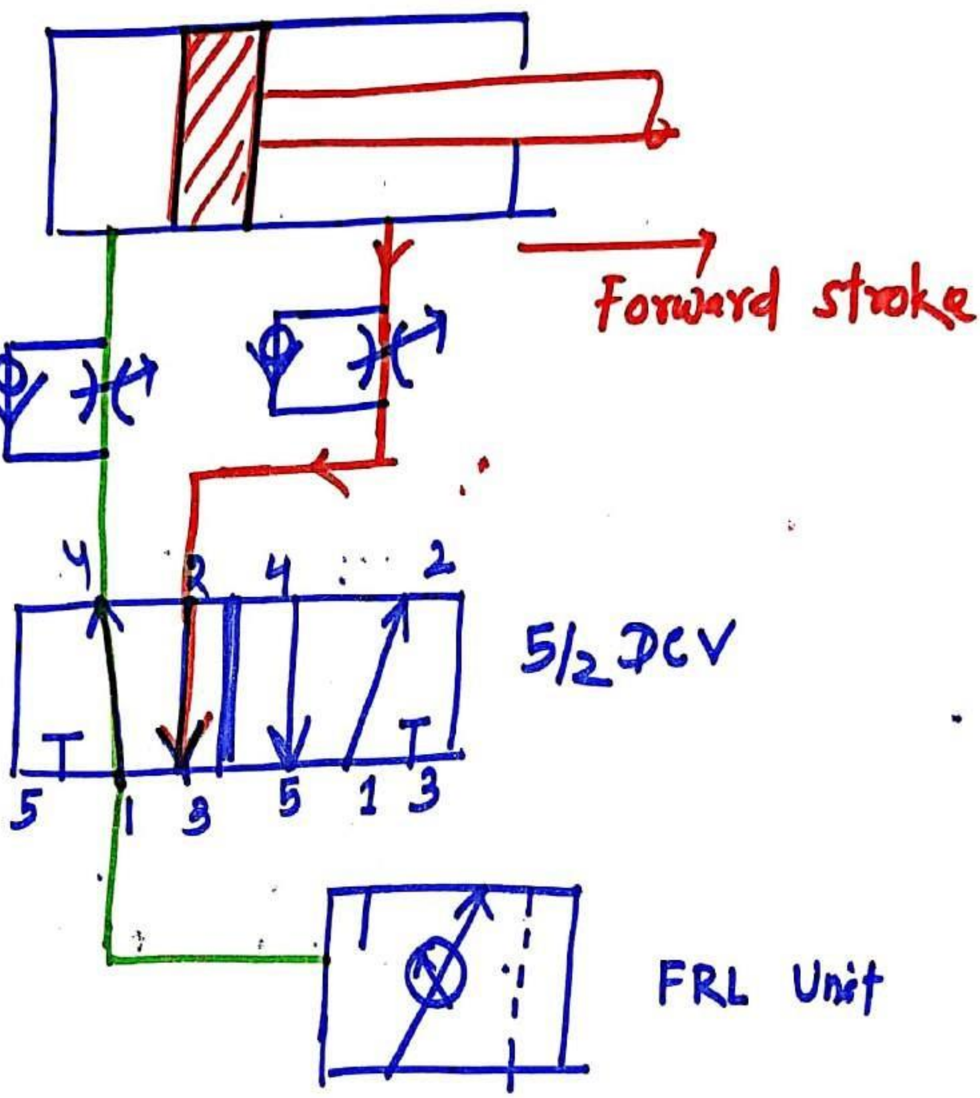


OPERATION OF DOUBLE ACTING CYLINDER WITH METERING IN CIRCUIT.



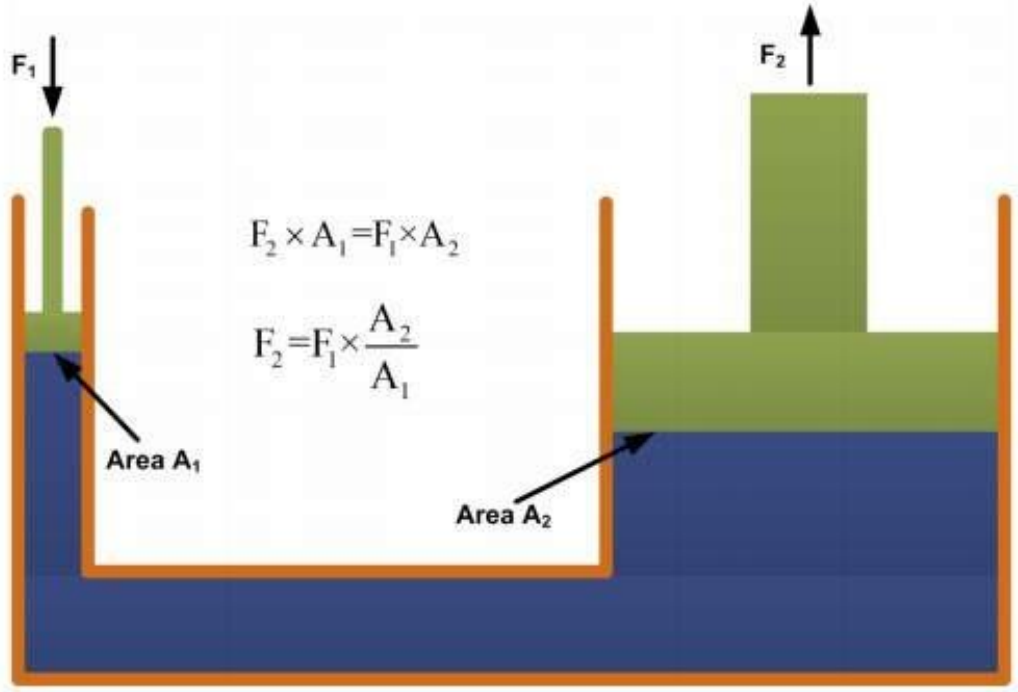
OPERATION OF DOUBLE ACTING CYLINDER WITH METERING OUT CIRCUIT :

Metering OUT .



Hydraulic Systems

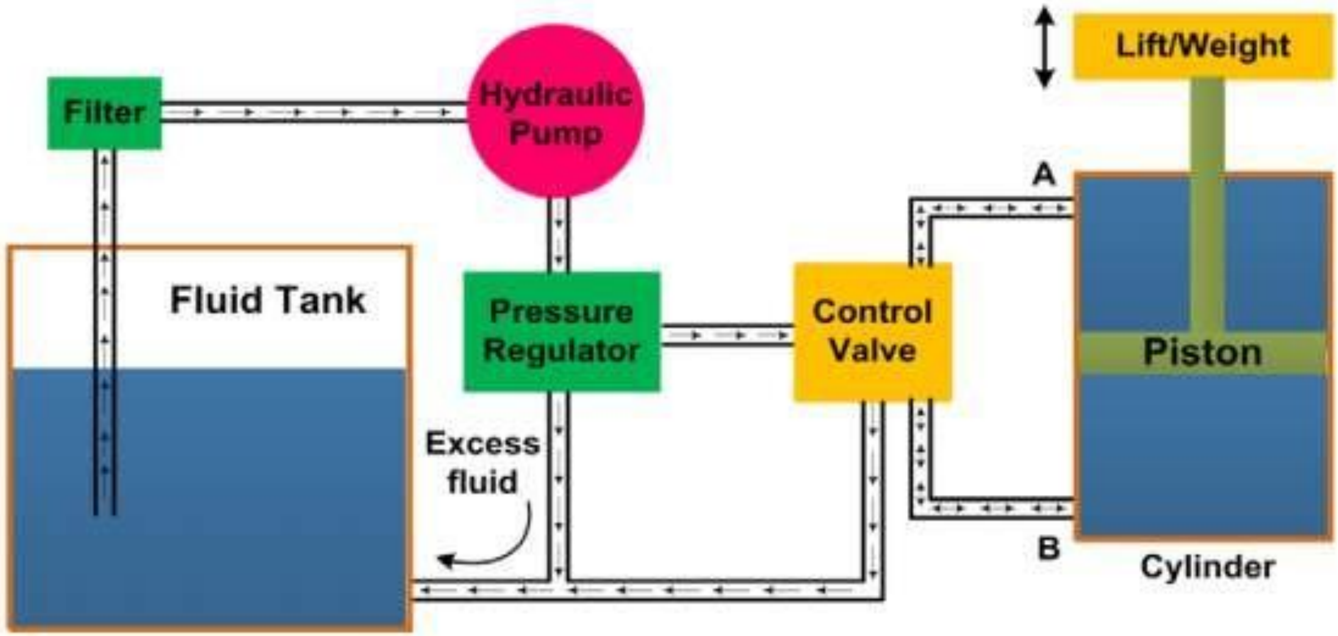
Introduction



The hydraulic system works on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions. The Pascal's law is illustrated in figure The force given by fluid is given by the multiplication of pressure and area of cross section. As the pressure is same in all the direction, the smaller piston feels a smaller force and a large piston feels a large force. Therefore, a large force can be generated with smallerforce input by using hydraulic systems.

Hydraulic Systems

The hydraulic systems consists a number of parts for its proper functioning. These include storage tank, filter, hydraulic pump, pressure regulator, control valve, hydraulic cylinder, piston and leak proof fluid flow pipelines. The schematic of a simple hydraulic system is shown in figure 5.1.2



. It consists of:

- a movable piston connected to the output shaft in an enclosed cylinder
- storage tank
- filter
- electric pump
- pressure regulator
- control valve
- leak proof closed loop piping.

The output shaft transfers the motion or force however all other parts help to control the system. The storage/fluid tank is a reservoir for the liquid used as a transmission media. The liquid used is generally high density incompressible oil. It is filtered to remove dust or any other unwanted particles and then pumped by the hydraulic pump. The capacity of pump depends on the hydraulic system design. These pumps generally deliver constant volume in each revolution of the pump shaft. Therefore, the fluid pressure can increase indefinitely at the dead end of the piston until the system fails. The pressure regulator is used to avoid such circumstances which redirect the excess fluid back to the storage tank. The movement of piston is controlled by changing liquid flow from port A and port B. The cylinder movement is controlled by using control valve which directs the fluid flow. The fluid pressure line is connected to the port B to raise the piston and it is connected to port A to lower down the piston. The valve can also stop the fluid flow in any of the port. The leak proof piping is also important due to safety, environmental hazards and economical aspects. Some accessories such as flow control system, travel limit control, electric motor starter and overload protection may also be used in the hydraulic systems which are not shown in figure 5.1.2.

Applications of hydraulic systems

The hydraulic systems are mainly used for precise control of larger forces.
The main applications of hydraulic system can be classified in five categories:

1 Industrial: Plastic processing machineries, steel making and primary metal extraction applications, automated production lines, machine tool industries, paper industries, loaders, crushes, textile machineries, R & D equipment and robotic systems etc.

2.Mobile hydraulics: Tractors, irrigation system, earthmoving equipment, material handling equipment, commercial vehicles, tunnel boring equipment, rail equipment, building and construction machineries and drilling rigs etc.

3.Automobiles: It is used in the systems like breaks, shock absorbers, steering system, wind shield, lift and cleaning etc.

4.Marine applications: It mostly covers ocean going vessels, fishing boats and navel equipment.

5.Aerospace equipment: There are equipment and systems used for rudder control, landing gear, breaks, flight control and transmission etc. which are used in airplanes, rockets and spaceships.

Advantages and Disadvantages of Hydraulic system

Advantages

- • The hydraulic system uses incompressible fluid which results in higher efficiency.
- • It delivers consistent power output which is difficult in pneumatic or mechanical drive systems.
- • Hydraulic systems employ high density incompressible fluid. Possibility of leakage is less in hydraulic system as compared to that in pneumatic system. The maintenance cost is less
- . • These systems perform well in hot environment conditions

Disadvantages

- • The material of storage tank, piping, cylinder and piston can be corroded with the hydraulic fluid. Therefore one must be careful while selecting materials and hydraulic fluid.
- • The structural weight and size of the system is more which makes it unsuitable for the smaller instruments.
- • The small impurities in the hydraulic fluid can permanently damage the complete system, therefore one should be careful and suitable filter must be installed.
- • The leakage of hydraulic fluid is also a critical issue and suitable prevention method and seals must be adopted.
- • The hydraulic fluids, if not disposed properly, can be harmful to the environment.

Hydraulic Pumps

Classification of Hydraulic Pumps

These are mainly classified into two categories: A. Non-positive displacement pumps B. Positive displacement pumps.

. Non-Positive Displacement Pumps

These pumps are also known as hydro-dynamic pumps. In these pumps the fluid is pressurized by the rotation of the propeller and the fluid pressure is proportional to the rotor speed. These pumps can not withstanding high pressures and generally used for low-pressure and high-volume flow applications. The fluid pressure and flow generated due to inertia effect of the fluid. The fluid motion is generated due to rotating propeller. These pumps provide a smooth and continuous flow but the flow output decreases with increase in system resistance (load). The flow output decreases because some of the fluid slip back at higher resistance. The fluid flow is completely stopped at very large system resistance and thus the volumetric efficiency will become zero. Therefore, the flow rate not only depends on the rotational speed but also on the resistance provided by the system. The important advantages of non-positive displacement pumps are lower initial cost, less operating maintenance because of less moving parts, simplicity of operation, higher reliability and suitability with wide range of fluid etc. These pumps are primarily used for transporting fluids and find little use in the hydraulic or fluid power industries. Centrifugal pump is the common example of non-positive displacement pumps. Details have already discussed in the previous lecture.

B. Positive displacement pump

These pumps deliver a constant volume of fluid in a cycle. The discharge quantity per revolution is fixed in these pumps and they produce fluid flow proportional to their displacement and rotor speed. These pumps are used in most of the industrial fluid power applications. The output fluid flow is constant and is independent of the system pressure (load). The important advantage associated with these pumps is that the high-pressure and low-pressure areas (means input and output region) are separated and hence the fluid cannot leak back due to higher pressure at the outlets. These features make the positive displacement pump most suited and universally accepted for hydraulic systems. The important advantages of positive displacement pumps over non-positive displacement pumps include capability to generate high pressures, high volumetric efficiency, high

power to weight ratio, change in efficiency throughout the pressure range is small and wider operating range pressure and speed. The fluid flow rate of these pumps ranges from 0.1 and 15,000 gpm, the pressure head ranges between 10 and 100,000 psi and specific speed is less than 500.

It is important to note that the positive displacement pumps do not produce pressure but they only produce fluid flow. The resistance to output fluid flow generates the pressure. It means that if the discharge port (output) of a positive displacement pump is opened to the atmosphere, then fluid flow will not generate any output pressure above atmospheric pressure. But, if the discharge port is partially blocked, then the pressure will rise due to the increase in fluid flow resistance. If the discharge port of the pump is completely blocked, then an infinite resistance will be generated. This will result in the breakage of the weakest component in the circuit. Therefore, the safety valves are provided in the hydraulic circuits along with positive displacement pumps. Important positive displacement pumps are gears pumps, vane pumps and piston pumps. The details of these pumps are discussed in the following sections.

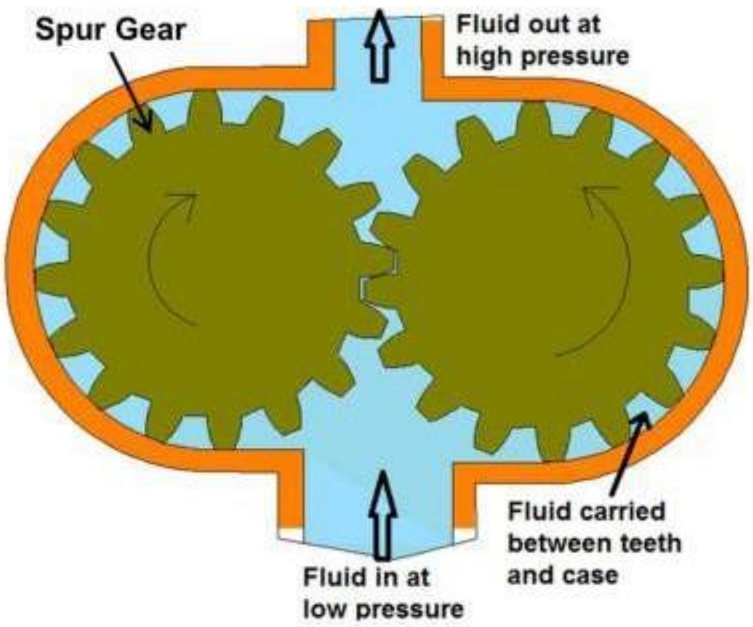
Gear Pumps

Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids. They are suitable for a wide range of fluids and offer self-priming performance. Sometimes gear pumps are designed to function as either a motor or a pump. These pump includes helical and herringbone gear sets (instead of spur gears), lobe shaped rotors similar to Roots blowers (commonly used as superchargers), and mechanical designs that allow the stacking of pumps. Based upon the design, the gear pumps are classified as:

• External gear pumps • Internal gear pumps •
Gerotor pumps

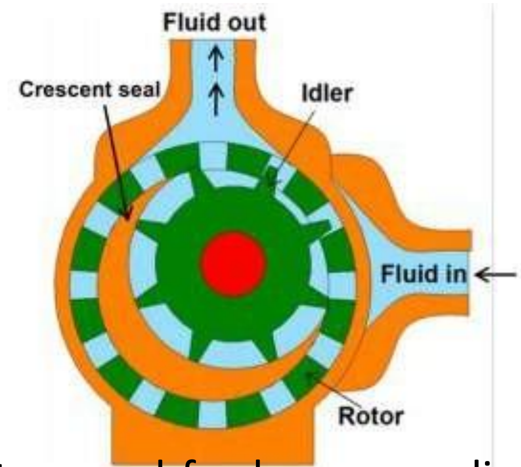
Generally gear pumps are used to pump:
• Petrochemicals: Pure or filled bitumen, pitch, diesel oil, crude oil, lube oil etc.
• Chemicals: Sodium silicate, acids, plastics, mixed chemicals, isocyanates etc.
• Paint and ink • Resins and adhesives • Pulp and paper: acid, soap, lye, black liquor, kaolin, lime, latex, sludge etc.
• Food: Chocolate, cacao butter, fillers, sugar, vegetable fats and oils, molasses, animal food etc.

External gear pump



The external gear pump consists of externally meshed two gears housed in a pump case as shown in figure 5.2.1. One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear. The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion whereas the gear teeth come out of the mesh. When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears. The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth. The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port. The gear pumps are often equipped with the side wear plate to avoid the leakage. The clearance between gear teeth and housing and between side plate and gear face is very important and plays an important role in preventing leakage. In general, the gap distance is less than 10 micrometers. The amount of fluid discharge is determined by the number of gear teeth, the volume of fluid between each pair of teeth and the speed of rotation. The important drawback of external gear pump is the unbalanced side load on its bearings. It is caused due to high pressure at the outlet and low pressure at the inlet which results in slower speeds and lower pressure ratings in addition to reducing the bearing life. Gear pumps are most commonly used for the hydraulic fluid power applications and are widely used in chemical installations to pump fluid with a certain viscosity

Internal Gear Pump



Internal gear pumps are exceptionally versatile. They are often used for low or medium viscosity fluids such as solvents and fuel oil and wide range of temperature. This is non pulsing, self-priming and can run dry for short periods. It is a variation of the basic gear pump. It comprises of an internal gear, a regular spur gear, a crescent-shaped seal and an external housing. The schematic of internal gear pump is shown in figure 5.2.4. Liquid enters the suction port between the rotor (large exterior gear) and idler (small interior gear) teeth. Liquid travels through the pump between the teeth and crescent. Crescent divides the liquid and acts as a seal between the suction and discharge ports. When the teeth mesh on the side opposite to the crescent seal, the fluid is forced out through the discharge port of the pump. This clearance between gears can be adjusted to accommodate high temperature, to handle high viscosity fluids and to accommodate the wear. These pumps are bi-rotational so that they can be used to load and unload the vessels. As these pumps have only two moving parts and one stuffing box, therefore they are reliable, simple to operate and easy to maintain. However, these pumps are not suitable for high speed and high pressure applications. Only one bearing is used in the pump therefore overhung load on shaft bearing reduces the life of the bearing.

Applications Some common internal gear pump applications are:

- All varieties of fuel oil and lube oil
- Resins and Polymers
- Alcohols and solvents
- Asphalt, Bitumen, and Tar
- Polyurethane foam (Isocyanate and polyol)
- Food products such as corn syrup, chocolate, and peanut butter
- Paint, inks, and pigments
- Soaps and surfactants
- Glycol

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

MECHATRONICS

5TH SEMESTER

PREPARED BY

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Unit 1: INTRODUCTION TO MECHATRONICS

1.1 Definition of Mechatronics

The synergistic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and manufacturing processes.

"Mechatronics" involves a number of technologies such as:

- Mechanical engineering;
- Electronic engineering;
- Electrical engineering;
- Computer technology;
- Control engineering

1.2 Advantages and Disadvantages of Mechatronics

Following are the advantages and disadvantages of mechatronics:

Advantages:

1. The products produced are cost effective and of very good quality.
2. The performance characteristics of mechatronics products are such which are otherwise very difficult to achieve without the synergistic combination.
3. High degree of flexibility.
4. A mechatronics product can be better than just sum of its parts.
5. Greater extent of machine utilization.
6. Due to the integration of sensors and control systems in a complex system, capital expenses are reduced
7. Owing to the incorporation of intelligent, self-correcting sensory and feedback systems, the mechatronic approach results in:

- Greater productivity;
- Higher quantity and producing reliability.

Disadvantages:

1. High initial cost of the system.
2. Imperative to have knowledge of different engineering fields for design and implementation.
3. Specific problems for various systems will have to be addressed separately and properly.
4. It is expensive to incorporate mechatronics approach to an existing/old system.

1.3 Application of Mechatronics

Following are the examples of mechatronics systems:

l. Home appliances:

- Washing machines

- Bread machines etc.

2. Automobile:

- Electrical fuel injection

- Antilock brake system.

3. Aircraft:

- Flight control

- Navigation system.

1. Automated manufacturing:

- Robots

- Numerically controlled (NC) machine tools.

1.4 Scope of Mechatronics in Industrial Sector

Mechatronics helps in designing and maintaining automated equipment. Technicians and engineers work in laboratories, offices or on-site manufacturing plants. The goal is to produce safe and efficient automated equipment. Technicians primarily maintain machinery, while engineers are more concerned with design and development of components and products.

A Mechatronics engineer unites the principles of engineering disciplines like mechanics, electronics, and computing to generate a simpler, more economical and reliable system the process of mechatronics engineering involves designing, assembling, testing, and evaluating components and products.

Mechatronics technicians apply their knowledge of engineering to solve technical problems and maintain automated mechanical equipment. A job of a mechatronics technician includes inspecting, troubleshooting and repairing electrical and electronic components.

1.5 Components of a mechatronic system:

- Actuators
- Sensors
- Input signal conditioning & interfacing
- Digital control architectures
- Output signal conditioning & interfacing
- Graphical displays

1. Actuators: Solenoids, voice coils; D.C. motors; Stepper motors; Servomotor; hydraulics; pneumatics.

2. Sensors: Switches; Potentiometer; Photoelectric; Digital encoder; Strain gauge; Thermocouple; accelerometer etc.

3. lnput signal conditioning and interfacing: Discrete circuits; Amplifiers, Filters; A/D, D/D.

4. Digital control architectures: Logic circuits; Microcontroller; SBC; PLC; Sequencing and timing; Logic and arithmetic; Control algorithms; Communication.

5. Output signal conditioning and interfacing: Amplifiers; PWM; Power transistors.

6. Graphical displays: LEDs; Digital displays; LCD; CRT.

- The actuators produce motion or cause some action;
- The sensors detect the state of the system parameters, inputs and outputs;
- Digital devices control the system;
- Conditioning and interfacing circuits provide connection between the control circuit and the input/output devices;
- Graphical displays provide visual feedback to users.

1.6 Importance of Mechatronics in automation

Today's customers are demanding more variety and higher levels of flexibility in the products. Due to these demands and competition in the market, manufacturers are thriving to launch new/modified products to survive. It is reducing the product life as well as lead-time to manufacture a product. It is therefore essential to automate the manufacturing and assembly operations of a product.

Mechatronics concurrently employs the disciplines of mechanical, electrical, control and computer engineering at the stage of design itself. Mechanical discipline is employed in terms of various machines and mechanisms, whereas electrical engineering as various electric prime movers viz. AC/DC, servo motors and other systems is used. Control engineering helps in the development of various electronics-based control systems to enhance or replace the mechanics of the mechanical systems. Computers are widely used to write various softwares to control the control systems; product design and development activities; materials and manufacturing resource planning, record keeping, market survey, and other sales related activities.

Using computer aided design (CAD) / computer aided analysis (CAE) tools, three-dimensional models of products can easily be developed. These models can then be analyzed and can be simulated to study their performances using numerical tools. These numerical tools are being continuously updated or enriched with the real-life performances of the similar kind of products. These exercises provide an approximate idea about performance of the product/system to the design team at the early stage of the product development. Based on the simulation studies, the designs can be modified to achieve better performances.

During the conventional design manufacturing process, the design assessment is generally carried out after the production of first lot of the products. This consumes a lot of time, which leads to longer (in months/years) product development lead-time. Use of CAD–CAE tools saves significant time in comparison with that required in the conventional sequential design process. CAD-CAE generated final designs are then sent to the production and process planning section.

Mechatronics based systems such as computer aided manufacturing (CAM): automatic process planning, automatic part programming, manufacturing resource planning, etc. uses the design data provided by the design team. Based these inputs, various activities will then be planned to achieve the manufacturing targets in terms of quality and quantity with in a stipulated time frame.

Mechatronics based automated systems such as automatic inspection and quality assurance, automatic packaging, record making, and automatic dispatch help to expedite the entire manufacturing operation. These systems certainly ensure a supply better quality, well packed and reliable products in the market.

Automation in the machine tools has reduced the human intervention in the machining operation and improved the process efficiency and product quality. Therefore, it is important to study the principles of mechatronics and to learn how to apply them in the automation of a manufacturing system.

Unit 2: SENSORS AND TRANSDUCERS

2.1Definition of Transducers

It is defined as an element when subjected to some physical change experiences a related change or an element which converts a specified measure and into a usable output.

It can also be defined as a device that converts a signal from one form of energy to another form.

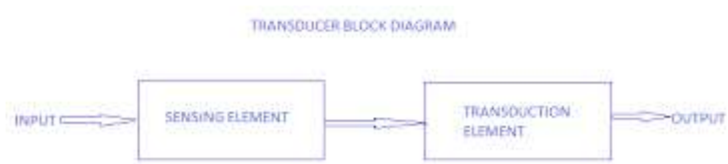
Most of the transducers either convert electrical energy into mechanical displacement and/or convert some non-electrical physical quantity (e.g., force, sound, temperature etc.) to an electrical signal.

A transducer performs the following functions:

1. Detects or senses the presence, magnitude and changes in physical quantity being measured.

2. Provides a proportional electrical output signal.

A transducer can be broadly defined as a device which converts a non-electrical quantity into an electrical quantity.



2.2 Classification of Transducers

Inverse transducer

An inverse transducer is defined as a device which converts an electrical quantity into a non-electrical quantity.

A piezoelectric crystal acts as an inverse transducer because when a voltage is applied across its surfaces, it changes its dimensions causing a mechanical displacement.

Active transducers

They are also known as self-generating type transducers. These transducers develop their own voltage or current. The energy required for production of an output signal is obtained from the physical phenomenon being measured.

Examples: Thermocouples and thermopiles, piezoelectric pick-up, photovoltaic cell.

Passive transduces

They are known as externally-powered transducer. These transducers derive the power required for the energy conversion from an external power source. However, they may absorb some energy from the physical phenomenon under study.

Examples: Resistance thermometers and thermistors, potentiometric devices, differential transformer, photoemission cell etc.

Analogue transducers

These transducers convert the input physical phenomenon into an analogous output which is a continuous function of time.

Examples: Strain gauge, a thermocouple, a thermistor or an LVDT (linear voltage differential transformer).

Digital transducers

These transducers convert the input physical phenomenon into an electrical output which may be in form of pulse'

Classification based on electrical principle involved:

1. Variable-resistance type:

- Strain and pressure gauges.
- Thermistors, resistance thermometers'
- Photoconductive cell etc.

2. Variable-inductance type:

- Linear voltage differential transformer (LVDT).
- Reluctance pick-up.
- Eddy current gauge.

3. Variable-capacitance type:

- Capacitor microphone.
- Pressure gauge.
- Dielectric gauge.

4. Voltage-generating type:

- Thermocouple.
- Photovoltaic cell.
- Rotational motion tachometer'
- Piezoelectric pick-up.

5. Voltage-divider type:

- Potentiometer position censor'
- Pressure-actuated voltage divider.

2.3 Electromechanical Transducers

Any type of device that either converts an electrical signal into sound waves (as in a loudspeaker) or converts a sound wave into an electrical signal (as in the microphone).

Advantages:

1. Less power consumption

2. Friction effect is minimum

3. More compact instrumentation

4. Possibility of non-contact measurements

5. Good frequency

2.4 Transducers actuating mechanisms

Actuating mechanism converts a source of energy, which can be mechanical force, electrical current, hydraulic fluid pressure or pneumatic pressure etc. into motion.

An actuating mechanism not only changes the state of the object being controlled but also moves the controlled member with the minimum possible deviations.

Eg. corrugated diaphragm, bellows, corrugated bourdon tube (all used for pressure measurement)

2.5 Displacement or Position sensors

Sensors

A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena.

A displacement sensor is a device used for measuring positional movement or detecting the movement of a given object, these movements can be in either a linear or rotary fashion.

Displacement sensors, also known as position sensors, are a very common type of sensor.

Some of the most common industries for displacement sensors are; Motorsport, automotive, industrial applications, agriculture, aerospace, robotics and many more.

2.6 Velocity, Motion, Force and Pressure

sensors

Velocity sensor

A velocity sensor is a sensor that responds to velocity

The magnet of the velocity sensor is suspended on a membrane (spring) which moves through a coil of wire. Due to the vibration, the coil of wire moves through the magnetic field of the permanent magnet and generates (induces) a voltage signal which is proportional to the vibration (velocity).

Eg.tachometers (employed in a motor to calculate the rotational speed of a shaft), piezoelectric sensor (uses piezoelectric effect to measure changes in velocity)

Motion sensor

A motion sensor is an electronic device that uses a sensor to detect nearby people or objects. Motion sensors are an important component of any security system. When a sensor detects motion, it will send an alert to your security system, and with newer systems, right to your mobile phone.

Active ultrasonic sensors and passive infrared sensors are the two most common motion sensor technologies, both of which are known for their accuracy and reliability.

Active ultrasonic sensors emit ultrasonic sound waves at a frequency above the range of human hearing. These waves bounce off objects in the immediate vicinity and return to the motion sensor.

Passive infrared sensors are a bit more complex than active ultrasonic sensors, but the result is the same.

Infrared motion sensors detect the presence of a person or object by detecting the change in temperature of a given area.

Force sensor

A Force Sensor is defined as a transducer that converts an input mechanical load, weight, tension, compression or pressure into an electrical output signal.

Force Transducers became an essential element in many industries from Automotive (car sensors or vehicle sensors), High precision manufacturing, Aerospace & Defense, Industrial Automation, Medical & Pharmaceuticals and Robotics

Pressure sensor

A pressure sensor is a device or instrument which is able to measure the pressure in gases or liquids.

Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude.

2.7 Temperature and light

Sensors

Temperature sensor

A temperature sensor is a device used to measure temperature.

The sensor is made up of two metals, which generate electrical voltage or resistance once it notices a change in temperature.

Eg. Thermocouple (a sensor made up of two wires with two different metals connected at two points. The voltage between the two wires reflects the change in temperature.)

Light sensor

The light sensor is a device that converts the light energy into an electrical signal output. Light sensors are more commonly known as Photoelectric Devices or Photo Sensors because they convert light energy (photons) into electronic signal (electrons).
Photoelectric sensors use a beam of light to detect the presence or absence of an object.

Unit 3: ACTUATORS-MECHANICAL, ELECTRICAL

Actuators produce physical changes such as linear and angular displacement.

3.1Mechanical Actuators

Mechanical actuators are devices that transform motion from one form to some other required form,

For e.g. they might transform linear motion into rotational motion, or perhaps a linear reciprocating motion into rotary motion

3.1.1 Machine, Kinematic Link, Kinematic Pair

Machine

It is an apparatus for applying mechanical power, consisting of a number of interrelated parts each having a definite function.

Or

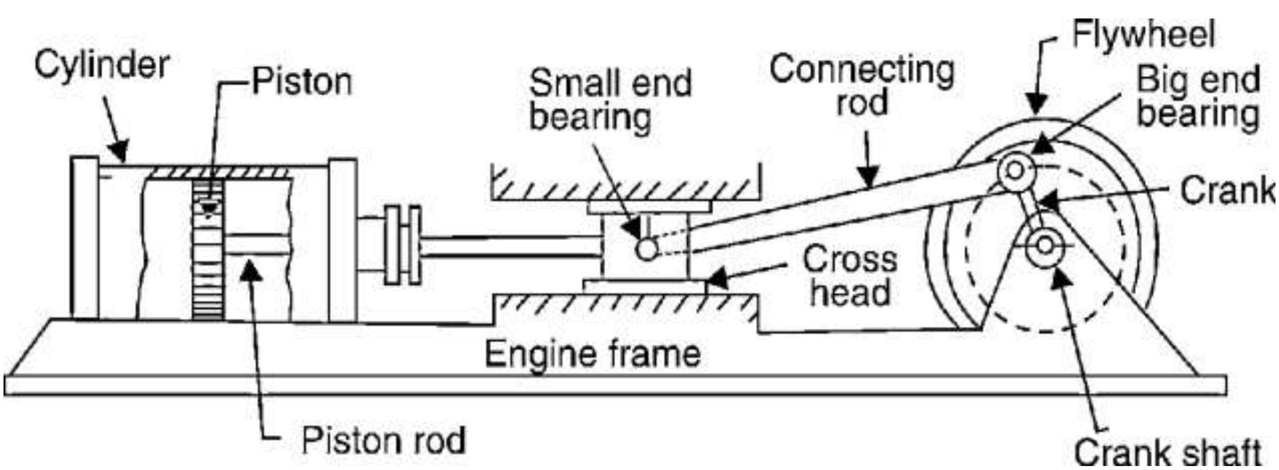
It is a device by means of which available energy can be converted into desired form of useful work.

A Machine is the assembly of resistant bodies whose relative motions are successfully constrained so that available energy can be converted into useful work

Kinematic link

it is a resistant body or an assembly of resistant bodies which make a part or parts of a machine to connect with other parts which have motion 'relative' to it.

A kinematic link is assumed to be completely rigid.



Reciprocating Steam Engine

Piston, piston rod and cross head ... one link.
- Connecting rod with big and small end bearings ... second link.
- Crankshaft and flywheel ... third link.
- Cylinder, engine frame ... fourth link.

Characteristics of a link.
A link should have two characteristics:

1. It should have relative motion.
2. It must be a resistant body (need not be rigid body).

Types of links:
The various types of links are:

1. **Rigid link**- A link which does not undergo any deformation while transmitting motion is called a "rigid link". Strictly speaking, rigid links do not exist

2. **Flexible link**- A flexible link in one which is partly deformed in a manner not to the transmission of motion.
Example: Belts, ropes, chains and wires (these link transmit tensile forces only).

3. **Fluid link-** A fluid link is one which is formed by having a fluid in receptacle & the motion is transmitted through the fluid by pressure or compression only
Example: Hydraulic presses, jacks and brakes.

Kinematic Pair

A kinematic pair is a joint of two links that permits relative motion.
The relative motion between the elements or links that form a pair is required to be completely constrained or successfully constrained.

Completely constrained motion-When the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion.

Examples: The motion of a square bar in a square hole and the motion of a shaft with collars at each end are the examples of the completely constrained motion.
The motion of the piston and cylinder, (forming a pair) in a steam engine in which the motion of the piston is limited to a definite direction (i.e., it will only reciprocate) is also an example of completely constrained motion.

Successfully constrained motion-The motion is said to be successfully constrained when the motion between the elements, forming a pair, ---is such that constrained motion is not completed by itself, but by some means.

For e.g. the load is placed on the shaft to prevent axial upward movement of the shaft, then the motion of the pair is said to be successfully constrained.

Classification of kinematic pairs:

1. Classification based on nature of relative motion between the elements:

(i) **Sliding pair**- If two links have a sliding motion relative to each other, they form a sliding pair.
Examples. Piston and cylinder pair, rectangular rod in rectangle hole

(ii) **Turning pair**.-When one link has turning or revolving motion relative to the other, they constitute a turning or revolving pair.
Examples. A shaft rotating in a bearing, Rotation of a crank in a slider crank mechanism is another turning pair.

(iii) **Rolling pair-** When the links of a pair have a rolling motion relative to each other, they form a rolling pair.
Examples. Ball and roller bearings. In a ball bearing, the ball and the shaft constitute one rolling pair whereas the ball and the bearing is the second rolling pair.

4. **Screw (or helical) pair**-When the two elements of a pair are connected in such a way that one element can turn about the other by screw threads, the pair is known as 'screw pair'.
Example. Nut and bolt arrangement

5**. Spherical pair**-When two elements of a pair are connected in such a way that one element with spherical shape turns about the other fixed element; the pair formed is called a ‘spherical pair'.
Examples. The ball and socket joint, attachment of a car mirror

2. Classification based on the nature of contact between elements:

(l) Lower pairs (ll) Higher pairs.

(i**) Lower pair**-If a pair in motion has a surface contact between its elements it is called a lower pair.
Eg.shaft rotating in a bearing

(ll**) Higher pair**- In a higher pair there is a line or point contact between the elements of a pair. The contact surfaces of the two elements are not alike or similar.
Examples. toothed gearing, belt and rope drives, cam and follower, ball and roller bearings

3. Classification based on the nature of mechanical constraint:

(i) Closed pairs (ii) Unclosed pairs.
(i**) Closed pairs**-If the elements of the pair, are held together mechanically, they constitute a' closed pair'.
Examples. All lower pairs.

(ii**) Unclosed pairs**-if the two elements are not held together mechanically, it forms an ‘unclosed pair'.
Example. Cam and follower pair

3.1.2 Mechanism, Slider crank Mechanism

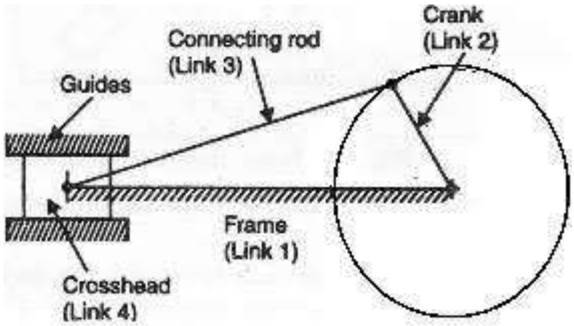
Mechanism
When one of the links of a kinematic chain is fixed, the chain is known as mechanism.

Mechanisms are of two types:
Simple mechanism-A mechanism with/our links is known as simple mechanism.

Compound mechanism- The mechanism with more than four links is known as compound mechanism. It may be made by adding two or more simple mechanisms.

Slider crank Mechanism
It consists of one sliding pair and three turning pairs. It is, usually, found in reciprocating steam engine mechanism. This type of mechanism converts rotary motion into reciprocating motion and vice versa

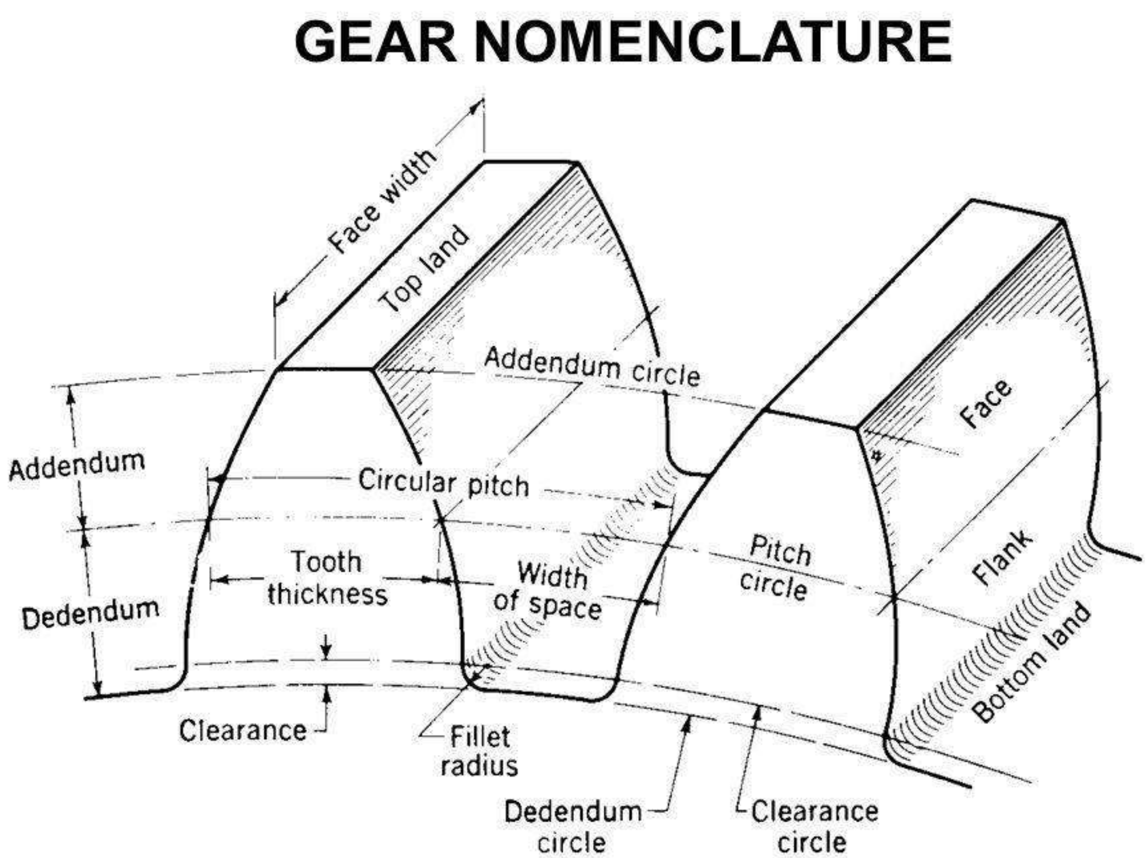
In a single slider crank chain, the links 1 and2,links 2 and 3 and links 3 and 4 form three turning pairs while links 4 and 1 form a sliding pair'



3.1.3 Gear Drive, Spur gear, Bevel gear, Helical gear, worm gear

A gear is a wheel provided with teeth which mesh with the teeth on another wheel, or on to a rack, so as to give a positive transmission of motion from one component to another.

Gears constitute the most commonly used device for power transmission or for changing power-speed ratios in a power system. They are used for transmitting motion and power from one shaft to another when they are not too for apart and when a constant velocity ratio is desired.



1. **Pitch circle**-It is an imaginary circle which would transmit the same motion as the actual gear, by pure rolling action.
The diameter of the pitch circle is known as pitch circle diameter.

2. **Addendum circle**- A circle concentric with the pitch circle and bounding the outer ends to the teeth is called an addendum circle.
The diameter of the addendum circle is known as addendum circle diameter.

3. **Addendum**-It is the radial distance between the pitch circle and addendum circle.

4. **Dedendum (Or root) circle**-It is a circle concentric with the pitch circle and bounding the bottom of the tooth.

5. **Dedendum**.-It is the radial distance between the pitch circle and the dedendum circle.

6. **Clearance**. The difference between the dedendum (of one gear) and addendum (of the mating gear) is called as clearance.

7. **Working depth**- It is the sum of the addenda of the two mating gears.

8. **Circular thickness (or Thickness of tooth**)-The length of arc between the sides of a gear tooth, measured on the pitch circle is known as circular thickness (or thickness of tooth).

9. **Tooth space**- It is the width of the space between two adjacent teeth measured along pitch circle.

10. **Backlash**-It is the difference between the tooth space and the tooth thickness.

11. **Face**- It is the action or working surface of the addendum.

12. **Flank**-The working face of the dedendum is called the flank.

13. **Top land**- It is the surface of the top of the tooth.

14**. Bottom land**-It is the surface of the bottom of the tooth space.

15. **Whole depth**-It is the total depth of the tooth space, equal to addendum plus dedendum; also it is equal to the working depth plus clearance

16**. Tooth fillet**- It is the radius which connects the root circle to the tooth profile.

17. **Circular pitch**. The distance measured along the pitch circle from a point on one tooth to the corresponding point on an adjacent tooth is called circular-pitch.

$p = \pi d / z$

That is, the circular pitch is calculated by dividing the pitch circle circumference by the number of teeth.

18. **Pitch diameter** -It is the diameter of a pitch circle.

19. Diametral pitch. Number of teeth on a wheel per unit of its pitch diameter is
called the diametral pitch.

diametral_pitch **=** Number of teeth on the wheel**/**Diameter of the pitch circle

20. **Module-** It is the reverse of the diametral pitch. Ratio between the pitch diameter
and the number of teeth is known as module

Types of gears:
The types of gear are discussed below:

1. Spur gear-A spur gear is a gear wheel or pinion for transmitting motion between two parallel shafts. It is the simplest form of geared drive.

The teeth are cast or machined parallel with the axis of rotation of the gear.
The efficiency of power transmission by these gears is very high

The disadvantages are that they are liable to be more noisy in operation and may wear out

2. Helical gear-helical gear is one in which teeth instead, of being parallel with shaft as in ordinary spur gears, are inclined. This ensures smooth action.

3. Bevel gear-A bevel gear transmits motion between two shafts which intersect.

If the shafts are at right angles and wheels equal in size, they are called mitre gears;

If the shafts are not at right angles, they are sometimes called angle bevel gears.

Spiral toothed bevel gears are preferred to straight-toothed bevels in certain applications, because they will run more smoothly and make less noise at high speeds.

4. Worm gear-Worm gears connect two non-parallel, non-intersecting shafts which are usually at right angles. One of the gears is called worm .it is essentially part of a screw meshing with the teeth on a gear wheel, called "worm wheel".
Worm gearing is smooth and quiet.

3.1.4 Belt & Belt drive

A belt is a continuous band of flexible material passing over pulleys to transmit motion from one shaft to another.

Belts are available:
1. with a narrow rectangular cross-section-Flat belts
2. with a trapezoidal cross-section-V-belts
3. Round cross-section-Round belts

Flat belts:
Flat belts are used for their simplicity and because they are subjected to minimum bending stress on the pulleys. The load capacity of flat belts is varied by varying their width, and only one is used in each drive.

They are made of leather, rubber, textile, balata and steel.

V-belts:
A V-belt is a belt of trapezoidal section running on pulleys with grooves cut to match the belt. The normal angle between the sides of the groove is 40 deg.
V-belts are usually made of fabric coated with rubber
They are used when the distance between the shafts is too short for flat-belt drives;
The V-belt is less likely to slip, hence more power can be transmitted for the same belt tension.

Round belts
These are employed to transmit low power, mainly in instruments, machinery of the clothing industry and household appliances.
They may be made of leather and rubber. The diameter range is from 3 to 12 mm, usually from 4 to 8 mm.

Belt drive:
A belt drive consists of the driving and driven pulleys and the belt which is mounted on the pulleys with a certain amount of tension

Belt drives may be:

(l) Open belt drive
(ll) Crossed belt drive.

Open belt drives -are applied, between parallel shafts which rotate in the same direction. Here the belt is subject to tension ‘and bending.

Crossed belt drives- the power is transmitted between small shafts rotating opposite direction. Since the angle of contact in this type of drive is more, it can transmit more power than open belt drive. However there is more wear and tear of the belt in this drive.

Applications of belt drives:
The main applications of belt drives are:
(l) To transmit power from low or medium capacity electric motors to operative machines.
(ii) To transmit power from small prime movers (internal combustion engines) to electric generators, agricultural and other machinery.

3.1.5 Bearings

A bearing is a device which supports, guides and restrains moving elements.
The material used for bearing is commonly cast-iron for slow speeds, bronze or brass lining being fitted for higher steels.
White metal or antifriction metal is used as a lining for the bronze, or it may be held directly in the cast-iron or in the steel of a connecting rod.

Classification of Bearings
Bearings may be classified as follows

1. Plain bearings:
(a) Journal bearing.
(b)Pivot bearing
(c) Collar or thrust bearing.

2. Ball and roller bearings.

Plain bearings

A journal bearing is one in which the bearing pressure is perpendicular to the axis of the shaft. The portion of the rotating element which is in contact with the bearing is called journal.

A pivot bearing is one in which the pressure is parallel to the axis of the shaft and the end of the shaft rests on the bearing surface.

In **collar bearing** the pressure is parallel to the axis of the shaft, which is passed and extended through the bearings. These bearings are employed to take up unbalanced axial loads on the horizontal Shaft

Ball and roller bearings
are also known as rolling contact bearings or rolling element bearings because the bearing elements especially are in a rolling contact.
Sometimes these are also referred to as “antifriction bearings”, through some friction is always present owing to rolling resistance between the balls/rollers and contacting parts etc.
The starting friction in ball and roller bearings is lower than that in an equivalent journal bearing in which metal-to-metal rubbing takes place at the time of starting.
The ball and roller bearings are also quite suitable at moderate speeds but at high speeds it is found that a properly designed and lubricated journal bearing has less friction.

3.2 Electrical actuator

An actuator receiving electrical energy for motion is called an electrical actuator.

Designs for electric actuators are based on the specific tasks they accomplish and they can vary in both dimension and size.

Most electric actuators operate through the interaction of magnetic fields and current-carrying conductors to generate force.

Electric actuators are found in applications as diverse as industrial fans, blowers and pumps, machine tools, household appliances.

3.2.1 Switches and relay

Switches

A switch is an electromechanical device used to make or break the circuits.

Switches can be controlled mechanically.

It controls the flow of current by opening or closing of circuits.

They are operated manually by a lever or by pushing the buttons.

It operates slowly when compared to relay because it requires a physical object to make the changes.

Example: Manual control of switch (Physical control of fans & lights at Home)

An electric switch is a device that interrupts the electron flow in a circuit. Circuits consist of a source of power and load. A load is a power-powered device. The function of an electric switch is to regulate the current between the load and source of power. The power source is the electrons that push through the circuits. The voltage is the quantity of force or pressure applied by the power source. Power sources must have a negative and positive endpoint. The negative terminal connects to the charge, and the electrons drive through the circuit. The load receives the current and returns it via the positive terminal to the power source. The electrical switch is inserted in this loop.

Relay

A relay is basically just a switch, but it's a switch operated via remote control.

Relays can be controlled electronically.

It controls high power circuits with low power signals by opening or closing the contacts.

It is used to protect the system from damage.

It operates faster than the switches.

It is a remote control switch.

Example: To turn ON/OFF an Air Conditioner

Relay works on the principle of electromagnetic induction. When the electromagnet is applied with some current it induces a magnetic field around it. In the relay, Copper coil and the iron core acts as an electromagnet.

When the coil is applied with DC current it starts attracting the contact as shown. This is called energizing of relay.

When the supply is removed it retrieves back to the original position. This is called De energizing of relay.

3.2.2 Solenoid

A "solenoid" consists of a coil and a movable iron core called the armature. When the current is passed through the coil it gets energized and consequently the core moves to increase the flux linkage by closing the air gap between the cores. The movable core is usually spring-loaded to allow the core to retract when the current is switched off. The force generated is approximately proportional to the square of the current and inversely proportion to the square of the width of the air gap.

They are frequently used in:
- Home appliances
- Automobiles
- Factory automation.

3.2.3 D.C Motors

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. Dc motors take electrical power through direct current, and convert this energy into mechanical rotation.

DC motors use magnetic fields that occur from the electrical currents generated, which powers the movement of a rotor fixed within the output shaft. The output torque and speed depends upon both the electrical input and the design of the motor.

DC motors can vary in size and power from small motors in toys and appliances to large mechanisms that power vehicles, pull elevators and hoists, and drive steel rolling mills.

DC motors include two key components: a **stator** and an **armature**. The stator is the stationary part of a motor, while the armature rotates. In a DC motor, the stator provides a rotating magnetic field that drives the armature to rotate.

WORKING

A simple DC motor uses a stationary set of magnets in the stator, and a coil of wire with a current running through it to generate an electromagnetic field aligned with the centre of the coil. One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field.

The windings of insulated wire are connected to a commutator (a rotary electrical switch), that applies an electrical current to the windings. The commutator allows each armature coil to be energized in turn, creating a steady rotating force (known as torque).

When the coils are turned on and off in sequence, a rotating magnetic field is created that interacts with the differing fields of the stationary magnets in the stator to create torque, which causes it to rotate. These key operating principles of DC motors allow them to convert the electrical energy from direct current into mechanical energy through the rotating movement, which can then be used for the propulsion of objects.

Types of DC Motors

- **Brushless DC motors** are also known as electronically commutated motors, or synchronous DC motors.

The key differences between brushless DC motors and other varieties is that they do not have a commutator, which is replaced by an electronic servomechanism that is able to detect and adjust the angle of the rotor.

The **brushless DC motor** has several advantages. Commutators use soft contacts called ‘brushes’ which wear down over time. A brushless DC motor is therefore more durable, and also safer than the more classical design.

- The **brushed DC motor** is the original DC motor. The classic brushed motor features a commutator, to reverse the current every half cycle and create single direction torque.

While brushed DC motors remain popular for electrical propulsion, cranes, paper machines, and steel rolling mills, many have been phased out for the more efficient brushless model in recent years.

- A **DC shunt motor** is a variety of brushed motor that has the field windings connected in parallel with the armature. Shunt wound DC motors have a lower current because of the parallel windings.

A shunt motor is used for applications that require a constant torque, where the load is not significantly altered by speed, such as conveyor belts, mixers and hoists.

The specific field windings provide unique shunt motor characteristics that make it such an effective choice for constant torque applications.

Applications of DC motors

At home, small DC motors are used in tools, toys and various household appliances. In retail, the applications of DC motors include conveyors and turntables, while in an industrial setting, large DC motor uses also include braking and reversing applications.

3.2.4 A.C Motors

An AC motor is an electric motor that uses alternating current to produce mechanical energy using magnetism blended with alternating current. The structure of an AC motor includes coils that produce a rotating magnetic field inside a rotor attached to an output shaft, which produces a second magnetic field.

WORKING

The main components of an AC motor are the stator, stationary outer drum, and the rotor, the rotating inner portion attached to the motor shaft. The stator and the rotor produce rotating magnetic fields. The winding of the stator that creates the rotating field is created by alternating current.

In an AC motor the winding serves as the armature and field winding. When the stator is connected to an AC supply flux an air gap is formed rotating the flux at a fixed synchronous speed, which produces voltages in the stator and rotor winding.

The term AC motor describes several versions of the motor, which include single phase, three phase, brake, synchronous, asynchronous, customized, two speed, and three speed single phase. The difference between the various versions relates to the type of work that is required where some forms of AC motors are simple and used for small jobs while other versions are designed for bigger more demanding work. A key difference is the phase of the electrical feed, which is different for residential use compared to industrial use.

Residential electricity is single or double phased while electricity for industrial use is three phased. This distinction is the reason for the difference between industrial AC motors and residential ones.

AC motors are referred to as induction motors since they use electric current to produce torque, which is created by electromagnetic induction from the magnetic field of the stator

The stator produces a rotating magnetic field. It has a solid metal axle, a loop of wire, coils, squirrel cage, and interconnections. Though a squirrel cage is not found in all AC motors, it is the most common type. In AC motors, electricity is sent directly to the outer coils of the stator. The stator has multiple plates that extend out from its center with copper magnetic wire.

For a three phase AC motor, it has three phase windings with a core and housing. The windings are 120o apart, which can be six or twelve windings. The windings are placed on a laminated iron core.

Unlike a DC motor, the rotor on an AC motor does not have any connection with the external power source. It receives its power from the stator. In a three phase induction motor, the rotor can be a squirrel cage or wound version.

In the squirrel cage version, the rotor consists of rotor bars with end rings at both ends. In the majority of cases, the squirrel cage is made of aluminum or copper. In the operation of a squirrel cage motor, the bars of the rotor interact with the stator's electromagnetic field (EMF). As the current fluctuates, the EMF does the same causing the rotor to rotate producing rotational motion. A key factor in the motion is that the rotor does not turn at the same frequency as the AC current and is constantly trying to catch up, which is how the rotation is produced. If it did have the same frequency, the rotor would freeze, and there would not be any motion.

A wound or slip ring AC motor is a special type of AC motor. It contains the exact same parts as all AC motors but is always three phase. The cylindrical laminated core of the rotor is wound exactly like the windings on the stator with wire. The terminal ends of the wires are connected to slip rings on the output shaft. The slip rings connect to brushes and a variable speed resistor. The slip rings provide control of the speed and torque of the motor, which is the main positive feature of a wound rotor.

Types of AC Motors

Single Phase AC Motor

Single phase AC motors are used where there is a single phase supply. This type of AC motor is smaller and less expensive. They are constructed using fractional kilowatt capacity. The stator is activated by a single phase AC electrical supply. Unlike a three phase AC motor, a single phase motor has one main winding and one auxiliary winding, which is perpendicular to the main winding.

The rotor rotates according to the sum of two oppositely rotating fields, which is the double revolving field theory. The torque that is produced is equal and opposite.

Polyphase AC Motor

Polyphase Motors, or many phase motors, are a type of AC motor that can be two or three phase and are similar to single phase motors in how they operate. The stator poles in a polyphase motor are not aligned with each other, which means that the rotor passes by the stator poles at different times. A polyphase system has a group of equal voltages at the same frequency that are placed to have an equal phase difference between the adjacent electromagnetic fields (EMF). A polyphase system can be two, three, or six phase with the majority being three phase.

Synchronous AC Motor

A synchronous AC motor is where the rotation of the shaft is at the same frequency as the current supply with the rotation period being equal to the integral number of AC cycles. The synchronous speed is constant and at which the motor generates electromotive force.

The speed of a synchronous motor is independent of the load where variations in the load does not affect the speed of the motor. Synchronous motors are not self-starting, which is unlike self-starting motors where the power supply is connected directly to the stator.

Asynchronous Motor

An asynchronous motor uses an induced current in its rotor to produce rotatory motion. This is the most common of the AC motors since it relies on AC current that is connected to the stator for its power supply. All of the power for an asynchronous motor is connected to the stator, none of which is connected to the rotor. The power for the rotor comes from induction.

The induction for the rotor is due to its close proximity to the stators electromagnetic field, which causes the rotor to generate its own electromagnetic field that causes it to spin. Since there aren't any brushes or slip rings, an asynchronous motor is the most efficient and reliable of all of the AC motors. It is used for heavy duty applications because of its simplicity of design and ruggedness.

3.2.5 Stepper Motors

A stepper motor is an electromechanical device it converts electrical power into mechanical power.

The stepper motor uses the theory of operation for magnets to make the motor shaft turn a precise distance when a pulse of electricity is provided.

The **construction of a stepper motor** is fairly related to a DC motor. It includes a permanent magnet like Rotor which is in the middle & it will turn once force acts on it. This rotor is enclosed through a no. of the stator which is wound through a magnetic coil all over it. The stator is arranged near to rotor so that magnetic fields within the stators can control the movement of the rotor.

The stepper motor can be controlled by energizing every stator one by one. So the stator will magnetize & works like an electromagnetic pole which uses repulsive energy on the rotor to move forward. The stator's alternative magnetizing as well as demagnetizing will shift the rotor gradually &allows it to turn through great control.

The **stepper motor working principle** is Electro-Magnetism. It includes a rotor which is made with a permanent magnet whereas a stator is with electromagnets. Once the supply is provided to the winding of the stator then the magnetic field will be developed within the stator. Now rotor in the motor will start to move with the rotating magnetic field of the stator.
In this motor, there is a soft iron that is enclosed through the electromagnetic stators. The poles of the stator as well as the rotor don't depend on the kind of stepper. Once the stators of this motor are energized then the rotor will rotate to line up itself with the stator otherwise turns to have the least gap through the stator. In this way, the stators are activated in a series to revolve the stepper motor.

Types of Stepper Motor

There are three main types of stepper motors, they are:

- Permanent magnet stepper
- Hybrid synchronous stepper
- Variable reluctance stepper

Permanent Magnet Stepper Motor

Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets.

This is the most common type of stepper motor. This motor includes permanent magnets in the construction of the motor. The main benefit of this stepper motor is less manufacturing cost.

Variable Reluctance Stepper Motor

Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles.

The stepper motor like variable reluctance is the basic type of motor

Hybrid Synchronous Stepper Motor

Hybrid stepper motors are named because they use a combination of permanent magnet (PM) and variable reluctance (VR) techniques to achieve maximum power in small package sizes.

The most popular type of motor is the hybrid stepper motor because it gives a good performance. But, this type of stepper motor is expensive as compared with permanent magnet stepper motors.

3.2.6 Specification and control of stepper motors

- Size: 42.3 mm square × 48 mm
- Weight: 350 g
- Shaft diameter: 5 mm
- Steps per revolution: 200
- Current rating: 1.2 A per coil
- Voltage rating: 4 V
- Resistance: 3.3 Ω per coil
- Holding torque: 3.2 kg-cm
- Inductance: 2.8 mH per coil
- Lead length: 30 cm
- Output shaft supported by two ball bearings

Stepper motor control provides this input train of pulses to command the motor to move to the desired position or at the desired speed.

Stepper motor control constant voltage drives are used to apply a constant positive or negative voltage to each winding to drive motion.

3.2.7 Servo Motors D.C & A.C

A **servo motor** is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you want to rotate an object at some specific angles or distance, then you use a servo motor. It is just made up of a simple motor which runs through a **servo mechanism**.

If motor is powered by a DC power supply then it is called DC servo motor, and if it is AC-powered motor then it is called AC servo motor.

Servo Motor Working Mechanism

It consists of three parts:

1. Controlled device
2. Output sensor
3. Feedback system

It is a closed-loop system where it uses a positive feedback system to control motion and the final position of the shaft. Here the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

Here reference input signal is compared to the reference output signal and the third signal is produced by the feedback system. And this third signal acts as an input signal to the control the device. This signal is present as long as the feedback signal is generated or there is a difference between the reference input signal and reference output signal. So the main task of servomechanism is to maintain the output of a system at the desired value at presence of noises.

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly, and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase torque of the motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer.

Difference between AC Servo Motor and DC Servo Motor

Characteristics	AC Servo Motor	DC Servo Motor
Efficiency	Low (about 5-20%)	High
Speed & Torque	Adaptable to strong torque and high-sped working condition.	Adaptable to a limited torque and speed.
Stability	Less stability issues	More problems of stability
Noise	No radio frequency noise	Brushes cause radio frequency noise
Operation	Have stable and smooth operation	Noisy operation
Weight & Size	Lighter weight and small in size	Heavy weight and large in size
Repair & Maintenance	Since no commutators, Less maintenance is required	Because of commutation process, regular maintenance is needed.
Output Power	Deliver low power normally between 0.5W and 100W	Provide high power

Unit 4: PROGRAMMABLE LOGIC CONTROLLERS (PLC)

4.1 Introduction

A PLC is an industrial computer that has been adapted for the control of manufacturing processes, such as assembly lines, machines, robotic devices, or any activity that requires high reliability, ease of programming, and process fault diagnosis.

4.2 Advantages

PLC increases the reliability, flexibility, and accuracy of the automation system.

PLC has a lower cost associated with it as compared to the other automation technology.

PLC has good capabilities and flexibility for programming. Even, you can easily make the modification in the existing program at any time.

Programming used for PLC is easy to write and understand.

PLC does not take much space. It occurs smaller in size, especially compact PLC.

Fast operation

PLC has low maintenance associated with it.

In the PLC system, we require less and simple wiring as compare to the other systems.

One can easily make the changes in an already implemented design.

In the case of PLC design, if anything goes wrong, one can easily troubleshoot the problem.

It can sustain in a robust environment with less maintenance.

4.3 Selection and uses of PLC

Uses

1. Industrial Applications of PLC-

Transportation System likes Conveyor Belt System.

Packing and Labeling System in Food & Beverage.

Automatic Bottle or Liquid Filling System.

Packaging and Labelling System in Pharma Industries.

Industrial Crane Control System for Operation of Overhead Traveling Crane.

Glass Industries for glass production and recording data.

Paper Industries for the production of Pages, Books or Newspapers, etc.

Cement Industries for manufacturing or mixing the right quality and quantities of raw materials, and accuracy of data regarding.

Fault Detection and Protection of Industrial Machines

2. Power Station Applications of PLC-

PLC is used to Monitor and Detect fault conditions.

It is used in the Power Generation, Transmission, and Distribution System.

PLC used in Underground Coal Mine or Water Level Sensing and Data Survey.

3. Commercial Applications of PLC-

Smart Traffic Control Signal System.

Fire Detection and Alarm System.

Luggage Handling System.

Sequence or Numerical Counting and Packing System.

Mining Equipment Line Detection

Selection of a PLC

For selection of a PLC, the following criteria need to be considered:

1. Types of inputs/outputs required
2. lnput/Output capacity required.
3. Size of memory required.
4. Speed and power required for CPU

4.4 Basic Internal Structures

The main components of a PLC consist of a central processing unit (CPU), power supply, programming device, and input and output (I/O) modules.

CPU
The CPU is the brain of the PLC and carries out programmed operations. These operations or outputs are executed based on signals and data provided from connected inputs.

I/O Modules
PLC input modules connect various external devices, such as sensors, switches, and push buttons to the PLC to read various digital and analog parameters, such as temperature, pressure, flow, speed, etc.

Output modules convert signals from the CPU into digital or analog values to control output devices.

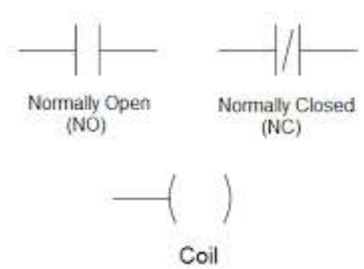
PLC Programming Language

The most common methods of PLC programming include Ladder Logic, Function Block, and structured text.

Ladder Logic
Ladder Logic is a graphical PLC programming language and is the most common method of programming. Ladder Logic can be used to execute tasks such as sequencing, counting, timing, data manipulation, and more.

For the Ladder Diagram (LD) programming language, normally open and normally closed contact is used in the form of input. And the coil or lamp is used in the form of output.

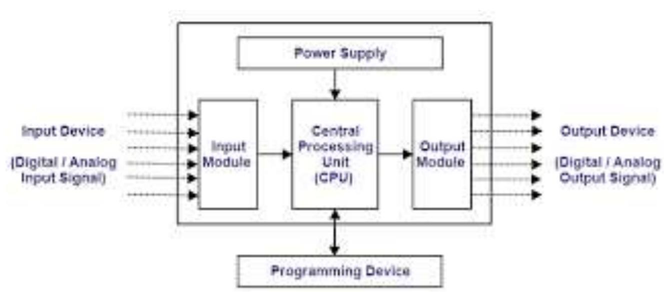
The symbolic representation of I and O modules in the LD program.



Structured Text
Structured text is a text-based PLC programming. Programming with structured text has multiple advantages, such as the program requiring less space due to being text based instead of graphic based.

Function Block
Function block PLC programs are represented in the form of graphical blocks. Function blocks can have standard functions such as timers, counters, calculating min and max values, obtaining averages, and more.

4.5 Input/Output Processing & Programming



Block Diagram of PLC Input and Output Modules

The input device provides a signal to an input module. This input module is connected with the CPU for the initial automated processes. CPU processes all the input data.

After processing by CPU, it gives output data to the output module. The output module provides a signal to the output device.

And the main function of the programming device is to change or monitor the PLC programming.

Classification of PLC Input and Output Modules

The classification of input and output (I/O) modules of PLC is based on the types of signals.

1. Digital I/O Module

The digital module is also called Discrete Module.
In this module, the I/O signal work on the binary system i.e. only 0 or 1 value.

It is useful in the ON or OFF condition.

2. Analog I/O Module

The analog module is called a Continuous Module.
This analog signal provides any intermittent value between the two extreme limits (initial to final range) for the analog input module.

4.6 Mnemonics

Mnemonics are memory devices that help learners recall larger pieces of information, especially in the form of lists like characteristics, steps, stages, parts, etc.

Mnemonic code provides the same information as ladder diagram and can be typed directly on Programming Console.

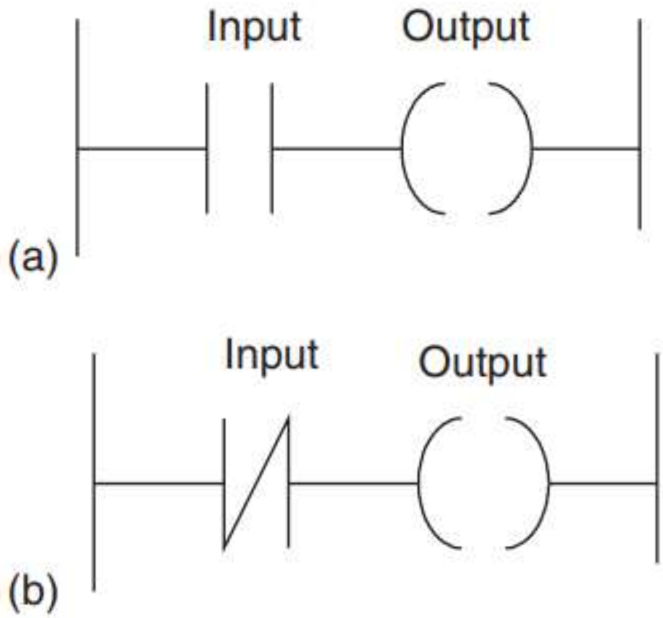
There are a lot of instructions used to develop the PLC program. Each instruction has a respective function.

LD - LOAD Instruction

These instructions are used to start a line of the program.
It is used in the first contacts in the normally open condition (NO).

LD NOT - LOAD NOT Instruction

These instructions are used to start a line of the program.
It is used in the first contacts in the normally closed condition (NC).

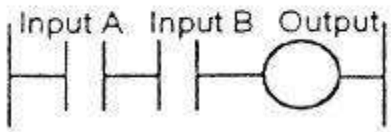


AND - AND Instruction
These instructions are used in the second contact in a normally open (NO) and a series with previous contacts

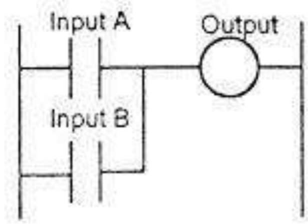
AND NOT - AND NOT Instruction
These instructions are used in the second contact in a normally closed (NC) and in series with previous contacts

OR - OR Instruction
These instructions are used in the second contact in a normally open (NO) and in line (parallel) with previous contacts**.**

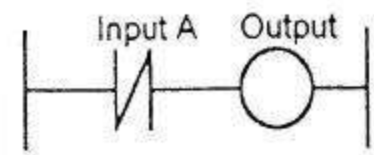
OR NOT - OR NOT Instruction
These instructions are used in the second contact in a normally closed (NC) and in line (parallel) with previous contacts



AND



OR



NOT

OUT - OUTPUT Instruction
These instructions are used for the coil output.

END
- END instruction has no physical contact device.
- It is the last instruction required for completion of a program.
- If no END instruction, the program cannot be implemented

4.7 Master and Jump Controllers

Master controls can be thought of as "emergency stop switches".

PLC manufacturers offer a form of a master control relay as part of their instruction set. These instructions function in a similar manner to the hardwired master control relay; that is, when the instruction is true, the circuit functions normally, and when the instruction is false, non-retentive outputs are switched off.

Jump instruction in ladder logic is used to skip some process or rungs according to the requirement

When the jump instruction is used, the PLC will not execute the instructions of a rung that is jumped

The MCR instruction sets all non-retentive outputs to the false state and keeps the retentive outputs in their last state. The JMP instruction leaves all outputs in their last state.

Unit 5: ELEMENTS OF CNC MACHINES

5.1.1 NC machines

Numerical control, popularly known as the NC is very commonly used in the machine tools.

The numerical control machine is defined as the machine that is controlled by the set of instructions called as the program.

In numerical control method the numbers form the basic program instructions for different types of jobs; hence the name numerical control is given to this type of programming.

When the type of job changes, the program instructions of the job also change.

It is easier to write the new instructions for each job, hence NC provides lots of flexibility in its use.

The NC technology can be applied to wide variety of operations like drafting, assembly, inspection, sheet metal working, etc. But it is more prominently used for various metal machining processes like turning, drilling, milling, shaping etc.

Due to NC all the machining operations can be performed at the fast rate resulting in bulk manufacturing becoming quite cheaper.

There are 3 types of NC machines and are as follows.

- **Traditional Numerical Control (NC Machine)**

They can run with the help of a tape reader system i.e. whatever the operation you want to perform, you can punch it on the tape, and thereby the NC machine can perform that operation.

- **Computer Numerical Control (CNC Machine)**

The Evolution of the CNC machine takes place after the evolution of NC machines. To overcome the limitation of the NC machine, the CNC machine has come into the picture.

In the case of NC machines, the Tape Reader system is used, which after several usages, the wear and tear of the tape take place and the operator has to punch again on the new tape to carry out the operation.

In order to avoid this limitation of NC Machine, the CNC machine uses a computer-generated file to store the program which was written by the usage of G-Codes and M-Codes.

Whatever operation you need to change like speed, feed, depth of cut, etc. can be changed in the program instantly and there is no damage to the file as of tape reader. This is the reason, CNC machines are used which are highly accurate compared to NC Machines.

- **Distributed Numerical Control (DNC Machine)**

The DNC Machine is similar to CNC Machine, except a remote computer is used to control no. of machines that can perform no. of operations at a time

A NC Machine is consist by following parts:

1. MCU or CPU
2. Drive Unit
3. Feedback Devices
4. Tape Reader system
5. Very Few Manual Controls

MCU (Memory Controlled Unit):
MCU is the Memory Control Unit that is taking the information from the input devices via the keyboard or mouse and analyze the data, and send the data to the output devices available in the NC machine.

Drive Unit:
Drive unit is a device that is used for converting Electrical energy into Mechanical energy which is required for traveling the axis.

Feedback Devices:
Feedback device is a Displacement Measuring Equipment. MCU will compare the distance traveled by the axis with the distance to be traveled and determines the difference in distance.
The MCU will calculate the no.of pulses and send it to the drive unit. This process continues in the form of a cycle.
Feedback Device→MCU→Drive Unit.

Tape Reader System:
The instructions for doing operation was punched on the paper tape. For reading the instruction given in the punched paper tape, a **tape reader system** will be used.

Light is provided on one side of the tape and light receiving sensors are placed on the other side.
When the tape is moving and stopping at some location where the holes are present, the light is passing and is incident on light receiving sensors. The sensors which are receiving the light generate the electrical pulse and that is to be sent to the Memory Control Unit (MCU) to drive the motor of a machine to do the operation precisely.

Very Few Manual Controls:
Even though the above parts are present in the NC machine, still the manual interventions are required for loading and unloading of the work piece, switching ON and OFF, etc. called manual controls.

5.1.2 CNC machines

Computer Numerical Control (CNC) machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to control a range of complex machinery, from grinders and lathes to mills

With a numerical control machine, programs are inputted via punch cards. By contrast, the programs for CNC machines are fed to computers through small keyboards. CNC programming is retained in a computer's memory. The code itself is written and edited by programmers.

The language behind CNC machining is alternately referred to as G-code, and it's written to control the various behaviors of a corresponding machine, such as the speed, feed rate and coordination.

Functions of CNC:
The principal functions of CNC are:
1. Machine tool control.
2. In-process compensation.
3. Improved programming and operating features.
4. Diagnostics.

Advantages of CNC machines:
CNC machines offer the following advantages in manufacturing:
1. Greater flexibility.
2. Reduced data reading error.
3. Increased productivity.

4. Consistent quality.
5. Automatic material handling.
6. Elimination of operator errors.
7. Reduced operator activity.
8. Lower labour cost.
9. Smaller batches.
10. Longer tool life.
11. Just-in-time manufacture.
12. Reliable operation.
13. Elimination of special jigs and fixtures.
14. Reduced inspection.
15. Less scrap.
16. Accurate costing and scheduling.
17. CNC machine can diagnose program and can detect the machining malfunctioning even before the part is produced.
18. Conversion of units - possible within computer memory.

Disadvantages of CNC machines:
1. Higher investment cost.
2. Higher maintenance cost.
3. Costlier CNC personnel.
4. Air-conditioned places are required for the installation of the machines.
5. Unsuitable for long run applications.
6. Planned support facilities.

Applications of CNC:
CNC is being used in the following machines/areas:
Drilling machines.
Turning machines.
Boring machines.
Milling machines.
Grinding machines.
Pipe bending machines.
Coil winding machines.
Flame cutting machines.
Welding, wire cut EDM and several other areas.

5.1.3 CAD/CAM

CAD/CAM (Computer-Aided Design/Computer-Aided Manufacture) technology was initiated in the aerospace industry but presently it is spreading at a rapid pace in all industries.
It can be defined most simply as the use of computers to translate a product's specific requirements into the final physical product.

With this system, a product is designed, produced and inspected in one automatic process.
It plays a key role in areas such as design analysis, production planning, detailing, documentation,N/C part programming, tooling fabrication, assembly, jig and fixture design, quality control, and testing.

Whenever any deviation is noted, a programmable controller takes automatic corrective action to compensate for the deviation. Thus a closed loop system is formed which produces consistent quality products, reduces wastes and increases productivity.

CAD/CAM system is ideally suited for designing and manufacturing mechanical components of free form complex with three dimensional shapes

5.1.3.1**CAD**

CAD (Computer Aided Design) is defined as:
A design process using sophisticated computer graphics techniques, backed up with computer software packages to aid in the analytical, development, costing and ergonomic problems associated with design work

Advantages:
The following are advantages of CAD:
1. Drawings can be produced at a faster rate.
2. Drawings produced by CAD systems are more accurate and neat.
3. In this system there is no repetition of the drawings.
4. CAD systems assimilate several special draughting techniques which are not available with conventional means.
5. Design calculations and analysis can be carried out quickly.
6. With CAD systems superior design forms can be produced.
7. CAD simulation and analysis techniques can drastically cut the time and money spent on prototype testing and development - often the costliest stage in the design process.
8. Using CAD systems design can be integrated with other disciplines.

5.1.3.**2 CAM**

CAM (Computer-Aided Manufacture) concerns any automatic manufacturing process which controlled by computers.

The most important elements of CAM are:
1. CNC manufacturing and programming techniques.
2. Computer controlled robotics manufacture and assembly.
3. Flexible Manufacturing Systems
4. Computer Aided Inspection (CAI)
5. Computer Aided Testing (CAT)

Advantages:
CAM entails the following, advantages '.
1. Product obtained is superior in quality.
2. The manufactured form has a greater versatility.
3. Higher production rates with lower work-forces.
4. There is less likelihood of human error.
5. Increased manufacturing efficiency
6. The production processes can be repeated via storage of data.

5.1.3.**3Software and hardware for CAD/CAM**

Software usually consists of a number of separate application packages to perform the desired function. The size of computer depends on the number and sizes of packages and number of work stations

Hardware is responsible for the reliability and speed of response of the system.

CADD Hardware

- System Unit
- Central Processing Unit (CPU)
- Memory
- Hard Disk, Floppy Disk, CD-ROM

- External Storage Devices
- The Monitor
- Printers and Plotters
- Digitizer, Puck and Mouse

CADD Software

- Draw
- Edit
- Data output
- System control
- Data storage and management

5.1.3.4 <u>Functioning of cad cam systems</u>

In order to generate the actual model, **CAM works alongside CAD**—using CAD designs, CAM uses numerical coding to run the machine that creates the product. A CAD/CAM package allows companies to develop and save their own product designs, and program machines to create the actual component.

Computer-aided design & computer-aided manufacturing (CAD/CAM) software is **used to design and manufacture prototypes, finished products, and production runs of products**.

5.1.3.5 <u>Features and characteristics of CAD/CAM system</u>

1. A major portion of the output of the engineering sector involves batch production and CAD/CAM offers immense cost and quality benefits for such requirements.

2. The work-in-progress, in batch production, is reduced considerably.

3. It is possible to produce at random all the variants and series of a product planned to be manufactured by a firm.

4. Such a system has inherent flexibility to cater to new models of the product in pipeline without major modification.

5. In such a system, several machining centres are arranged one after the other with robots and proper automatic materials handling equipment. Software is developed to integrate the machine CNC control and the handling system. Each machining centre is equipped with several tool magazines. All the tools required to complete each operation on each model of the product can be stored in the magazine.

6. All the part Programs for the different models are stored in the memory. System has only to identify the model of the product presented to a machine in order to complete the machining operations. Thus it is possible to have totally random mixes of models of a product proceeding down the line at any one time.

7. System can be conceived in multiplies of 15-20 minutes operations. If certain operations take longer, then multiples of similar machines can be installed in the line. Sometimes identical machines are introduced for each operation so that production can continue even if one machine goes down.

5.1.3.5 <u>Application areas for CAD/CAM</u>

1. Design and design analysis:

CAD system would be best suited for drawing offices where frequent modifications are required on drawing and several parts repeat.
It must be remembered that it is very easy with computer to make modifications and very fast to draw part profile once its details are fed into computer.
Once a drawing is entered in the CAD system, Iater modifications can be done quickly, and detail drawings can be prepared quickly from a general arrangement drawing.
Storing of the drawing is very convenient, easy, occupies very less space and symbols for electrical, hydraulic, control and instrumentation circuits can be called up quickly and positioned on the schematic drawing.

Standard components can be stored permanently in the data base and called up and positioned on the drawing, resulting in saving of time and enforcement of standards. It is possible to associate nongraphical information like past number, supplier, material etc., for any component assembly.
It is very convenient to calculate properties like weight, centre of gravity, moment of inertia, etc., because 3-D models can be easily produced.
It is also possible to carry out finite element analysis by producing meshing for analysis.

2. Manufacture:
With cAD/cAM system the complete NC part programming process can be carried out interactively,

5.**2Elements of CNC machines**

1. Machine structure.
2. Guideways/Slideways.
3. Drives.
4. Spindle and spindle bearings.
5. Measuring systems.
6. Controls.
7. Gauging
8. Tool monitoring.
9. Swarf removal.
10. Safety.

Measuring Systems-
Measuring systems are used on all the CNC machines to perform the following functions:
1. To monitor the position of a slide on a slideway.
2. To orient the spindle/table.
3. To measure the spindle speed.

Controls
For CNC machines, CNC controls are of significant importance. Earlier, CNC controls were developed for simple applications in turning, machining centres and grinding, but these days CNC systems have been developed to meet with the increased machine tools requirements of higher spindle speeds, higher rapid traverses and more number of axes. The new generation computer numerical controls allow simultaneous control of more axes, interpolate positions faster, and use more data points for precise control.

The new controllers offer the following:
- Advanced graphic interfaces;
- Program simulation;
- Some cutter selecting capabilities.

Gauging

The quality can be maintained by eliminating the effect of parameter like tool wear and thermal growth, with the use of automatic gauging system.

The gauging on a machine tool may be used for the following purposes-
To inspect workpiece.
To detect tool breakage.
To define tool offsets.
To automatically align the workpiece.
To detect the stock variation

Tool Monitoring System
The tools wear out or even break during machining. If tool n ear and breakage is not properly monitored, the productivity of the machine and the quality of the component produced are affected. Now-a-days established monitoring sensors and systems are available commercially which can be integrated with CNC machines.

Following are the two ways of monitoring tool wear and breakage:
1. Direct monitoring: In this type of monitoring a touch probe is directly used to monitor the tool condition by checking the tool edge position and checking for the existence of a tool edge.

2. lndirect monitoring: Here, the tool condition is checked indirectly by monitoring the change in certain parameter whose value when affected reflects the tool condition.

Following parameters are used to monitor tool condition:

(l) Cutting forces.
(ii) Tool life.
(iii) Workpiece dimensions.
(iv) Emission of noise during cutting
(v) Power of the spindle or a feed drive or a driven tool.

Swarf Removal
In CNC machines the cutting time is much more and as such the volume of swarf generated is also more.
- Unless the swarf is quickly and efficiently removed from the cutting zone, it can affect the cutting process and quality of the finished product.
- Also the swarf cannot be allowed to accumulate at the machine tool because it may hamper the access to the machine tool.
- In addition some auxiliary functions like automatic component loading or automatic tool change may also be affected by accumulation of swarf.
To overcome all above problems it is necessary to provide an efficient swarf control system with the CNC machine tools with some mechanism to remove the swarf from the cutter and cutting zone and for the disposal of swarf from the machine tool area itself.

Safety
As the CNC machines are under continuous automatic operation, there is a need to protect the machine guideways and to ensure operators safety since the machines run at high speeds with automatic auxiliary operations.
- In order to have efficient working and long life of the machine it is essential to protect machine guideways, drive screws and transducers etc. These elements are protected by the use of various types of collapsible guards and covers.

All the sliding elements are fitted with wipers and drive screws are normally protected by using telescopic covers. Jets of cutting fluids are used to wash away swarf and clear the tool work area.
- Operator's safety is very important aspect which cannot be overlooked. To ensure safe working conditions the CNC machine tools are provided with metallic or plastic guards.

5.2.**<u>1 Introduction</u>**

5.2.**<u>2Machine Structure</u>**

The "machine structure" is the load carrying and supporting member of the machine tool.
The design and construction of CNC machine should be such that it meets the main “objectives"

(i) High precision and repeatability
(ii) reliability;
(iii) Efficiency.

In order to meet these requirements, the numerically controlled machine tools should have a structure with the following characteristics:

1. It does not deform or vibrate beyond the permissible limits under the action of static and dynamic forces, to which it is subjected.
Static load of a machine tool results from the weights of slides and the workpiece, and the forces due to cutting.
Dynamic loads a term used for the constantly changing forces acting on the structure while the movement is taking place.
These forces cause the whole machine to vibrate and the origin of these vibrations may be due to unbalanced rotating parts, improper meshing of gears, bearings irregularities

2. Its design should be such that the thermal distortion is minimum. The machine tool should be protected from external and internal heat sources; some of these heat sources are: Electric motor; friction in mechanical drives, gear boxes, bearings and guideways; machinery Process; temperature of surrounding objects.

3. The machine structure design should be such that the removal of swarf is easy and the chips etc., do not fall on the slideways.

<u>5.2.3 Guideways/Slide ways</u>

5.2.3.**<u>1Introduction and Types of Guideways</u>**

Introduction

In machine tools the guideways are used to serve the following purposes;
(i) To control the direction or line of action of the carriage or the table on which a tool or a workpiece is held.
(ii) To absorb all static and dynamic loads.

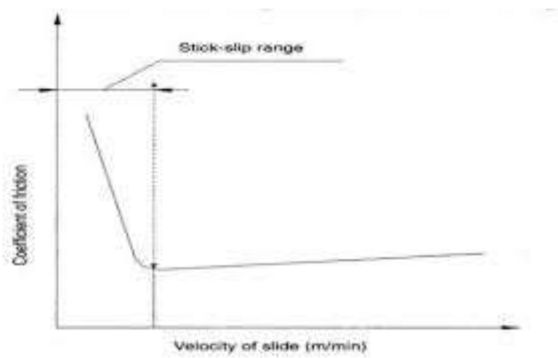
The guideways may be an integral part of the machine structure or may be mounted separately on the structure.
These guideways may be horizontal, vertical or inclined.
However vertical and inclined guideways are preferred so that chips produced during the cutting operation do not get collected on the quickways.
The shape and size of the work produced depends on the accuracy of the movement

Guideways are broadly classified as follows:
1. Friction guideways.
(i) Vee guideways.
(ii) Flat guideways
(iii) Dovetail guideways.
(iv) Cylindrical guideways

2. Antifriction linear motion (LM) guideways.

3. Frictionless guideways:
(l) Hydrostatic guideways.
(ii) Aerostatic guideways.

Friction guideways
These guideways find wide application in conventional machine tools due to their low manufacturing cost and good damping properties.
It operate under conditions of sliding friction and do not have a constant coefficient of friction. The frictional coefficient varies with the sliding velocity



At the commencement of the movement, the coefficient of friction is very high, but as the velocity increases it falls rapidly and beyond a certain critical velocity it remains almost constant. Thus, to start motion/movement, the force to overcome friction has to be correspondingly high. This phenomenon is known as, stick-slip phenomenon.

Vee guideways:
The Vee guideways are widely used on machine tools, especially ' on lathe beds.

These guideways wear away rapidly due to lack of bearing surface. These are difficult to manufacture.

Flat guideways
These guideways have better load bearing capabilities than other guideways.
- These are easier to manufacture.
- In such guideways the chip accumulation and lubrication problems are serious.
- These do not wear uniformly.
- Jibs are used to ensure accurate fitting of the slide on the flat surface.

Dovetail guideways
These guideways have large load carrying capacity and tend to check the overturning tendency under eccentric loading.
- They are preferred when both horizontal and vertical locations of moving parts are considered essential.
- Jibs are used to ensure accurate fitting of the slide on the dovetail surface. The jibs are tapered and can be adjusted to reduce excessive clearance caused by wear.

Cylindrical guideways
These guideways are aery efficient for relatively short traverses and light loads.

- Their use for long traverses and heavy loads is not suitable because the guideways may sag or bend in the centre of the span under a load.

Antifriction linear motion (LM) guideways

These guideways are used on CNC machine tools to reduce amount of wear, friction, heat generation and improve smoothness of the movement,

The antifriction guideways are employed to overcome the relatively high coefficient of friction in metal-to-metal contacts. .

They use rolling elements in between the moving and stationary elements of the machine.

Advantages: The antifriction guideways claim the following advantages over the friction guides:

1. High load carrying capacity.
2. Heavier preloading possibility.
3. High traverse speeds.
4. Low frictional resistance.
5. No stick-slip.
6. Ease of assembly.
7. Commercially available in ready-to-fit condition.

Their main disadvantage is 'lower damping capacity'.

Types of antifriction guideways

1. Linear bearing with balls uses recirculating balls within a bush type of bearing.

These are designed to run along precision ground shafts and offer frictionless movement making strokes of length with high linear precision.

2**. Linear bearing with rollers**:

The recirculating linear roller bearings are used for movement along a flat plane. Their main characteristic feature is that there is continuous roller circulation which allows unlimited linear movement.

Frictionless guideways

Hydrostatic guideways:

- In these guideways the surface of the slide is separated from the guideway by a very thin film of fluid supplied at pressures as high as 300 bar.
- In hydrostatic guideways frictional wear and stick slip are entirely eliminated.
- In such guideways a high degree of dynamic stiffness and damping is obtained, both the characteristics contributing to good machining capabilities.
- Owing to high cost and difficulty in assembly, their application is limited.

Aerostatic guideways:

In these guideways, the slide is raised in a cushion of compressed air which entirely separates the slide and guideway surfaces.

Advantages of frictionless guideways:

1. Longer life.
2. Large damping capability.
3. Frictionless.
4. High stiffness.
5. No stick-slip.
6. Less thermal distortion due to better heat dissipation.

Disadvantages:

1. Difficulty in assembling the guideways.
2. High cost.

3. Leakage problems.

5.2.3.2 **Factors of design of guideways**

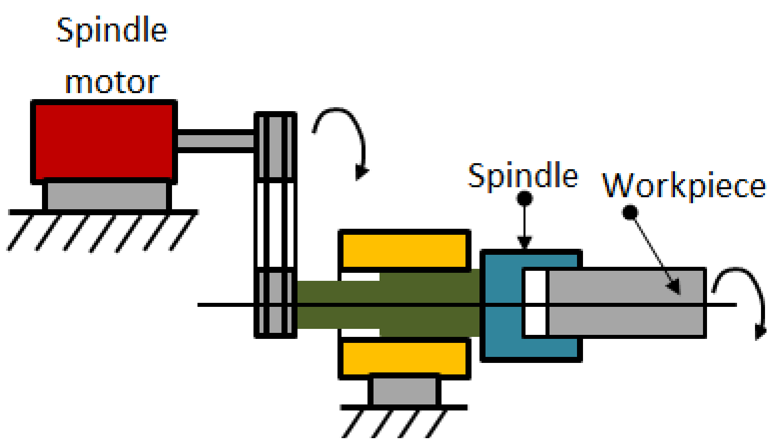
(i)Reduce friction;
(ii) Reduce wear;
(iii) Satisfy the requirements of movement of the slides;
(iv) Improve smoothness of the drive

The following factors should be considered while designing guideways:
1. Geometric and kinematic accuracy.
2. Position in relation to work area.
3. Provision for adjustment of play.
4. Rigidity.
5. Damping capability.
6. Velocity slide.
7. Friction characteristics.
8. Wear resistance.
9. Protection against swarf and damage.
10. Protective guards to safeguard the guideways against accidental damages.
11. Freedom from unnecessary restraints.
12. Effective lubrication and efficient lubrication svstems.

5.2.4 **Drives**
Devices which impart motion to mechanical components

The primary function of the drive is to cause motion of the controlled machine tool member to conform as closely as possible to the motion commands issued by the CNC system.

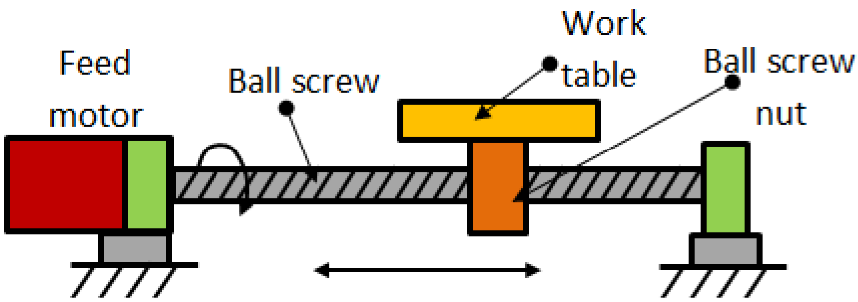
5.2.4.1 **Spindle drives**



The spindle drives are used to provide angular motion to the workpiece or a cutting tool.
These drives are essentially required to maintain the speed accurately within a power band which will enable machining of a variety of materials with variations in material hardness. The speed ranges can be from 10 to 20,000 rpm.

The machine tools mostly employ DC spindle drives. High overload capacity is also needed for unintended overloads on the spindle due to an inappropriate feed. It is desirous to have a compact drive with highly smooth operation.

5.2.4.2 Feed drive



These are used to drive the slide or a table
The requirements of an ideal feed drive are as follows.

- The feed motor needs to operate with constant torque characteristics to overcome friction and working forces.
- The drive speed should be extremely variable with a speed range of about 1: 20000, which means it should have a maximum speed of around 2000 rpm and at a minimum speed of 0.1 rpm.
- The feed motor must run smoothly.
- The drive should have extremely small positioning resolution.

5.2.5 Spindle and Spindle Bearings

Spindle

The spindle carrying the workpiece or tool when subjected to high cutting speeds and high material removal rates, experiences deflection and thrust forces. To ensure increased stability and minimize torsional strain, the machine spindle is designed to be short and stiff & the final drive to the spindles is located near to the front bearing as possible.

The rotational accuracy of the spindle is dependent on the quality and design of bearings used. The ball or roller are suitable for high speeds and high loads because of low friction, low wear rate &lesser liability to incorrect adjustment and ease of replacement when necessary.

Spindle bearings

In modern machine tools, which employ high performance cutting tool materials, the designed characteristics of spindles used are:
(l) Minimum deflection under varying loads.
(il) Long service life.
(lli) Stiffness.
(lv) Thermal stability'.
(v) Good running accuracy both in radial and axial directions.
(vi) Axial load carrying capacity'.
(vii) High speed of operation,

The various types of spindle bearings used in the design of a spindle for machine tools are:
1. Antifriction bearings.
2. Hydrostatic bearings.
3. Hydrodynamic bearings

1. Antifriction bearings

The antifriction bearings are suitable .for high speeds and high loads.
These are often preferred to hydrodynamic bearings because the following reasons-.
High reliability.
Ease of replacement.
Low friction.
Moderate dimensions.
Lesser liability to suffer from wear or incorrect adjustment.

2. Hydrostatic bearings

Here the spindle is supported by a relatively thick film of oil (called hydrostatic pockets) supplied under pressure; the oil in the pockets being stationary. The oil is supplied to the bearing through a throttling system to control pressure and volume. Lubricating seals are used to prevent the leakage of oil. There is no mechanical contact.
- The load carrying capacity of this type of bearing is independent of the speed of rotation.

They have the following merits '.
(i) High wear resistance.
(li) High damping properties.
(ili) High running accuracy.

These bearings are used in grinding and boring machines etc.

3. Hydrodynamic bearings

The Pressure of oil within the bearing is created by the rotation of the spindle. As the spindle rotates, the oil in contact with the spindle is carried into wedge shaped cavities between the spindle and the bearing due to centrifugal action. As the oil is forced through the small clearances between the bearing and spindle, the oil Pressure is increased.
In this type of bearing there is a constant flow of oil round the spindle, maintaining a thick oil film.

The essential features of these bearings are:
(i) Good running accuracy.
(il) Simplicity.
(lli) Good damping Properties.

(lli) Good damping Properties.

The main limitation of this type of bearing is that a definite clearance must be provided for the oil film to be maintained between bearing and the spindle; the clearances normally provided vary from 50 pm to 200 pm depending upon the journal diameter'
These bearings are used where the load carrying capacities are low-and frequent starting and stopping of the spindle is not required as in the case of grinding machines

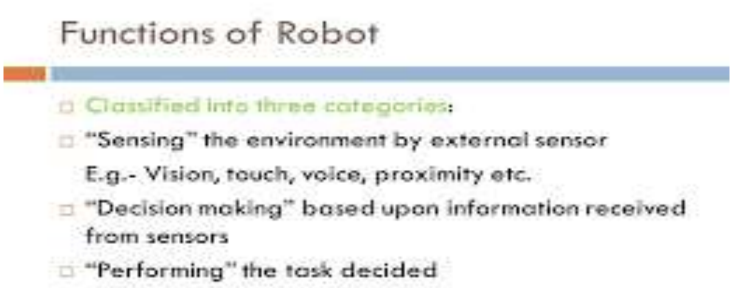
Unit 6: ROBOTICS

6.1 Definition, Function and laws of robotics

DEFINITION

Robotics is an interdisciplinary branch of computer science and engineering. Robotics involves design, construction, operation, and use of robots. The goal of robotics is to design machines that can help and assist humans.

FUNCTION



LAWS OF ROBOTICS

Isaac Asimov's "Three Laws of Robotics"

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

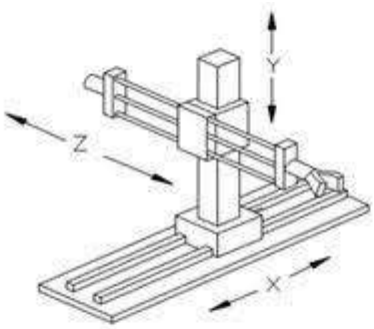
6.2 TYPES OF INDUSTRIAL ROBOTS

1. Cartesian Robots

Cartesian robots, which are also called linear robots or gantry robots, are industrial robots that work on three linear axes that use the Cartesian Coordinate system (X, Y, and Z), meaning they move in straight lines on 3-axis (up and down, in and out, and side to side).

Cartesian robots are a popular choice due to being highly flexible in their configurations, giving users the ability to adjust the robot’s speed, precision, stroke length, and size.

Cartesian Robots are one of the most commonly used robot types for industrial applications and are often used for CNC machines and 3D printing.



2. SCARA Robots

SCARA stands for Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm.

SCARA Robots function on 3-axis (X, Y, and Z), and have a rotary motion as well.

SCARA Robots excel in lateral movements and are commonly faster moving and have easier integration than Cartesian Robots.

Typically, SCARA robots are used for assembly as well as bio-med application.

3. Articulated Robots

Articulated Robots mechanical movement and configuration closely resembles a human arm.

The arm is mounted to a base with a twisting joint.

The arm itself can feature anywhere from two rotary joints up to ten rotary joints which act as axes, with each additional joint or axis allowing for a greater degree of motion.

Most Articulated Robots utilize four or six-axis.

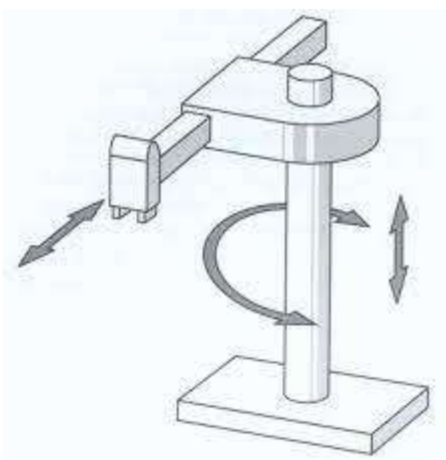
Typical applications for Articulated Robots are assembly, arc welding, material handling and packaging.

4. Cylindrical Robots

Cylindrical Robots have a rotary joint at the base and a prismatic joint to connect the links.

The robots have a cylindrical-shaped work envelop, which is achieved with rotating shaft and an extendable arm that moves in a vertical and sliding motion.

Cylindrical Robots are often used in tight workspaces for simple assembly, coating applications due to their compact design.



5. Delta Robots

Delta Robots, or parallel robots, possess three arms connected to a single base, which is mounted above the workspace.

Delta Robots work in a dome-shape and can move both delicately and precisely at high speeds due to each joint of the end effector being directly controlled by all three arms.

Delta Robots are often used for fast pick and place applications in the food, pharmaceutical, and electronic industries.

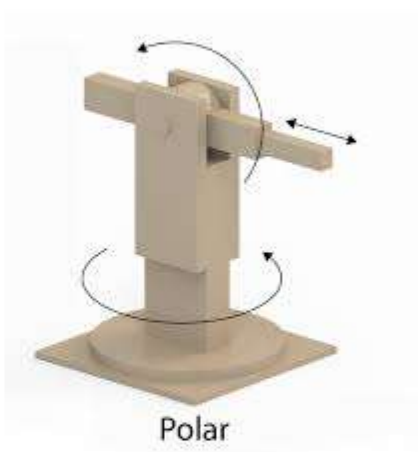
6. Polar Robots

Polar Robots, or spherical robots, have an arm with two rotary joints and one linear joint connected to a base with a twisting joint.

The axes of the robot work together to form a polar coordinate, which allows the robot to have a spherical work envelope.

Polar Robots are credited as one of the first types of industrial robots to ever be developed.

Polar robots are commonly used for die casting, welding, and material handling.



7. Collaborative Robots

Collaborative Robots or Cobots are robots that can directly and safely interact with humans in a shared workspace.

Cobots are typically used for pick and place, quality inspection, etc.

-

6.3 ROBOTIC SYSTEMS

There are three types of robotic systems –

1. Manipulation robotic system

The manipulation robot system is the most commonly used in the manufacturing industry.

These systems are made up of many of the robot arms with 4-6 axes and varying degrees of freedom.

They can perform several different functions, including welding, material handling and material removal applications.

2. Mobile robotic system

The mobile robotic system is a bit different.

This system consists of an automated platform that moves items from one place to another.

While these robot systems are used heavily in manufacturing for carrying tools and spare parts, they are also used in the agricultural industry for transporting products.

3. Data acquisition and control robotic system

Data acquisition and control robotic systems are used to gather, process and transmit data for a variety of signals.

They are also used in software for engineering and business.

Many of the mobile robotic systems can use signals from these systems.

6.4 ADVANTAGES AND DISADVANTAGES OF ROBOTS

Advantages

- Robots can increase productivity, efficiency, quality and consistency of products.
- Unlike humans, robots don't get bored
- Until they wear out, they can do the same thing again and again
- They can be very accurate
- Robots can work in environments which are unsafe for humans
- Robots don't have the same environmental requirements that humans do
- Robots have some sensors/actuators which are more capable than humans

Disadvantages

- The use of robots can create economic problems if they replace human jobs
- Robots can only do what they are told to do – they can't improvise
- Safety procedures are needed to protect humans and other robots
- Although robots can be superior to humans in some ways but they don't have such powerful brains, and cannot compete with a human's ability to understand.
- Often robots are very costly – in terms of the initial cost, maintenance, the need for extra components and the need to be programmed to do the task.

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

ADVANCED MANUFACTURING PROCESS

6TH SEMESTER

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1.1 Introduction – comparison with traditional machining

Modern Manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes.

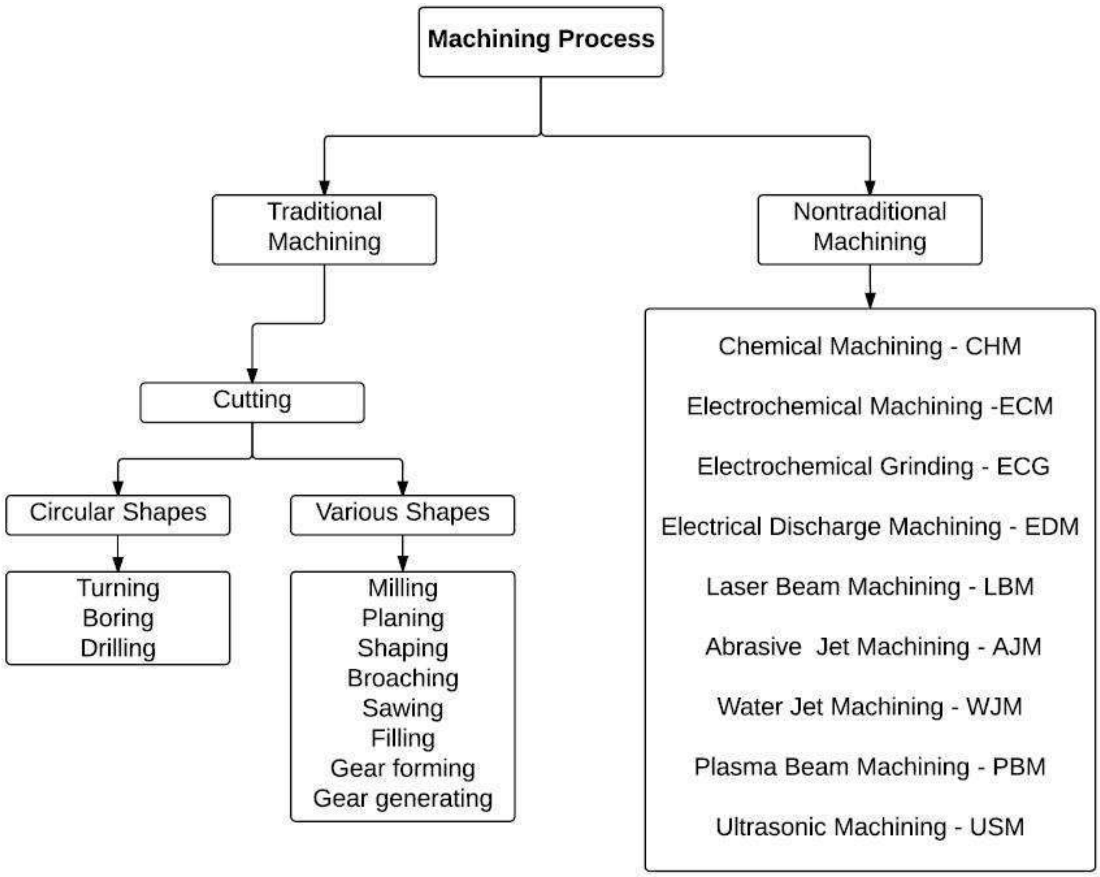
Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling. Modern Manufacturing processes, also called Non Traditional OR Advanced Manufacturing processes, are employed where traditional machining processes are not feasible, satisfactory or economical due to special reasons as outlined below.

*Very hard fragile materials difficult to clamp for traditional machining
*When the work piece is too flexible or slender
*When the shape of the part is too complex

Several types of non-traditional machining processes have been developed to meet extra required machining conditions. When these processes are employed properly, they offer many advantages over non-traditional machining processes.

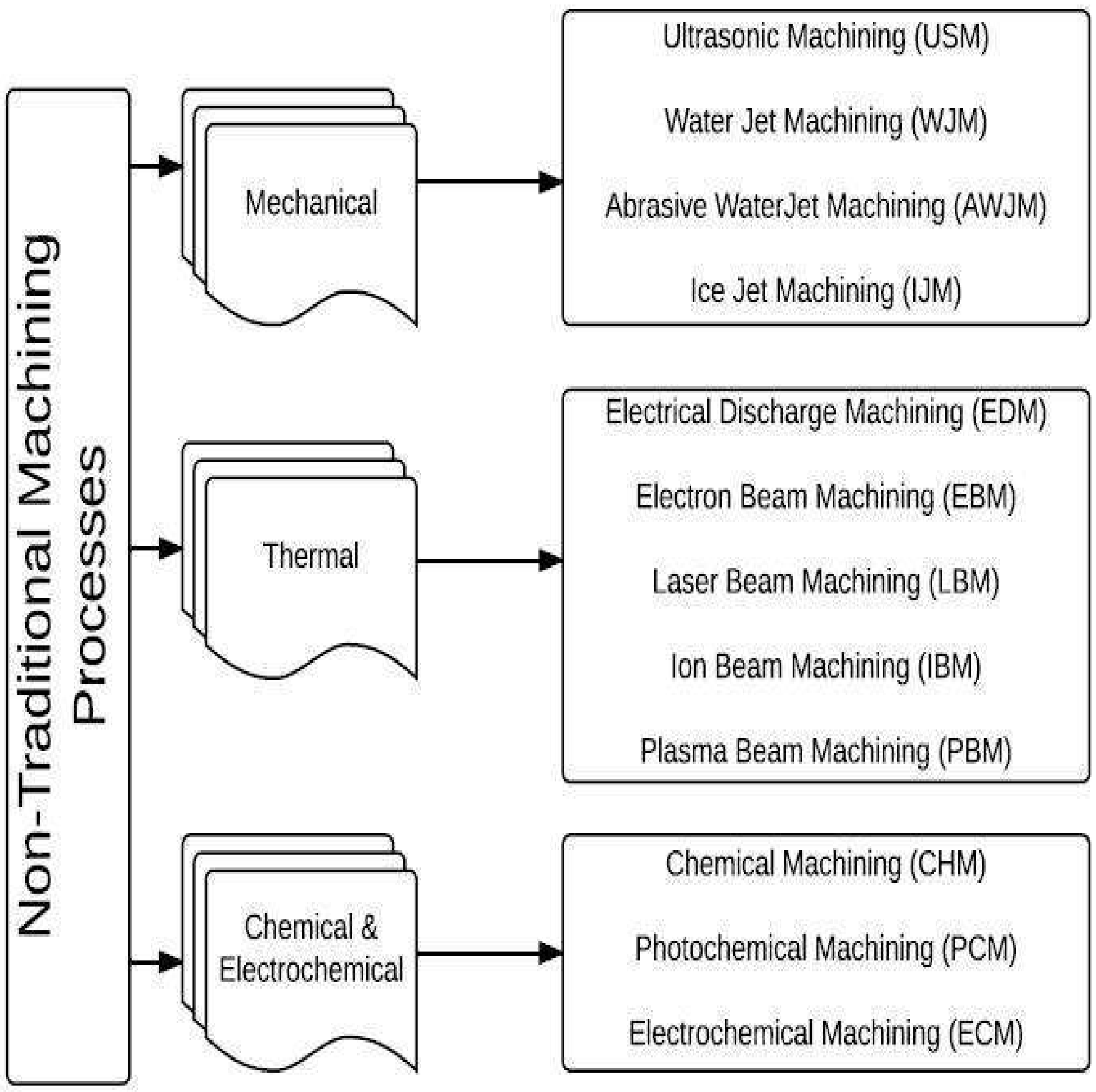
Definition:

A machining process is called non-traditional(Advance manufacturing) if its material removal mechanism is basically different than those in the traditional processes, i.e. a different form of energy (other than the excessive forces exercised by a tool, which is in physical contact with the work piece) is applied to remove the excess material from the work surface, or to separate the workpiece into smaller parts.



Comparison with TRADITIONAL PROCESSES

1.Tool used
2.Tool and workpiece contact
3. Accuracy
4. Waste material
5. Machining process
6. Energy source



Classification

Mechanical type AMP
Abrasive jet
Ultrasonic machining

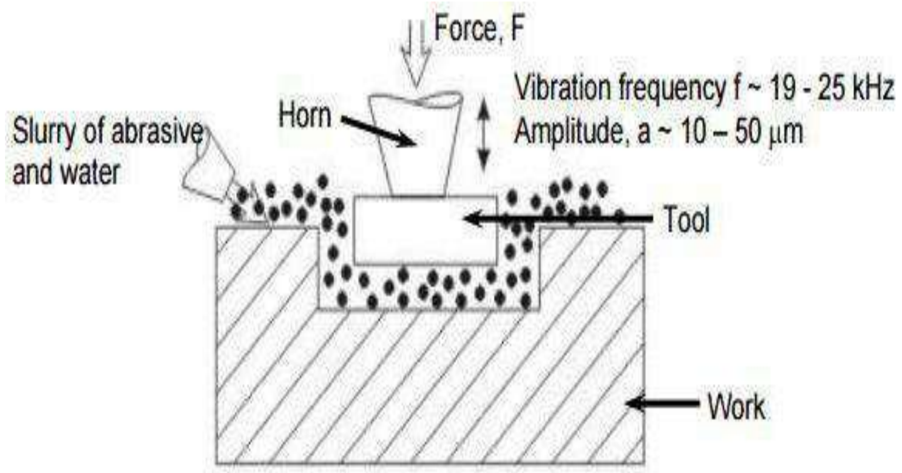
Thermoelectric type AMP

Electric discharge machining
Wire EDM
Laser beam
Electron beam
Plasma arc
Electro chemical machining

ULTRASONIC MACHINING PROCESS

Ultrasonic machining is a non-traditional machining process. USM is grouped under the mechanical group NTM processes. Fig. briefly depicts the USM process.

Principle Of Ultrasonic Machining :



The USM process

Ultrasonic Machining
In ultrasonic machining, a tool of desired shape vibrates at an ultrasonic frequency (19 ~ 25 kHz) with an amplitude of around 15 – 50 μm over the workpiece. Generally the tool is pressed downward with a feed force, F. Between the tool and workpiece, the machining zone is flooded with hard abrasive particles generally in the form of a water based slurry. As the tool vibrates over the workpiece, the abrasive particles act as the indenters and indent both the work material and the tool. The

abrasive particles, as they indent, the work material, would remove the same, particularly if the work material is brittle, due to crack initiation, propagation and brittle fracture of the material. Hence, USM is mainly used for machining brittle materials which are poor conductors of electricity and thus cannot be processed by Electrochemical and Electro-discharge machining (ECM and ED).

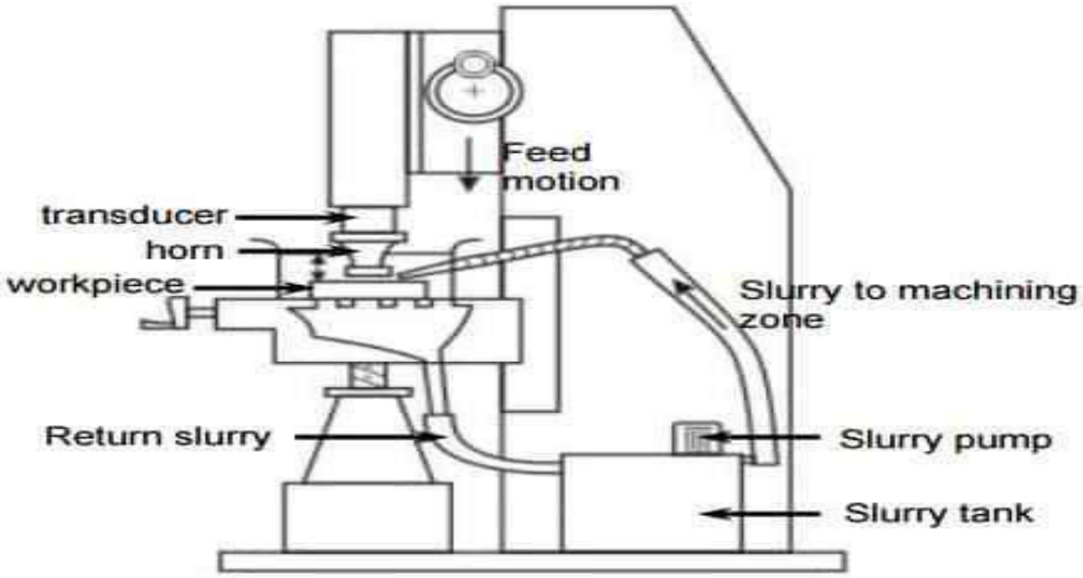
Process Parameters and their Effects.

During discussion and analysis as presented in the previous section, the process parameters which govern the ultrasonic machining process have been identified and the same are listed below along with material parameters

• Amplitude of vibration (ao) – 15 – 50 μm
• Frequency of vibration (f) – 19 – 25 kHz
• Feed force (F) – related to tool dimensions
• Feed pressure (p)
• Abrasive size – 15 μm – 150 μm
• Abrasive material – Al2O3
– SiC
– B4C
– Boronsilicarbide
– Diamond
• Flow strength of work material
• Flow strength of the tool material
• Contact area of the tool – A
• Volume concentration of abrasive in water slurry – C

Machine

The basic mechanical structure of an USM is very similar to a drill press. However, it has additional features to carry out USM of brittle work material. The workpiece is mounted on a vice, which can be located at the desired position under the tool using a 2 axis table. The table can further be lowered or raised to accommodate work of different thickness.



Schematic view of an Ultrasonic Machine

The typical elements of an USM are

• Slurry delivery and return system

• Feed mechanism to provide a downward feed force on the tool during machining

• The transducer, which generates the ultrasonic vibration

• The horn or concentrator, which mechanically amplifies the vibration to the required amplitude of 15 – 50 μm and accommodates the tool at its tip.
The ultrasonic vibrations are produced by the transducer. The transducer is driven by suitable signal generator followed by power amplifier. The transducer for USM works on the following principle

- *Piezoelectric effect*
- *Magneto strictive effect*
- *Electro strictive effect*

Applications

- Used for machining hard and brittle metallic alloys, semiconductors,
glass, ceramics, carbides etc.
- Used for machining round, square, irregular shaped holes and
surface impressions.
- Machining, wire drawing, punching or small blanking dies.

Limitations

- Low MRR
- Rather high tool wear
- Low depth of hole

ANIMATION LINK for ULTRASONIC MACHINING

https://youtu.be/5w6szZtOg5w

ELECTRIC DISCHARGE MACHINING

Electrical Discharge machining is the process of metal removal from the work surface due to an erosion of metal caused by electric spark discharge between the two electrodes tool (cathode) and the work (Anode).

Working Principle of Electrical Discharge Machining:

It consists of an electric power supply, the dielectric medium, the tool, workpiece, and servo control.

The workpiece is connected to the positive terminal and the tool is connected to a negative terminal of the DC power supply.

An air gap of 0.005 to 0.05 mm is maintained between the tool and the work.

The die electric fluid which is non-conductor of electricity is forced under pressure through the gap.

When a DC power is supplied, the fluid in the gap gets ionized and produces a spark between the tool and workpiece, causing a local rise in temperature at about 1000 degrees Celsius, when melts the metal in a small area of the workpiece and tool vaporizes.

The DC supply generates a pulse between 40 to 3000 V and the frequency of spark at the rate of 10000 sparks per second can be achieved.

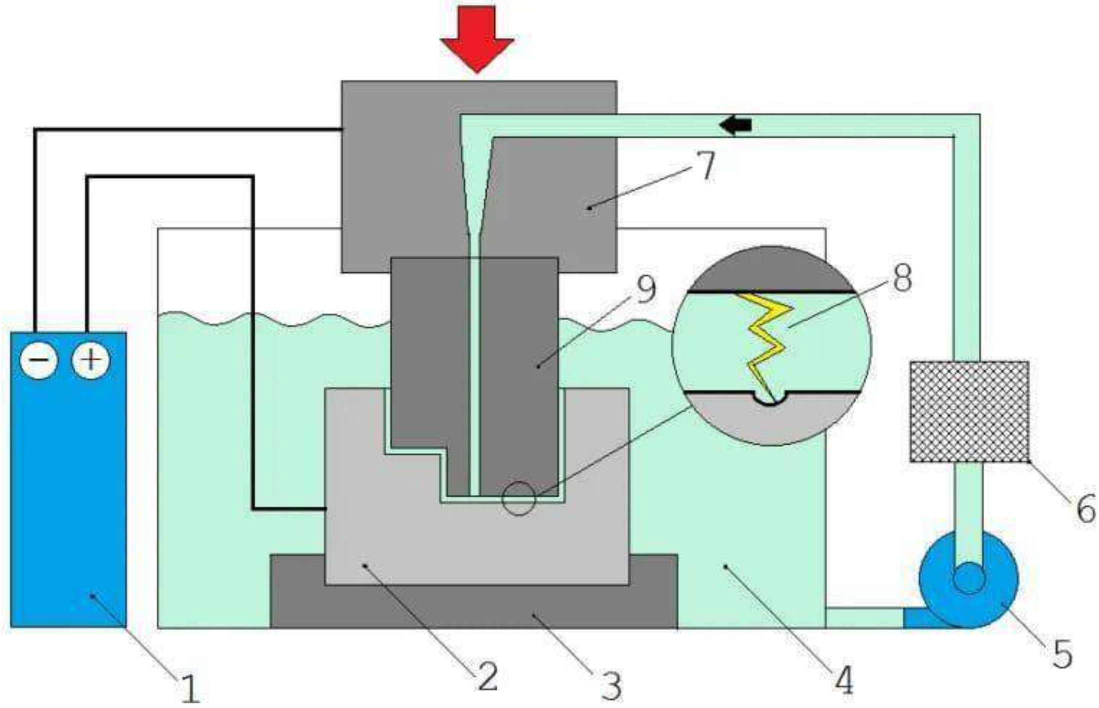
The electric and magnetic fields on heated metal cause a compressive force which removes the metal from the work surface.

The die electric fluid acts as a coolant carry the cooled metal from the work surface.

The die electric fluid acts as a coolant carries the eroded metal particles which are filtered regularly and supplied back to the tank.

A servomechanism is used to feed the tool continues to maintain a constant gap between two electrodes.

The accuracy of about 0.005 mm can be achieved in this process.



1. A pulse generator (DC).
2. Workpiece.
3. Fixture.
4. dielectric fluid.
5. Pump
6. Filter
7. Tool holder
8. Spark
9. Tool

Description of Equipment :

An Electric Discharge Machine consists of:

- DC pulse Generator
- Voltmeter
- Ammeter
- Tool
- Die electric fluid
- Pump
- Filter
- Servo Controlled Feed
- Fixtures
- Table

1. DC Pulse Generator:

This is a power source for the machining operation. DC power is supplied.

2. Voltmeter:

We know that the voltmeter measures the voltage. Here in this device the same for use.

3. Ammeter:

It measures or checks the flow of the current. If Ammeter is not connected we might not see or check current is flowing or not.

4. Tool:

A tool is connected to negative sources of power whereas the workpiece is connected to positive sources. from the filter, the fluid comes to the tool for the operation.

When Power supply will increase, between tools workpiece the spark generates and then machining starts.

5. Die electric fluid:

It has a property like insulation and we know what insulation means?

Insulation means no current flows from one to another.

The Die electric fluid will be ionized in the form of ion which will help between the tool and workpiece again when power supply stops the fluid comes to its initial position.

6. Pump:

The pump is connected there for sending the fluid to the filter. This works like flowing the fluid from one source to another one.

7. Filter:

As the name indicates the filter, is used to filtrate the different particles like:

In this device, if there is dust particles presence the filter will remove that particle and then it will send to the tool for the operation.

8. Servo controlled feed:

The constant feed will be supplied by the servo for the operation.

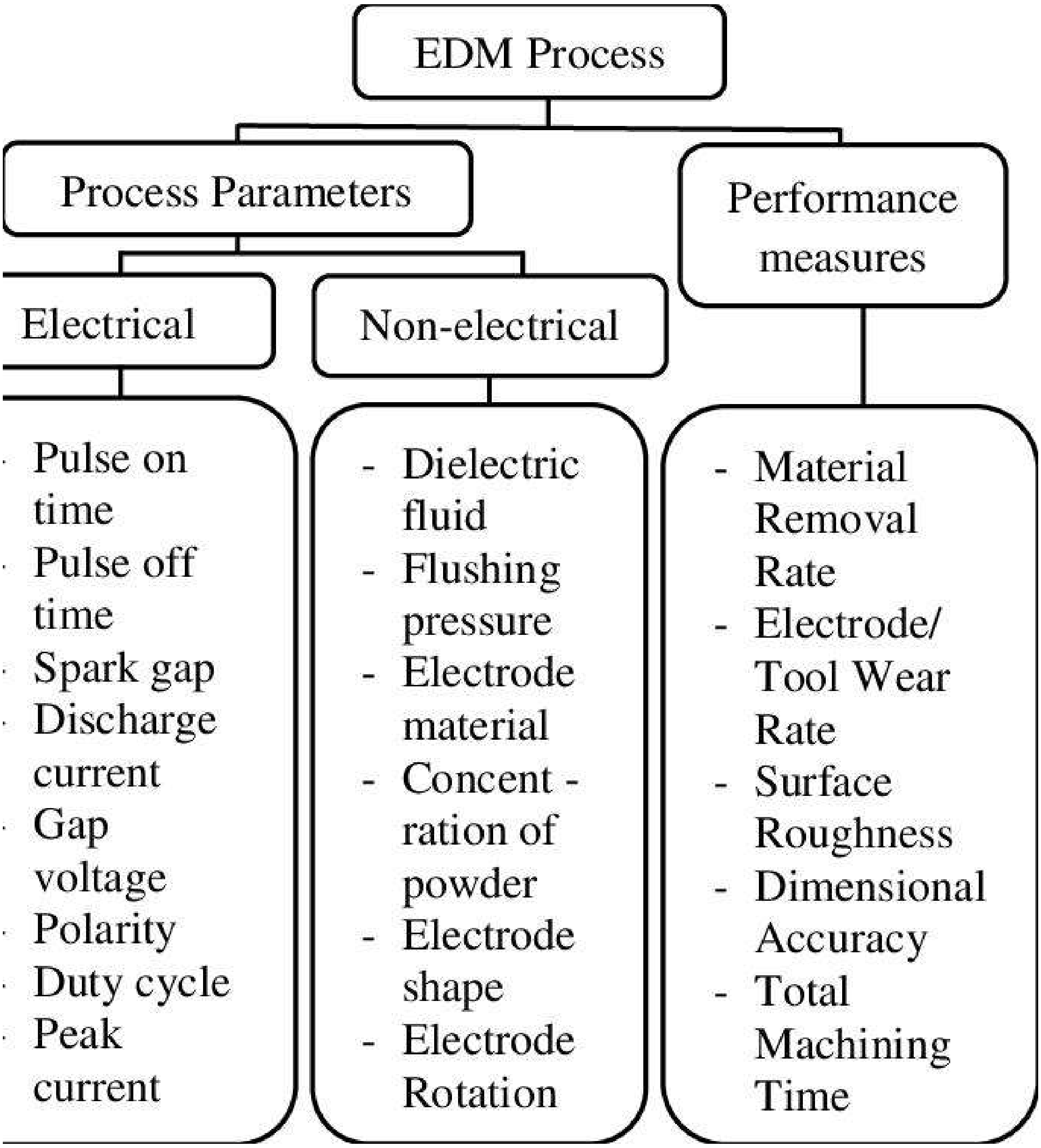
9. Fixture:

To hold the table.

10. Table:

To hold the workpiece.

Process Parameter



The EDM process parameters which drive this process are divided into two types, namely, electrical and non-electrical parameters.

The major electrical parameters are discharge voltage, peak current, pulse duration and interval (pulse-on and pulse-off times), electrode gap, polarity, and pulse wave form. Important non-electrical parameters include flushing of the dielectric fluid, workpiece rotation, electrode rotation, etc. These parameters are discussed below.

The discharge or machining voltage is the average voltage across the spark gap during machining. The discharge voltage directly influences the regulation of the size spark gap and overcut . Normally, electrode and workpiece materials of high electrical conductivity use low voltage.

In contrast, higher voltage is considered with materials of low conductivity. This parameter has a direct effect on the material removal rate (MRR), tool wear rate (TWR), and machining accuracy . An increase in current increases MRR and TWR and adversely affects the accuracy. These characteristics of the parameter current and its responses opened the door for electrodes of high wear resistance that can be used in high-current conditions [47]. The pulse-on time is the time during which the discharge is applied. The amount of energy generated during pulse-on time has a direct influence on the MRR .

Accordingly, increasing the discharge energy by applying longer pulse-on time also increases the MRR . The pulse-off time is the time during which there is no discharge. During this time, the debris as a result of sparking and erosion is flushed out of the gap between the workpiece and the electrode.

Flushing improves the ionization conditions and avoids the formation of an insulating layer; thus, proper selection of pulse-off time provides stable machining. A shorter period of this time increases MRR as long as enough flushing of debris takes place. Otherwise, it may result in unsuitable conditions during the next pulse-on time period.

Furthermore, a pulse wave has many forms such as rectangular and trapezoidal waves or even a composite geometric form. It is demonstrated in the literature that, among standard forms, the trapezoidal wave form generator minimizes the electrode wear. Recently, other generators were developed such as a typical one which initially facilitates the main pulse by producing a high-voltage pulse with a low current of narrower duration before the main pulse .

The polarity in EDM depends on many factors, including electrode and workpiece materials, current density, and pulse length. Either the electrode or the workpiece has a positive charge polarity and the other has a negative charge polarity.

Negative electrode polarity is recommended for high-precision machining when the MRR is high. In the wire EDM process, the electrode “wire” usually has a negative polarity to keep machining rate high, and, since the wire wear keeps on moving continuously during arcing, its wear rate is less.

The electrode and workpiece are located at a small predetermined distance called the “discharge gap” which is controlled by the discharge gap servo . A discharge gap on the order of 0.005 mm and 0.1 mm is usually maintained.

Finishing or high-precision machining requires a relatively low voltage in the gap on the order of 50 V and 300 V, as too high a voltage reduces machining precision. Non-electrical parameters include flushing of the dielectric fluid, workpiece rotation, and electrode rotation.

The function of the dielectric fluid is to provide insulation against premature discharging, reduce the temperature during machining, and clean away the debris from the machining area . Good dielectric fluids should have characteristics such as high dielectric strength, flushing ability, fast recovery after breakdown, etc.

In the case of a sinker type EDM, hydrocarbon- and silicon-based dielectric oil and kerosene are used after raising the flash point. Meanwhile, de-ionized water and oil are used in wire EDM.

Moreover, some sinker EDMs also use de-ionized water in high-precision machining, such as in fine hole drilling. Many studies were conducted recently to explore oil-based synthetics to avoid harmful effects on workers and the environment. Importantly, the dielectric type and flushing method influence MRR, TWR, and surface roughness (SR) .

The dielectric flushing conditions can be improved with workpiece and electrode rotation. This improvement in flushing caused by electrode rotation achieves better SR and higher MRR and minimizes the density of cracks on the surface and recast layer .

The effect of the EDM process parameters on the response parameters are difficult to explain because of the stochastic nature of the discharge mechanism. Several researchers performed studies related to EDM processes and explored the influence of process parameters on the performance measures .

Output Parameters

The two output parameters considered were: MRR and Ra.

Material Removal Rate (MRR)

Equation (1) could be used for the determination of the MRR (cubic centimetre/min) in the EDM process:

$$MRR = Wi - Wf /t \qquad (1)$$

where, Wi is the initial weight of the work piece before machining, Wf is the final weight of the work piece after machining, and t is the time period of trials.

MRR is directly proportional on the amount of current passed and the machining time (Pulse on Time, Pulse off Time). Besides these critical factors the MRR is also dependent on the type of voltage etc.

Average Roughness (Ra)

The deviation of a surface from its ideal level is defined in terms of surface roughness. The surface roughness is defined according to ISO 4287:1997 international standard. The term average roughness is often referred to as roughness and determines the surface texture. The average roughness is calculated by the deviations, i.e., deviation of surface from a theoretical centre line. If the deviations are large, the surface roughness is high, whereas the surface is considered to be smooth for small deviations. This is known as arithmetic mean surface roughness Ra.

The applications of EDM:

- Drilling for micro holes in the nozzle.
- This is used in thread cutting.
- Used in wire cutting.
- Rotary form cutting.
- Helical profile milling.
- Curved hole drilling.
- Engraving operation on harder materials.
- Cutting off operation.
- The shaping of alloy steel and tungsten carbide dies.

Advantages of Electrical Discharge Machining:

- It can be used for any hard material and even in the heat-treated condition.
- Any complicated shapes made on the tool can be reproduced.
- High accuracy of about 0.005 mm can be achieved.
- Good surface finish can be achieved economically up to 0.2 microns.
- Machining time is less than the conventional machining process.
- No mechanical stresses are developed in this process (There is no contact between tool and work)
- Higher tool life due to proper lubrication and cooling.
- Hard and erosion resistant surface on the dies can be developed easily.
- It can be applied to any electrically conductive materials.

Disadvantages of Electrical Discharge Machining:

- Excessive tool wear.
- High power consumption.

- The sharp corner cannot be reproduced.
- High heat developing causing the change in metallurgical properties of materials.
- The workpiece must be an electrical conductor.
- Surface cracking may take place in some materials.
- Redressing of a tool is required for deep holes.
- Over-cut is formed.
- Difficult finding expert machinists

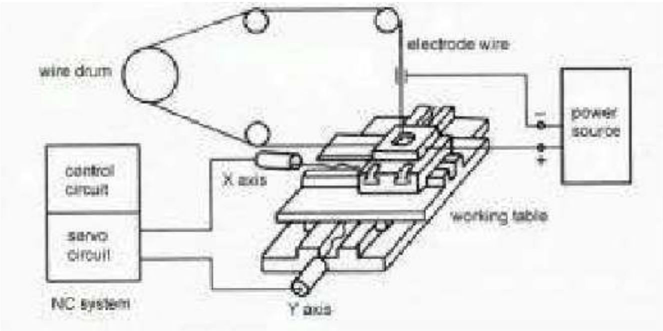
ANIMATION LINK for EDM Process

https://youtu.be/kh4DSOtef4k

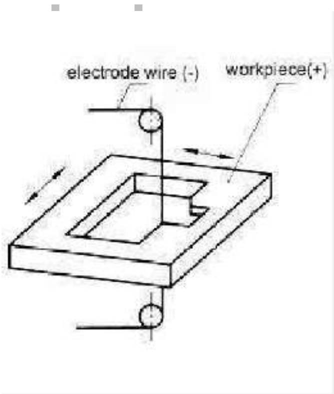
Wire Cut EDM

Principle

CNC wire cut EDM machine puts impulse voltage between electrode wire and workpiece through impulse source, controlled by servo system, to get a certain gap, and realize impulse discharging in the working liquid between electrode wire and workpiece. Numerous tiny holes appears due to erosion of impulse discharging, and therefore get the needed shape of workpiece(as show in figure 1-1).



Electrode wire is connecting to cathode of impulse power source, and workpiece is connecting to anode of impulse power source. When workpiece is approaching electrode wire in the insulating liquid and gap between them getting small to a certain value, insulating liquid was broken through; very shortly, discharging channel forms, and electrical discharging happens. And release huge high temperature instantaneously, up to more than 10000 degree centigrade, the eroded workpiece is cooling down swiftly in working liquid and flushed away. As show in figure 1-2



Description of equipment

In wire EDM, three elements are of particular importance: wire electrode, dielectric bath and workpiece. Both the workpiece and the wire electrode are **in the dielectric bath during the cutting process**. This is produced with the aid of a non-conductive liquid, for which either deionized water or special erosion oil is used. In some cases, a coaxial jet is used as an alternative to the dielectric bath. The wire is usually made of brass, but can just as easily be made of copper or steel. **Wire electrodes with a diameter between 0.02 mm and 0.33 mm** are normally used for wire EDM.

Finally, the exact process takes place in three phases: First, the wire electrode and the material to be machined are placed at a clearly defined distance from each other in advance. It is important that both are charged differently (workpiece = anode and wire = cathode). Now, with the help of electrical voltage pulses, an electric field is generated (ignition phase) - exactly where the distance between wire and workpiece is smallest.

In this field, an **acceleration of the electrically charged particles** takes place, which leads to the generation of a visible spark. This generates great heat, which causes the dielectric to evaporate and the material of the electrode and workpiece to melt. As a result, a gas bubble forms, which in turn fills with plasma (discharge phase). The current supply is interrupted by the onset of a pulse pause (pause phase), causing the bubble to implode. At this point, the molten material is detached from the workpiece and transported away with the dielectric. Depending on the machine, the processes from ignition phase to pause phase are repeated up to 100,000 times per second. **Temperatures of up to 40,000°C** are generated in the process.

Controlling parameters of wire cut EDM

Four process control parameters, namely
Wire speed
Gap voltage,
Flushing pressure and
Current
are analyzed for two response parameters viz surface roughness and material removal rate (MRR). It is found that MRR during WEDM have a predominant impact of current on it, while flushing pressure has the least impact on MRR. Whereas, surface roughness is most effected by wire speed during WEDM and gap voltage has the least impact on surface roughness of steel workpiece during WEDM process.

Applications of wire cut EDM

Applications of wire EDM include:

- Prototype production
- Automotive parts
- Aerospace parts
- Medical devices for implantations
- Prototypes
- Small hole drilling
- Blanking punches
- Extrusion dies
- Miniature parts

- Titanium needles
- Turbine blades
- Internal gear

Materials Used in Wire EDM

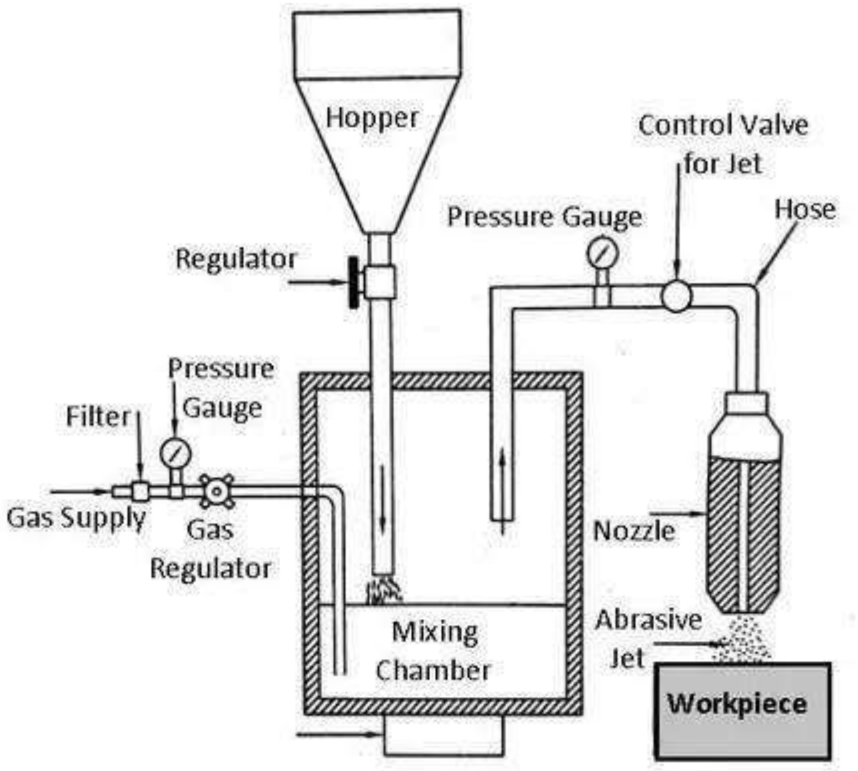
Wire EDM should be used with any conductive metal such as titanium, aluminum, brass, alloys, and superalloys. Thanks to wire EDM's accuracy, wire EDM has become a popular manufacturing method for various industries. Whether for part or prototype, Fathom has many materials suitable for wire EDM, including:

- Copper
- Carbide
- Tungsten
- Bronze
- Carbon steel
- Stainless steel
- Hastalloy
- Titanium
- Carbon graphite
- High alloy steel

Abrasive Jet Machining

The fundamental principle of Abrasive jet machining involves the use of a high-speed stream of abrasive particles carried by a high-pressure gas or air on the work surface through a nozzle.

The metal is removed due to erosion caused by the abrasive particles impacting the work surface at high speed. With repeated impacts, small bits of material get loosened and a fresh surface is exposed to the jet.



Principle of Abrasive Jet Machining

This process is mainly employed for such machining works which are otherwise difficult, such as thin sections of hard metals and alloys, cutting of material which is sensitive of heat damage, producing intricate holes, deburring, etching, polishing etc.

Equipment for abrasive jet machining

Air compressor: It compresses the carrier gas to a pressure of 15 – 20bar. Compressor unit also consists of drier and filter. So it removes water vapor and dust particles to avoid condensation or jamming during compression.

Pressure gauges: A number of such gauges are employed for measuring pressure of carrier gas as well as gas-abrasive mixture.

Flow regulating valves: These valves controls volume flow rate of carrier gas in order to maintain constant mixing ratio.

Hopper: In AJM, usually circular hopper with gradual compression is employed for continuously supplying fresh abrasive to the mixing chamber. Hopper is sometime vibrated to avoid bridging (jamming at outlet).

Mixing chamber: Its purpose is to mix abrasives with pressurized carrier gas. Here momentum transfer takes place and abrasives start flowing with carrier gas. Chamber is vibrated to obtain homogeneous mixing.

Nozzle: As an isentropic steady flow device, nozzle converts hydraulic energy (pressure) of the gas-abrasive mixture to the kinetic energy and thus high velocity jet is obtained.

Working chamber: A close working chamber, inbuilt with proper exhaust system, is usually maintained in order to avoid environmental pollution. It also helps protecting workers from lung dieses caused by exposing into atmosphere containing excessive tiny abrasive dust.

Servo controller: Sometime movement of work table is controlled by servo mechanism. This gives easy, accurate and precise control and is suitable for cutting intricate profiles and contours.

Material removal rate and its estimation

Knowledge of material removal rate (MRR) is beneficial for selecting process parameters and choosing feed rate of the nozzle. It also facilitates accurate estimation of productivity, delivery time as well as production cost. Since only kinetic energy of abrasive grits is utilized for erosion, the analytical formula for MRR can be established by equating available kinetic energy with the work done required for creating an indentation of certain cord length on a specific work material.

However, ductile and brittle materials behave differently in indent formation, and thus size of indentation created by the impact of single abrasive grit is different for ductile and brittle materials. Under few assumptions, MRR for abrasive jet machining for different materials can be modeled analytically and can be expressed as provided below.

Expression of MRR for ductile and brittle materials in AJM

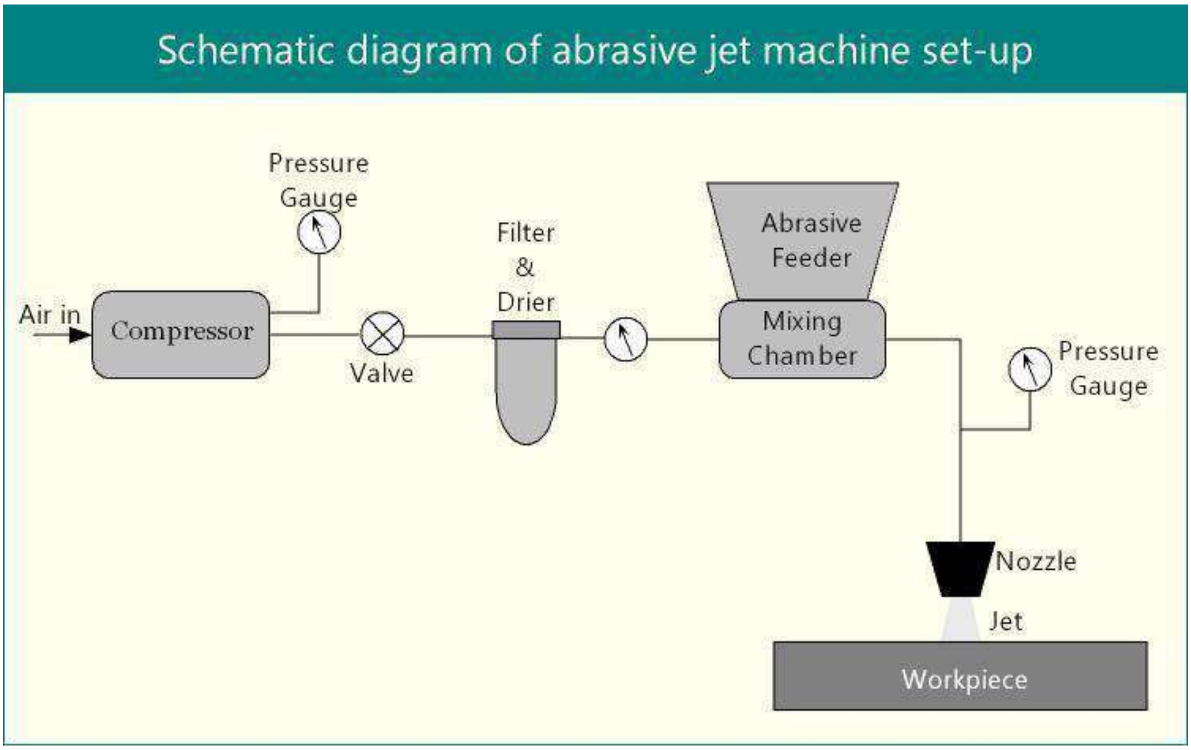
$$MRR_{Brittle} = 1.04 \frac{M_g U^{3/2}}{\rho_g^{1/4} \ H^{3/4}}$$

$$MRR_{Ductile} = 0.5 \frac{M_g U^2}{H}$$

Applications of AJM

Abrasive jet machining can be advantageously utilized for multifarious purposes including surface cleaning, deburring, abrading and even making holes. Common applications of abrasive jet machining process are provided below. It is to be noted that, irrespective of the purpose, abrasive jet machining (AJM) is beneficial only for hard and brittle materials. AJM should be avoided if work material is soft and ductile; otherwise quality of machined surface will be poor. Read also: Applications of AJM process.

- **Work surface cleaning**—AJM can be advantageously used for cleaning metallic or ceramic surfaces (substrate must be hard). Such cleaning processes include removal of oxide, paint, coating, stain, glue, loose sand particles, etc.
- **Deflashing and trimming**—Controlled abrasive jet machining can be utilized for removing flash to get desired clean product with higher dimensional accuracy and tolerance as well as sumptuous appearance.
- **Engraving**—As an alternative to laser beam machining, abrasive jet machining can also be applied for incising purposes irrespective of chemical and electrical properties of work material.
- **Ceramic abrading and glass frosting**—Very hard materials including glass, refractory, stone, etc. can be easily abraded by AJM in order to get finished surface having tight tolerance.
- **Deburring**—Abrasive jet machining is one of the efficient methods for deburring (process for removal of burr) of milled features and drilled holes, especially when work material is hard.
- **Cutting and drilling hole**—AJM can also be utilized for cutting various shapes as well as for drilling holes. However, holes, slots or pockets may lack accuracy as sharp corners cannot be obtained by this process.



Schematic diagram of abrasive jet machine set-up

Characteristics of AJM

Abrasive - Al_2O, or Sic to be used once

Size of abrasive - around 25 um

Flow rate - 2-20 g/min

Medium - Air or CO_2

Velocity - 150-300 m/sec

Pressure - 2 to 8 kg/cm sq

Nozzle - WC or sapphire with orifice area-0.05 to 0.2 mm sq

Life of nozzle - WC (12-30 hrs), sapphire (around 300 hrs)

Nozzle tip distance - 0.25 to 15 mm

Tolerance - ± 0.05 mm

Surface Roughness - 0.15-0.2 μm with particles of 10 μ m size, 0.4-0.8 μm and 1.0 to 1.5 μm, with particle size of 25 and 50 μm

Work material - Hard and brittle materials like glass, ceramic, mica, etc.

Machining operations - Drilling, cutting, deburring, cleaning

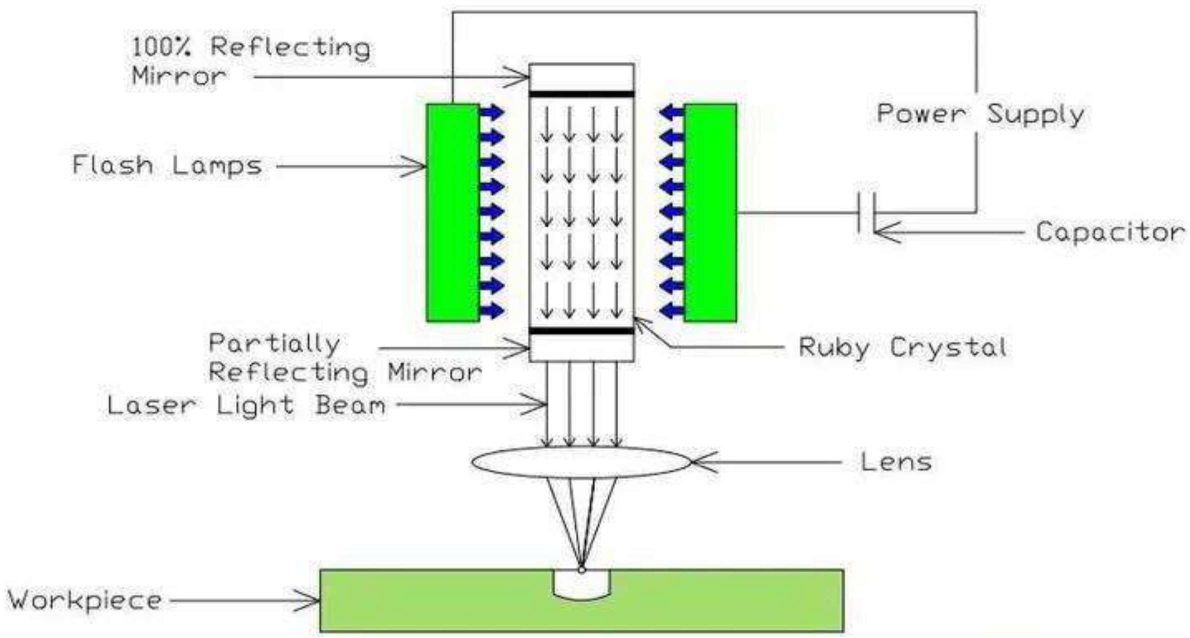
Advantages - Can cut intricate hole shapes in hard and brittle materials, fragile and heatsensitive materials can be cut without damage because there is no heating of working surface

Limitations -. Low material removal rate, low accuracy (0.1 mm) due to stray cutting (taper effect), abrasives get embedded in surface if material is soft

Laser Beam Machining:

A laser beam machining is a non-conventional machining method in which the operation is performed by laser light. The laser light has maximum temperature strikes on the workpiece, due to high temp the workpiece gets melts. The process used thermal energy to remove material from a metallic surface.

Laser Beam Machining Working Principle:



The working principle of laser machining is,

In this process, the Laser Beam is called **monochromatic light,** which is made to focus on the workpiece to be machined by a lens to give extremely high energy density to melt and vaporize any material.

The Laser Crystal (Ruby) is in the form of a cylinder as shown in the above figure or Diagram with flat reflecting ends which are placed in a flash lamp coil of about 1000W.

The Flash is simulated with the high-intensity white light from Xenon. The Crystal gets excited and emits the laser beam which is focused on the workpiece by using the lens.

The beam produced is extremely **narrow** and can be focused to a pinpoint area with a power density of **1000 kW/cm2**. Which produces high heat and the portion of the metal is **melted** and **vapourises**.

Power Supply:
It provides the energy for excitation of electron from lower energy level to higher energy level. This gives power to xenon flash lamps, which produce light energy. The laser material are exposed in light energy to keep storing energy.

Laser Discharge Tube:
The laser material filled in lased discharge tube. The excitation of electron and come back to its original state process takes place in it. It's one side is partially transparent for laser opening and other side is 100% reflected. It is situated between flash lamp.

Laser Material:
There are many different type of laser material available but in later machining mostly CO2(Pulsed or continuous waves) and Nd: YAG is Used. Carbon die oxide is a laser material that emits light in infrared region. It can provide up to 25 KW power in continuous wave mode. The other one is called Neodymium doped Yttrium Aluminum Garnet is a solid state laser which can delivery light through optical fiber. It can generate about 50 KW power in pulsed mode and 1 KW power in continuous mode.

Focusing Lens:
A focusing lens is used in laser machining operation. It is a convex lens which focus is at work piece.

DESCRIPTION OF EQUIPMENT

1. **A pumping Medium**: A medium is needed that contains a large number of atoms. The atoms of the media are used to produce lasers.
2. **Flash Tube/Flash Lamp:** The flash tube or flash lamp is used to provide the necessary energy to the atoms to excite their electrons.
3. **Power Supply:** A high voltage power source is used to produce light in flashlight tubes.
4. **Capacitor:** Capacitor is used to operate the laser beam machine at pulse mode.
5. **Reflecting Mirror:** Two types of mirror are used, first one is 100 % reflecting and other is partially reflecting. 100 % reflecting mirror is kept at one end and partially reflecting mirror is at the other end. The laser beams comes out from that side where partially reflecting mirror is kept.

MATERIAL REMOVAL RATE

If a lower amount of power supply is given to the Ruby rod, the intensity of the electromagnetic waves is reduced. Therefore the heat generated in the workpiece is sufficient to melt and join the blades called a **laser beam welding operation.**

In practical conditions, the wavelength of the laser beam is about 0.4 to 0.6 micrometers only.

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APPLICATIONS

- No vacuum is required.
- Mainly used for producing holes in the diesel injection nozzle.
- Also used for producing blind holes, Narrow slots in the workpieces.

CHARACTERISCTICS of LBM

Material removal technique - Heating, melting and vaporisation.

Tool - Laser beams in wavelength range of 0.4-0.6 μm.

Power density - As high as 107 W/mm^2

Output energy of laser and its pulse duration -20 J , 1 milli second.

Peak power - 20Kw

Medium - normal atmosphere

Material removal rate - 5 mm^3 /min.

Specific power consumption -1000 W/mm^3/min

Material of workpiece - All materials except those with high thermal conductivity and high reflectivity.

Applications .- Drilling micro holes (upto 250 μm) and cutting very narrow slots.

Dimensional accuracy - ±0.025 mm.

Efficiency - 0.3-0.5%

Limitations - Taper of 0.05 mm when work thickness is more than 0.25 mm.
Very large power consumption

Electro Chemical Machining

Electrochemical machining is a process of removing metal with the help of the electrolysis process. The electrochemical process is also known as the reverse of the electroplating process because, in electroplating, the metal is deposited on the surface of the workpiece, while in electro-chemical machining the metal is removed from the workpiece. This process is used for the large-scale production of machined parts.

PRINCIPLE OF ECM

The Electrochemical machining process is based on Faraday's law of electrolysis.

Faraday's law of electrolysis states that when two electrodes, anode (+ve) and cathode (-ve) are placed in an electrolyte the mass of the metal deposited on the cathode coming from the anode is directly proportional to the potential difference applied across the electrodes.

In the setup shown below, NaCl is used as an electrolyte, the workpiece is placed as the anode, tool (desired shape) is used as cathode and a potential difference is applied. There is a very small gap between the workpiece and the tool for the removal of material.

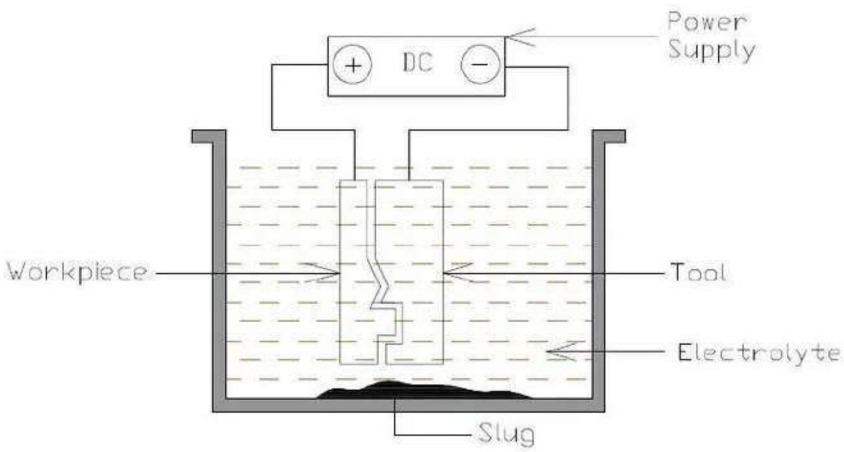


Diagram of Conceptual Electrochemical Model,

As soon as a potential difference is applied between the anode and the cathode, the ions start moving from anode to cathode.

The negative ions are attracted towards the workpiece which is placed at the +ve potential and positive ions are attracted towards the tool which is placed at the - ve potential.

The chemical reactions taking place in the basic process of electrochemical machining are as follows:

$2H^+ + 2e^- = H_2$

Hydrogen ions gain electrons and get converted into hydrogen gas. (at the cathode)

$Fe = Fe^{++} + 2e^-$

The iron atom releases its 2 electrons and gets converted into Iron ions. (at the anode)

$Na^+ + OH^- = NaOH$

$Fe^{2+} + 2Cl^- = FeCl_2$

Sodium ions react with hydroxyl ions to form Sodium hydroxide.

Iron ions react reacts with chlorine ions to form iron chloride (slug)

DESCRIPTION OF EQUIPMENT

An electrochemical plant has various parts, those are as follows,

#1 Power supply

The power supply is the source of energy that is provided to the setup. The power supply is generally a DC battery consisting of a potential difference from 3 to 30V depending upon the requirement.

#2 Electrolyte

An electrolyte is a salt solution in which the workpiece and tool are kept during the process of machining. It acts as a current-carrying medium between the workpiece and the tool.

It also helps in the removal of waste products from internal gaps and also acts as a coolant by preventing overheating of the tool and the workpiece. Different electrolytes used in ECM are Sodium chloride (NaCl), Sodium nitrate ($NaNO_3$), hydrochloric acid (HCl), etc.

#3 Tool

Tool or cathode used in ECM is one of the electrodes. It is also the desired shape in which the workpiece is to be cut. The tool used in ECM should always have accurate dimensions.

#4 Mechanical System

One of the most important elements in ECM is the mechanical system. It is used for the advancement of a tool that is perpendicular to the workpiece and is at a constant velocity.

#5 Tank

The tank contains the electrolyte, tool, and workpiece. All the reactions take place here.

#6 Pressure Gauge

A pressure gauge is used to measure the pressure of electrolytes which is supplied to the tool.

#7 Flow Control Valve

A flow control valve is used to control the flow of electrolyte which is supplied to the tool.

#8 Pressure Relief Valve

In case the pressure of electrolyte flow exceeds a certain limit, the pressure relief valve opens and it sends the electrolyte back to the tank.

#9 Reservoir Tank

The tank that stores pure Electrolytes is called the reservoir tank.

#10 Pump

There are two pumps used namely A and B. Pump A is used to draw electrolytes from the reservoir tank and pump B is used to supply the electrolyte to the reservoir tank.

#11 Filter and Centrifuge

A filter is used to filter the electrolyte reaching the reservoir tank. And prevents the accumulation of excess electrolytes. The function of a centrifuge is to separate the slug from the electrolyte.

#12 Slug Container

A slug container is used to store the slug which is separated from the electrolyte. This slug can be used for various experimental purposes.

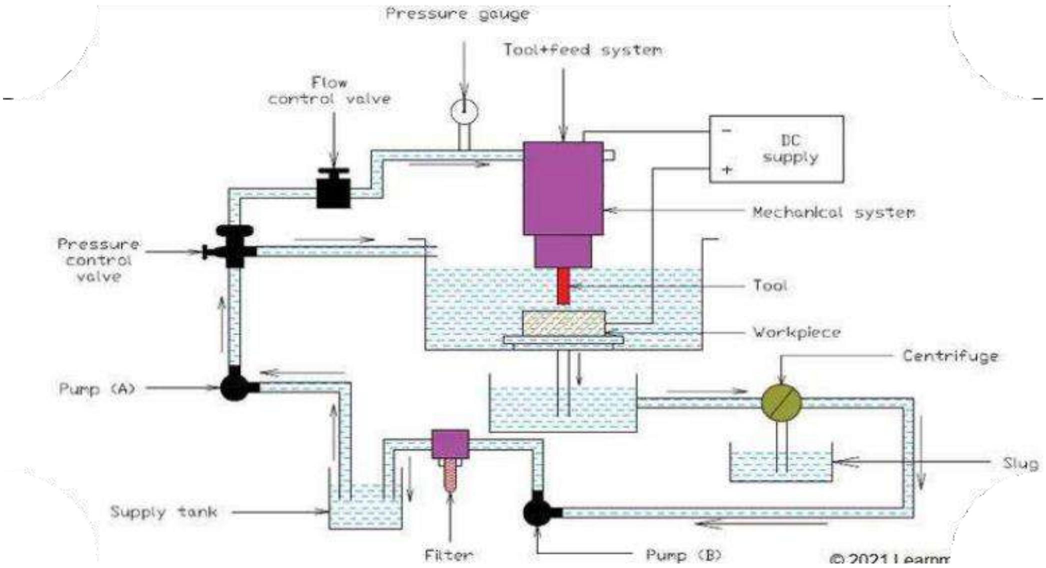


Diagram of Electro-Chemical Machining Setup

Working of Electrochemical Machining

The working of electrochemical machining starts with the advancement of the tool towards the workpiece. The tool and the workpiece are kept in a suitable electrolyte with a very small gap between them.

As soon as the potential difference is applied (DC), the workpiece starts behaving as an anode and the tool starts behaving as a cathode.

When the condition of electrolysis is fulfilled, the removal of metal from the workpiece starts. The removal takes place according to the shape of the tool. Material is removed from the workpiece and gets settled down in the form of a slug, which is due to the flow of electrolytes.

The electrolyte then goes through a filtration process. In the filtration process, the electrolyte is passed through a centrifuge where the slug is removed. Then it passes through a filter where other remaining impurities are removed. If there is an increase in the pressure of the electrolyte, the pressure valve deviates the flow of the electrolyte directly to the tank.

Material removal rate

- $m \alpha Q$ $\quad m \alpha ECE \alpha A/v \quad m \alpha QA/v \alpha ItA/v$
- $m = ItA/Fv$ $\quad$ F= Faraday's Constant
  = 96500 Colomb

MRR = $m/t\rho = itA/Fvt\rho = IA/F\rho v$

Applications

- As mentioned earlier in the article ECM is **used for heavy machining of hard materials** which cannot be machined using conventional methods.
- Due to its **high accuracy and surface finish**, ECM is **used for micromachining**. As there is no contact between the tool and workpiece the final product obtained is accurate at the atomic level.
- ECM is also **used for the production of very small gear systems** which cannot be machined using typical machining processes.
- ECM is **used for machining turbine blades** as it is difficult to machine due to its complex concave structure.
- ECM can also be **used for drilling and milling operations**.

CHARACTERISTICS of ECM

Material removal mechanism - Controlled removal of metal by anodie dissolution in an electrolytic medium.

Tool - Cu, brass or steel.

Power supply - Constant voltage DC supply

Voltage and Current - 5-30 V d.c, 50-40,000 Amp.

Material removal rate - 1600 mm/min.

Specific power consumption - 7 W/mm/min (around 150 times more in comparison to conventional methods)

Electrolytic solution - Neutral salts, acids and alkalies.

Accuracy and Surface finish - ±0.02mm, 0.4μm.

Applications -Used for machining difficult-to-machine materials and complex-shaped parts.

Mechanical and surface properties of metals - Stress free machining, burr-free surface, reduced tool wear,no thermal damage.

Limitations - High specific energy consumption, not suited for non-conducting pieces; high initial and working cost.

Plasma Arc Machining

Plasma-arc machining (PAM) employs a high-velocity jet of high-temperature gas to melt and displace material in its path. Called PAM, this is a method of cutting metal with a plasma-arc, or tungsten inert-gas-arc, torch. The torch produces a high-velocity jet of high-temperature ionized gas called plasma that cuts by melting and removing material from the workpiece. Temperatures in the plasma zone range from 20,000° to 50,000° F (11,000° to 28,000° C).

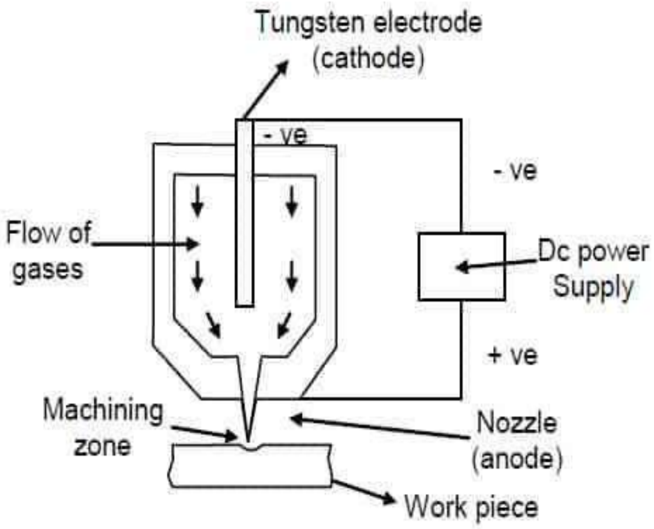


Figure Working Principle and Process Details of PAM

DESCRIPTION OF EQUIPMENTS

- **Plasma Gun**
  Gases are used to create plasma-like, nitrogen, argon, hydrogen, or a mixture of these gases. The plasma gun consists of a tungsten electrode fitted in the chamber. The electrode is given negative polarity and the nozzle of the gun is given positive polarity. The supply of gases is maintained into the gun. A strong arc is established between the two terminals anode and cathode. There is a collision between molecules of gas and electrons of the established arc. As a result of this collision, gas molecules get ionized and heat is evolved. This hot and ionized gas called plasma is directed to the workpiece with high velocity. The established arc is controlled by the supply rate of gases.
- **Power Supply and Terminals**
  Power supply (DC) is used to develop two terminals in the plasma gun. A tungsten electrode is inserted to the gun and made cathode and nozzle of the gun is made anode. Heavy potential difference is applied across the electrodes to develop a plasma state of gases.
- **Cooling Mechanism**
  As we know that hot gases continuously come out of nozzle so there are chances of its overheating. A water jacket is used to surround the nozzle to avoid its overheating.
- **Tooling**
  There is no direct visible tool used in PAM. Focused spray of ho0t, plasma state gases works as a cutting tool.

Workpiece

The workpiece of different materials can be processed by the PAM process. These materials are aluminum, magnesium, stainless steel, and carbon and alloy steels. All those material which can be processed by LBM can also be processed by the PAM process.

Material removal rate

The values of the material removal rates in Plasma beam machining will be nearly 150 cm3/min.

PROCESS PARAMETER

Parameters that govern the performance of PAM can be divided into three categories:

1. Those associated with the design and operation of the torch – eletrical power delievered , the gases used to form the plasma, the flow rate of the gases through the torch, the orifice diameter through the nozzle duct

2.Those associated with the physical configuration of the set up – torch standoff, angle to the work, depth of cut, feed into the work and speed of the work toward the torch

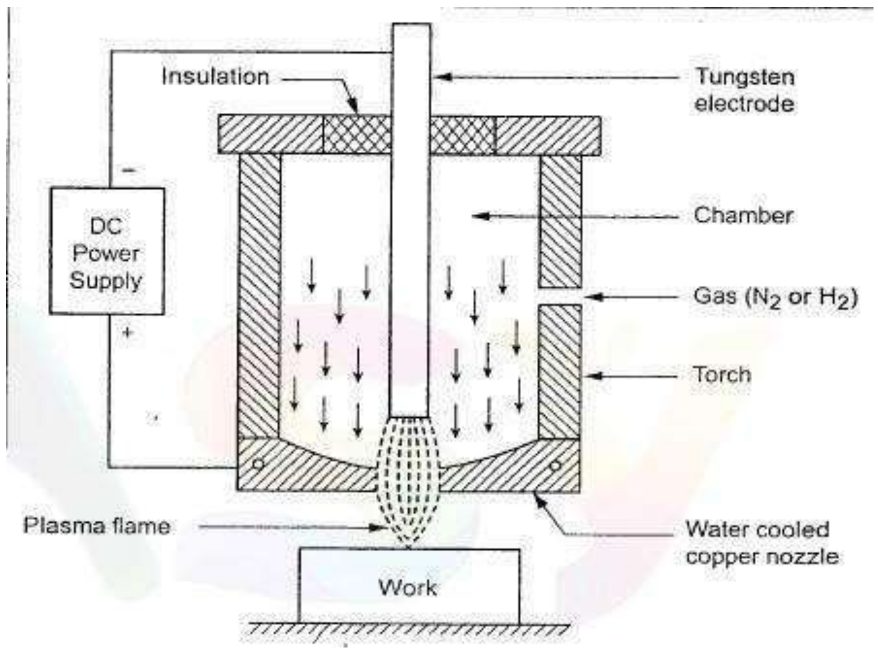
3. Environment in which the work is performed – cooling that is done on the bar, any protective type of atmosphere used to reduce oxidation fo the exposed high temperature machined surface and any means that might be utilized to spread out or deflect the arc and plasma impingment area

CHARACTERISTICS OF PAM

Technique of machining	Heating of workpiece by high temperature ionised gas (plasma) and causing quick melting
Tool	Plasma jet
Velocity of plasma jet	500 m/sec.
Material removal rate	150 cm^3/min
Specific energy	1000 W/cm^3-min
Power range	2 to 200 kW
Material of workpiece	All materials which conduct electricity
Voltage	30-250 V

Current	Upto 600 amp.
Cutting speed	0.1-7.5 m/min
Applications plates	Profile cutting of stainless steel, monel, and superalloy
Plate thickness	200 mm (max)
Limitation	Low accuracy.

Construction of PAM



APPLICATIONS

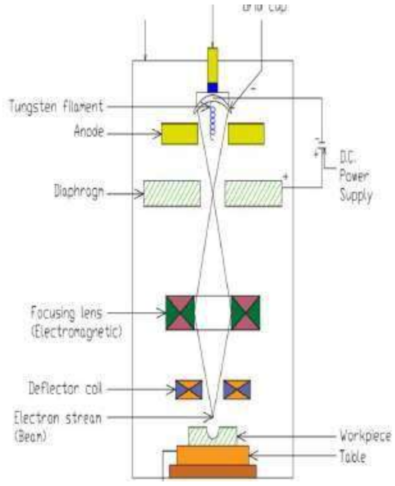
1. It is used for cutting alloy steels, stainless steel, cast iron, copper, nickel, titanium, aluminum, and alloy of copper and nickel, etc.
2. It is used for profile cutting.
3. It is successfully used for turning and milling of hard to machine materials.
4. It can be used for stack cutting, shape cutting, piercing, and underwater cutting.
5. Uniform thin film spraying of refractory materials on different metals, plastics, ceramics are also done by plasma arcs.

Electron Beam Machining

Electron beam machining (EBM) is **a thermal machining process in which high-velocity electrons concentrated into a narrow beam are used for instantly heating, melting, or vaporizing the material**. This process is used in many applications, including drilling, cutting, annealing, and welding

PRINCIPLE

In an electron beam machining, the electrons strike the workpiece with a high velocity. As the electron strikes the workpiece, the kinetic energy of the electron changes into heat energy. The heat energy so produced is used to melt and vaporize the materials from the w/p. The whole process takes place in vacuum. Vacuum environment is used to prevent the contamination and avoid collision of electrons with air molecules. If the electrons collide with the air molecules, it will lost its Kinetic energy.



DESCRIPTION OF EQUIPMENTS

The various equipment used in EBM machine are

1. Cathode

The cathode is negatively charged and it is used to produce Electrons.

2. Annular Bias Grid

It is present next to the cathode. Annular bias grid is a circular shaped bias grid and prevents the diversion of electrons produced by the cathode. It works as a switch and makes the electron gun to operate in pulse mode.

3. Anode

It is placed after the annular bias grid. It is positively charged. Annular anode attracts the beam of electron towards it and gradually the velocity of the electron increases. As the electron beam leave the anode section, its velocity becomes half of the velocity of light

.4. Magnetic Lenses

The magnetic lenses reduce the divergence of electron beam and shape them. It allows only convergent electrons to pass and captures the low energy divergent electrons from fringes. It improves the quality of the beam.

5. Electromagnetic Lens

It helps the Electron beam to focus on the desired spot.

6. Deflector Coils

The deflector coil carefully guides the high velocity electron beam to a desired location on the workpiece and improves the shape of the holes.

Material removal rate,

The values of the material removal rates in the process of electron beam machining are about **10 mm3/min**.

Process parameters

The process parameters of EBM are as follows.

- **Beam current**: It is related to the emission of electrons by the cathode in the beam whose value is as low as 1**µA**.
- **Duration of Pulse:** It can be varied from 50 **µs** to 15 **ms**.
- **Accelerating voltage** (V_a) is 100 **Kv**.
- **Energy per pulse** is 100 J/Pulse.

Characteristics 0f EBM

Material Removal Technique	High speed electrons impinge on surface and kinetic energy of electrons produces intense heat. or vaporise the metal
Voltage	150 KV
Electron velocity	228 x 1000 km/sec.
Power density	6500 billion W/mm2
Operations performed	Annealing, welding, or metal removal by cutting narrow slots, drilling holes of 25-125 um in 1.25mm thick shells. Complex contours possible by deflection by coils
Medium	Vacuum (10 mm Hg)
Materials of workpiece	All materials

Material removal rate 10 mm/min (max)

Specific power consumption 500 W/mm min

Limitations Not suitable for large workpieces. Small crates produced on beam incident side of work. A little taper produced on holes.Very high specific energy consumption, necessity of vaccum,high cost of machine

Advantages There is no effect of local heat on workpiece as the temperature of surrounding material(25-50 µm away from the machining spot)is not raised.

Applications

The applications of Electron Beam Machining Process are as follows.

- Mainly used for producing holes in the **diesel injection nozzles.**
- Also used for producing blind holes, narrow slots, etc. in the workpieces.
- In electron beam machining, if the voltage given to the electron gun is about 60 to 70000 volts, the velocity of electrons produced is reducing, heat generation at the workpiece is reducing.
- Therefore, the heat generated is sufficient to melt and join the workpiece called an electron beam welding operation.

Plastics Processing

Plastics Processing

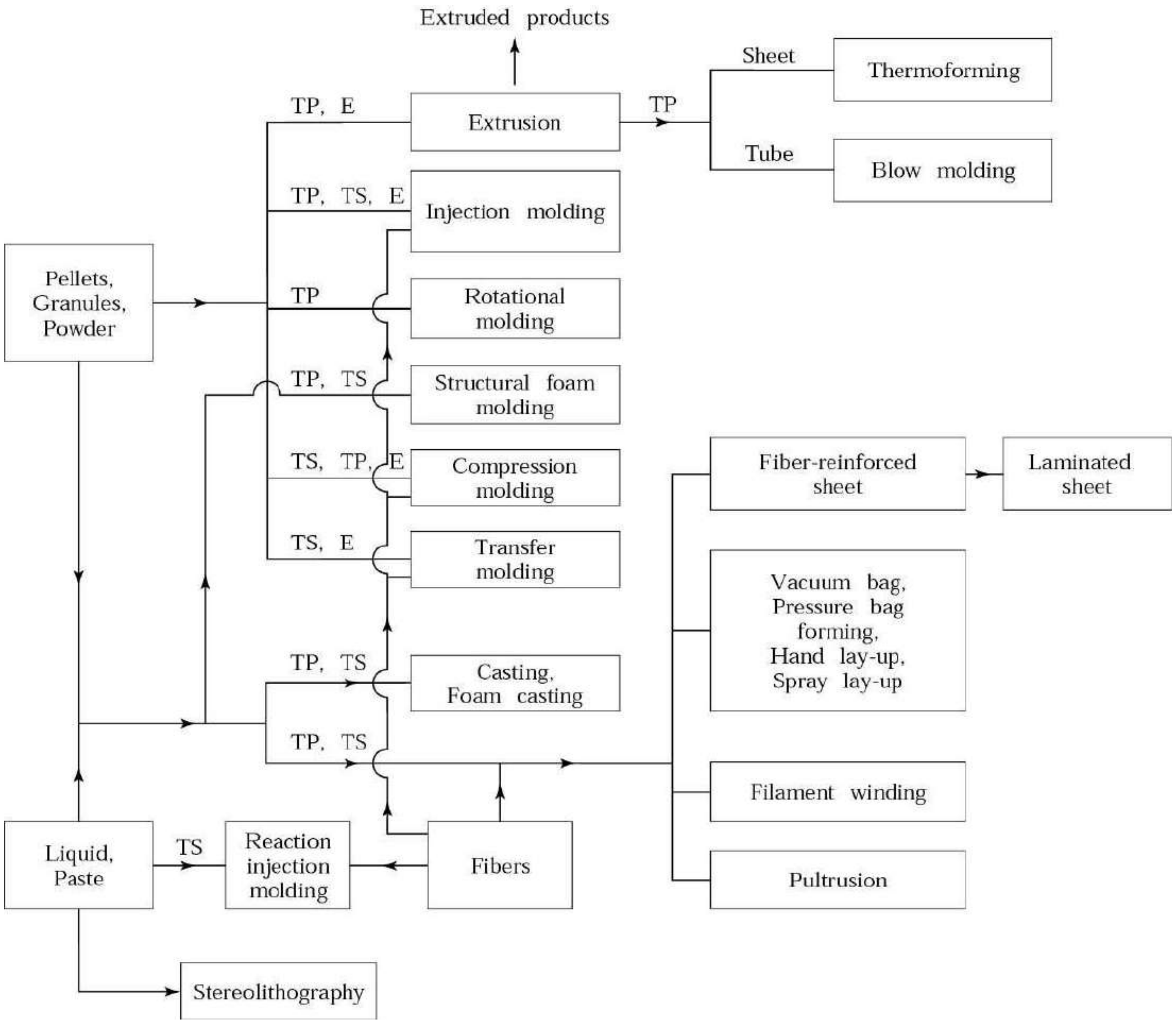
- Plastics can be machined, cast, formed, and joined with relative ease requiring little post-processing or surface-finish operations
- Plastics melt or cure at relative low temperatures
- Plastics require less energy to process than metals
- Raw materials most commonly are pellets, powders
- Also available as sheet, plate, rod, and tubing (produced by extrusion, etc.)
- Liquid plastics used to make reinforced plastic parts (composite materials)

Plastics Processes

TABLE 18.1

Process	Characteristics
Extrusion	Long, uniform, solid or hollow complex cross-sections; high production rates; low tooling costs; wide tolerances.
Injection molding	Complex shapes of various sizes, eliminating assembly; high production rates; costly tooling; good dimensional accuracy.
Structural foam molding	Large parts with high stiffness-to-weight ratio; less expensive tooling than in injection molding; low production rates.
Blow molding	Hollow thin-walled parts of various sizes; high production rates and low cost for making containers.
Rotational molding	Large hollow shapes of relatively simple shape; low tooling cost; low production rates.
Thermoforming	Shallow or relatively deep cavities; low tooling costs; medium production rates.
Compression molding	Parts similar to impression-die forging; relatively inexpensive tooling; medium production rates.
Transfer molding	More complex parts than compression molding and higher production rates; some scrap loss; medium tooling cost.
Casting	Simple or intricate shapes made with flexible molds; low production rates.
Processing of composite materials	Long cycle times; tolerances and tooling cost depend on process.

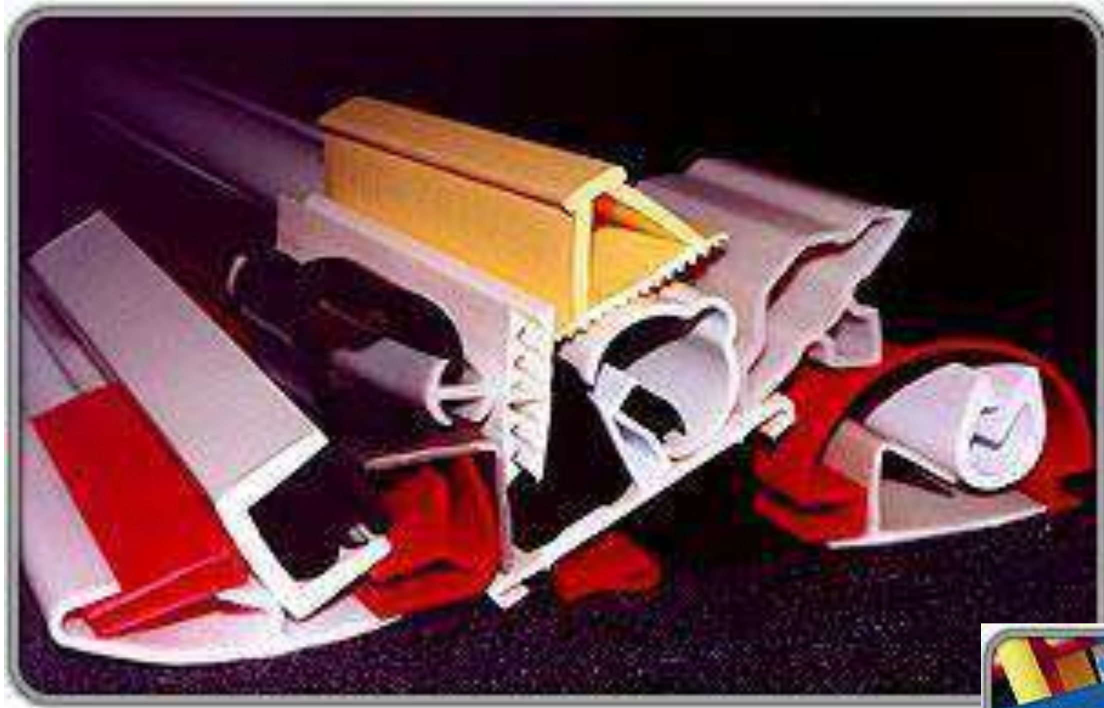
Plastics Processes

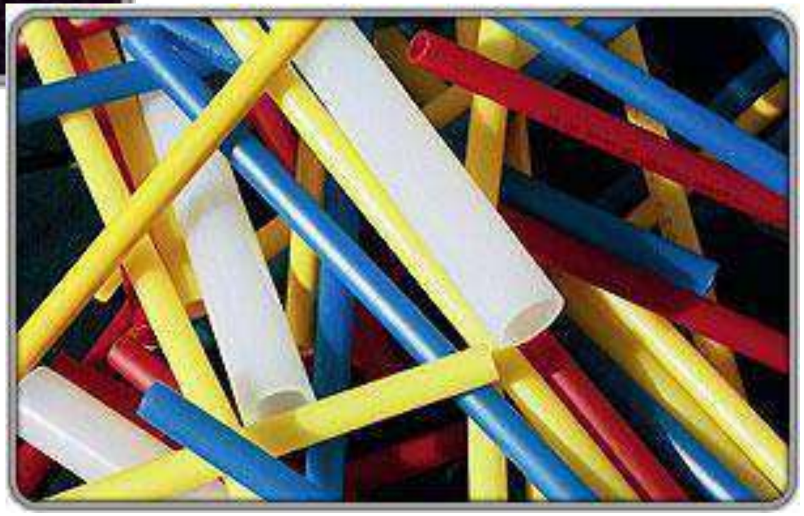


Extrusion

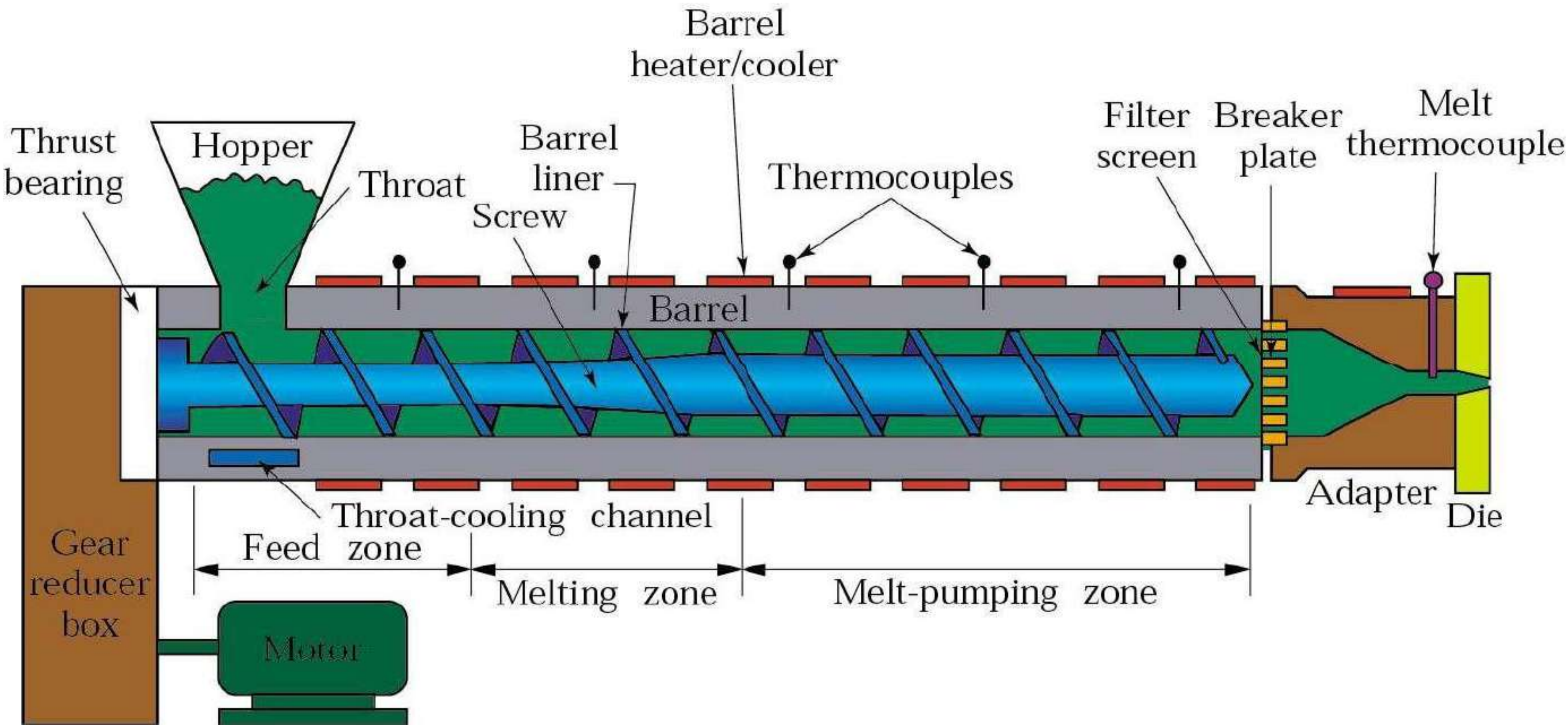
- Raw materials are thermoplastic pellets, granules, or powder
- Placed in hopper and fed into extruder barrel
- Screw blends pellets and pushes them down the barrel – through the feed, transition/melt, and pumping sections
- Barrel is heated from outside, and by friction
- Plastic (or elastomer) is liquefied and forced through a die under pressure
- Pellets for other plastics processes are made by extruding small-diameter rod and chopping into short segments
- Equipment costs on the order of $300,000
  - Rated by barrel diameter (D, 1-8 inch) and L/D ratio (5 to 30)

Extruded Products





Extrusion



Barrel
heater/cooler
Thrust
bearing
Hopper
Throat
Barrel
liner
Screw
Thermocouples
Filter
screen
Breaker
plate
Melt
thermocouple
Barrel
Adapter
Die
Throat-cooling channel
Gear
reducer
box
Feed zone
Melting zone
Melt-pumping zone
Motor

Polymer Melts

- Viscosity reduces with temperature
- Polymer melts have viscoelastic properties
- This causes die swell during extrusion

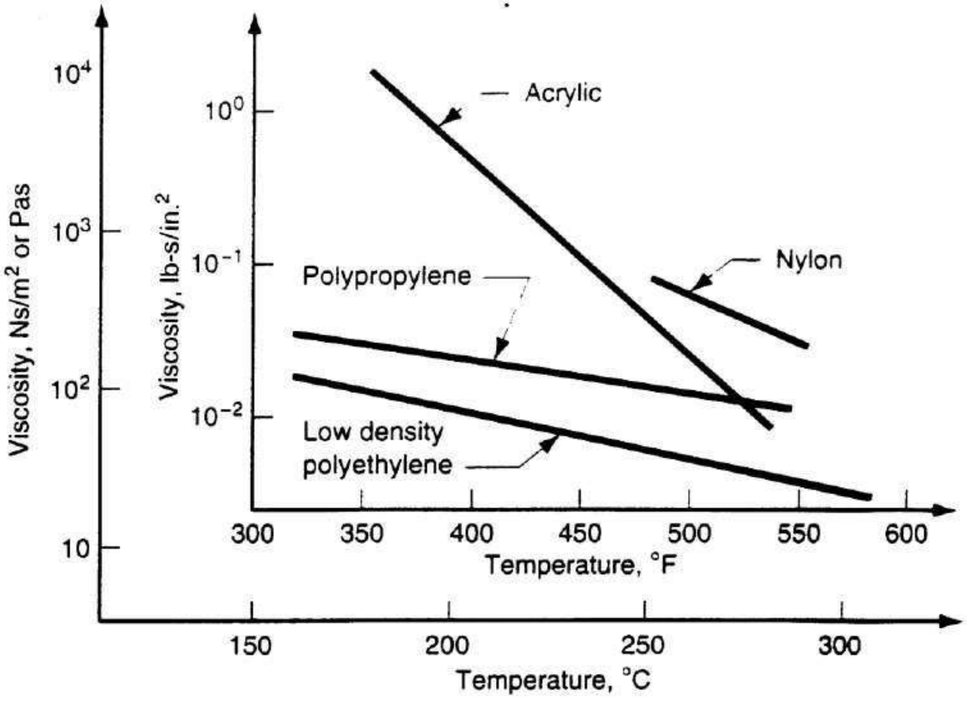


FIGURE 15.2 Viscosity as a function of temperatures for selected polymers at a shear rate of 10^3 sec^{-1}. Data compiled from [11].

Extrusion Die Swell

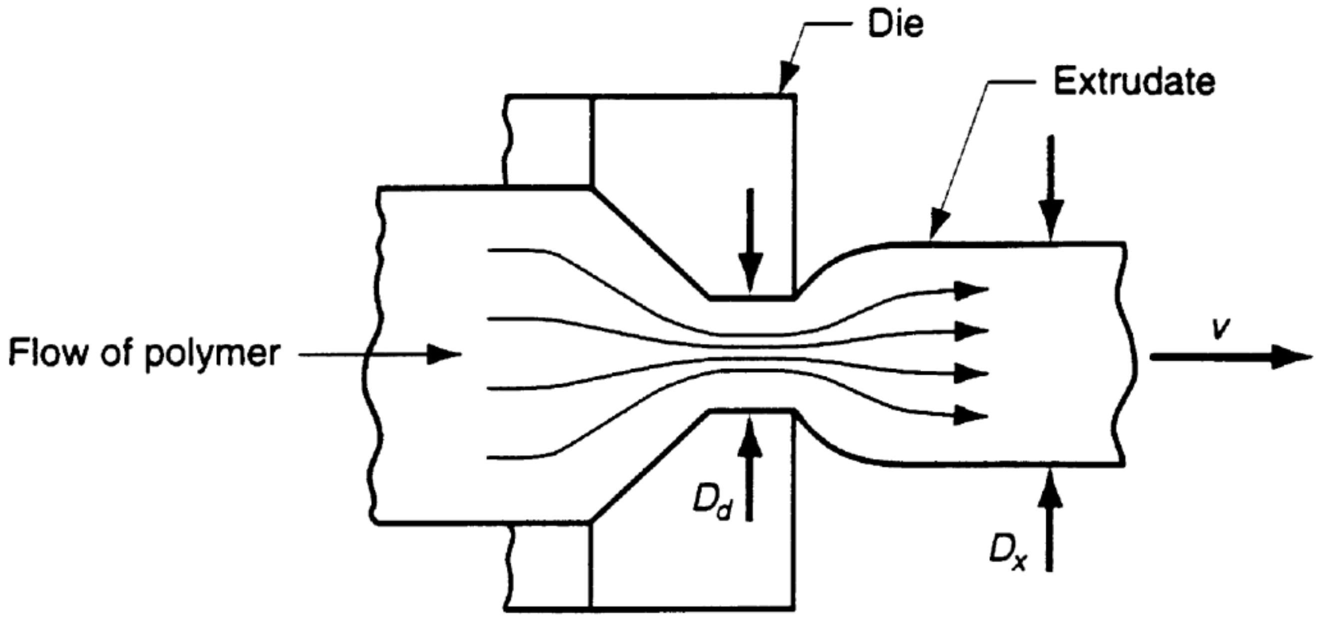
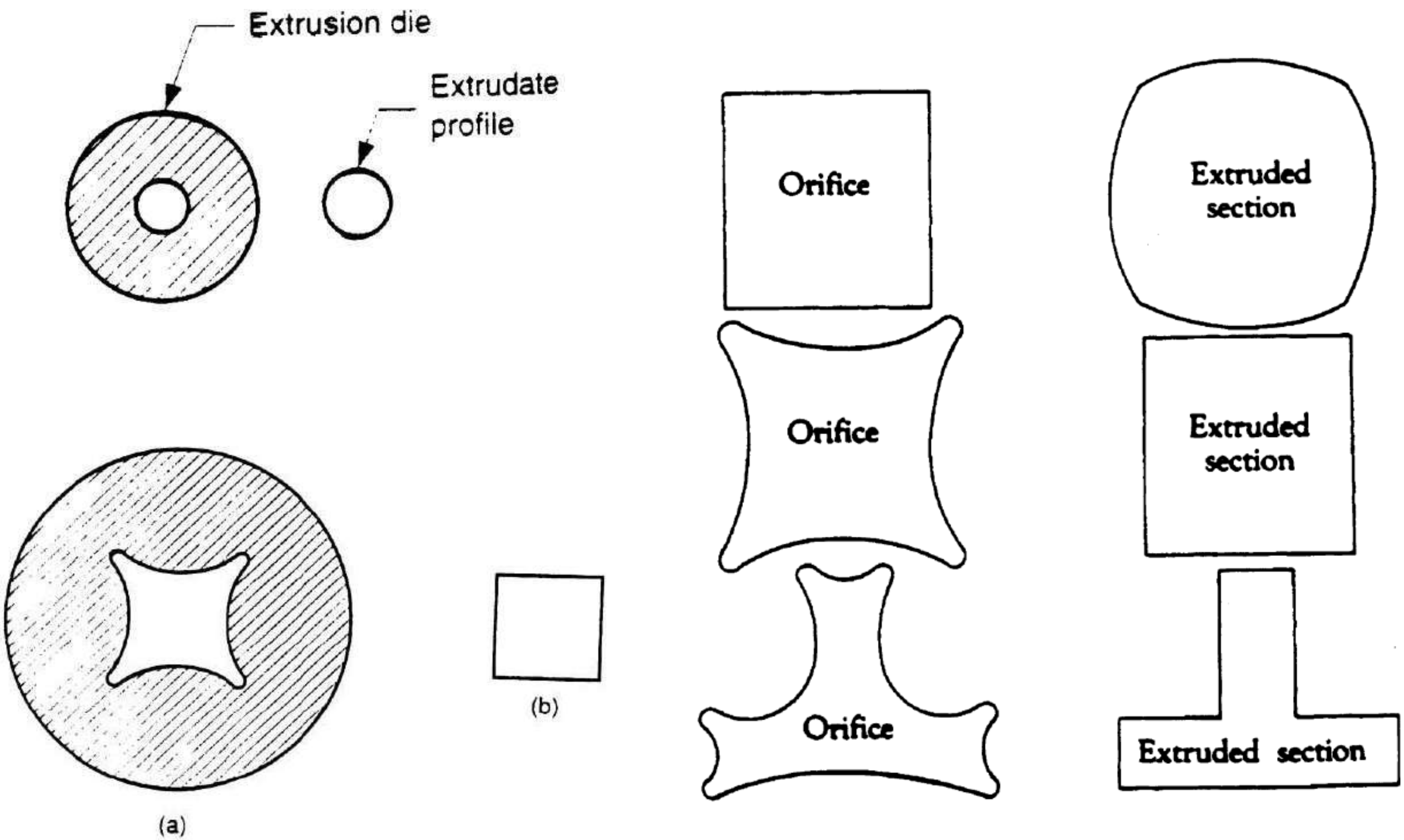


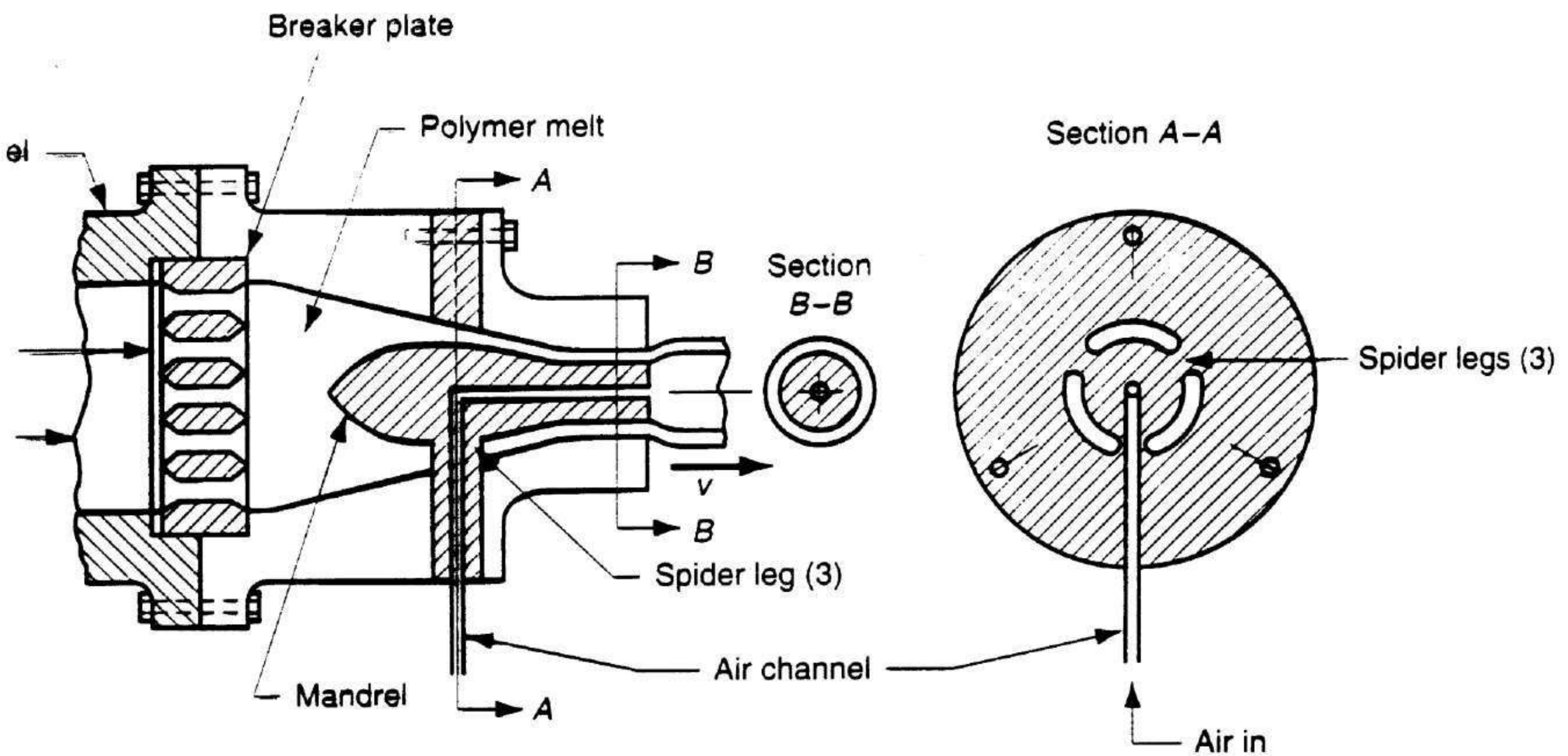
FIGURE 15.3 Die swell, a manifestation of viscoelasticity in polymer melts, as depicted here on exiting an extrusion die.

Swell ratio: $$r_s = \frac{D_x}{D_d}$$

Extrusion – Effects of Die Swell



Extrusion of Hollow Shapes



ɟe view cross section of extrusion die for shaping hollow cross sections such as
ction *A–A* is a front view cross section showing how the mandrel is held in place;
the tubular cross section just prior to exiting the die; die swell causes an enlarge-
ɜr. (Some die construction details are simplified.)

Extrusion Coating of Wires

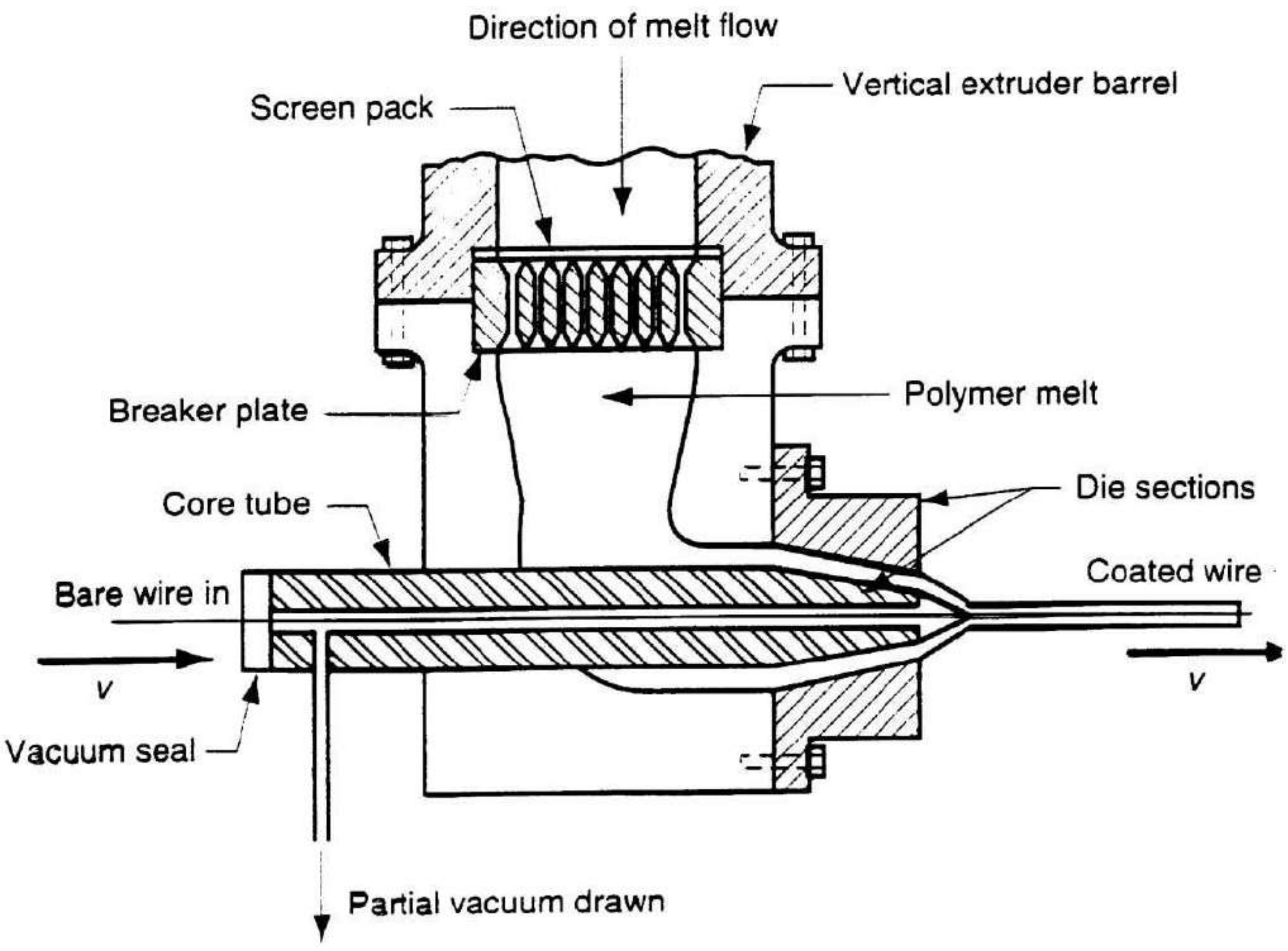


FIGURE 15.11 Side view cross section of die for coating of electrical wire by extrusion. (Some die construction details are simplified.)

Extrusion of Sheet

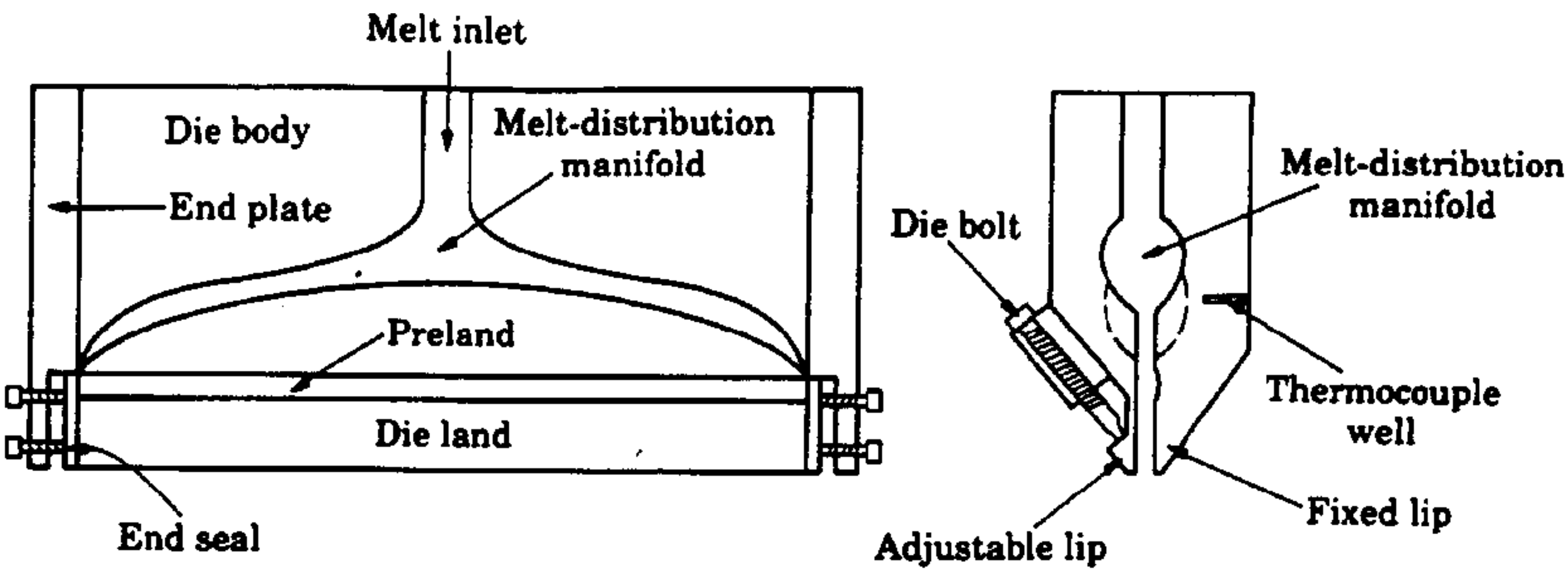
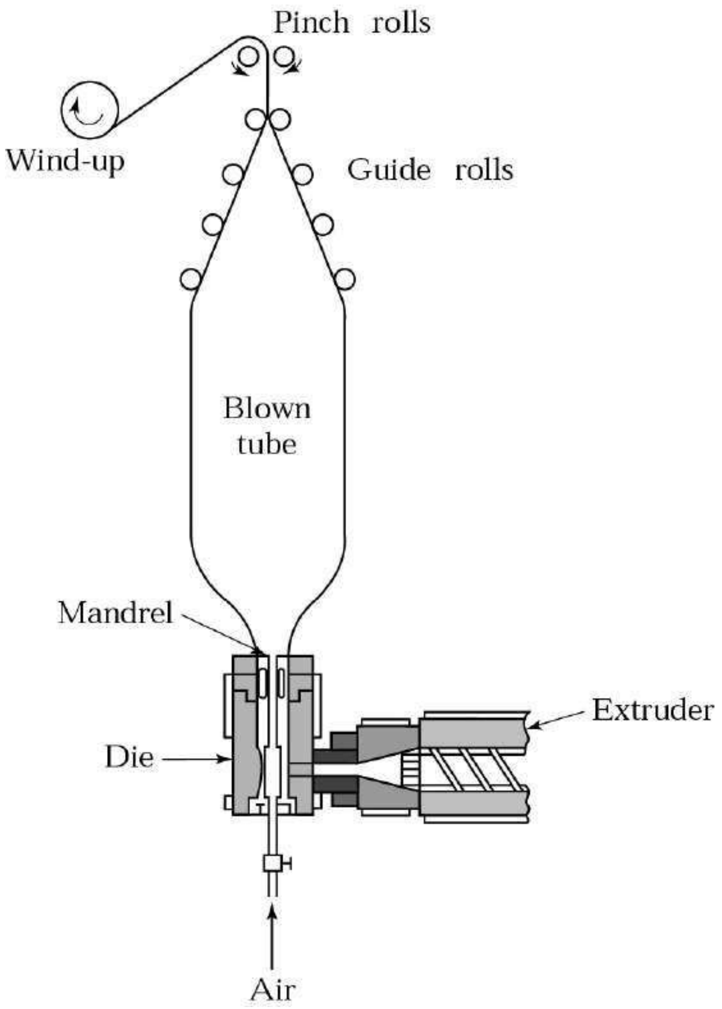


FIGURE 18.4

Die geometry (coat-hanger die) for extruding sheet. *Source: Encyclopedia of Polymer Science and Engineering*, 2d ed., Vol. 7, p. 93. New York: Wiley-Interscience, 1985.

Blown Film Extrusion

- Carried vertically
- Used to manufacture plastic film and plastic bags
- Mainly for materials such as LDPE and PVC

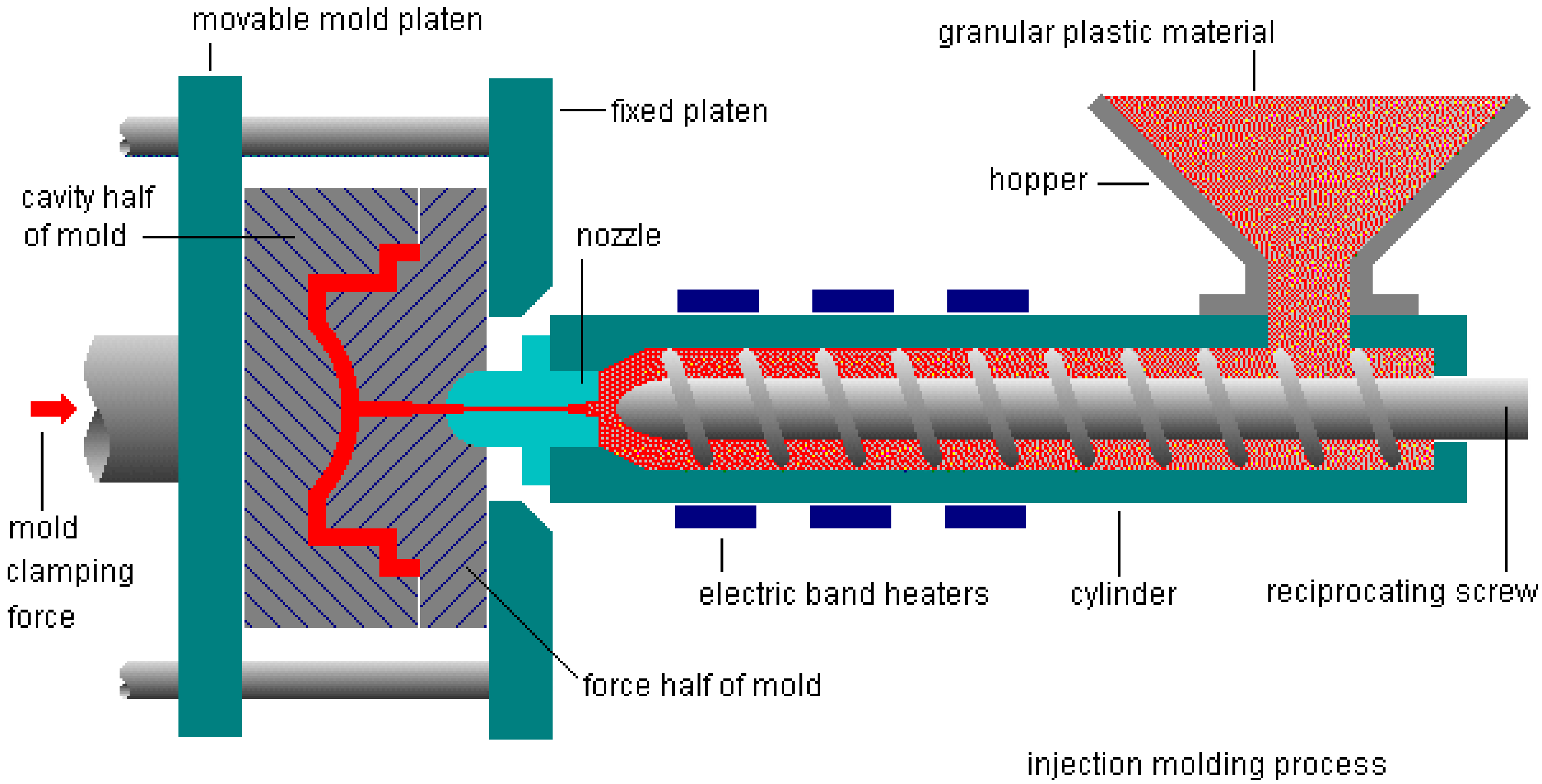


Injection Molding

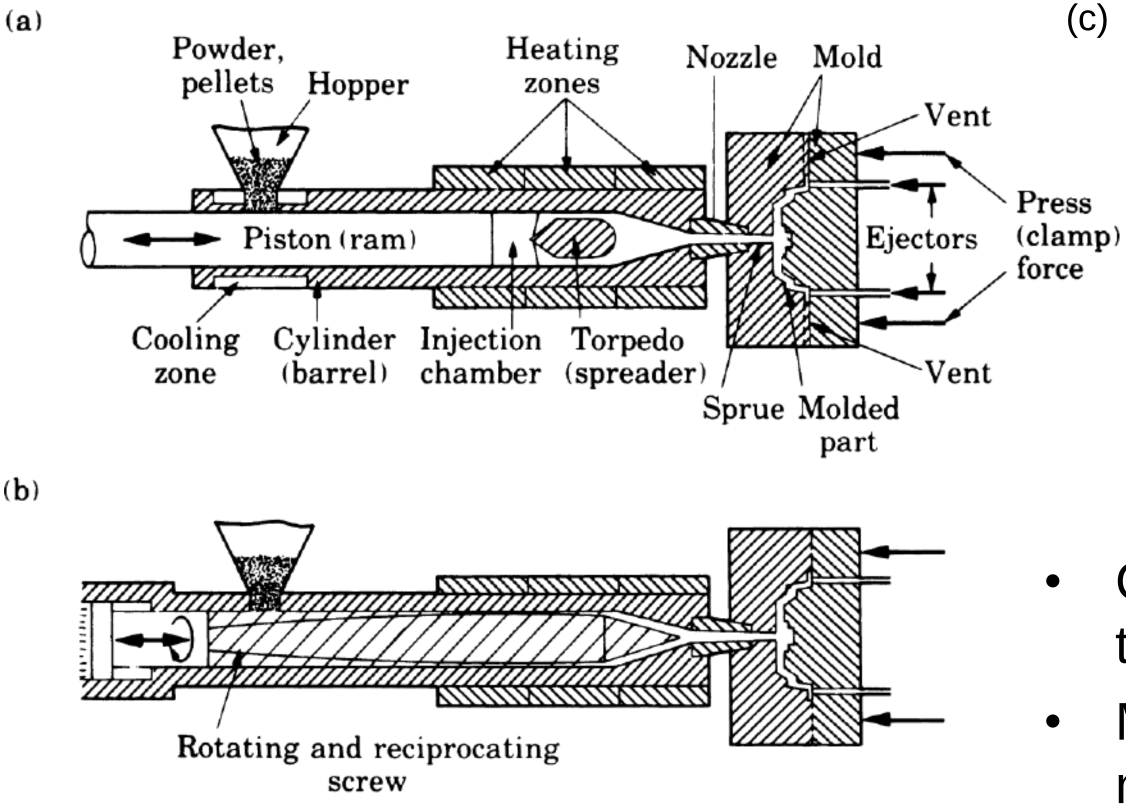
- Similar to hot-chamber die casting of metals
- Pellets, granules, or powder are fed into heated cylinder, then forced into die chamber by hydraulic plunger or rotating screw system
- Pressures from 70-200 MPa (10-30 Kpsi)
- Cool molds for thermoplastics. Heated molds for thermosets
- Complex shapes and good dimensional accuracy
- Using metallic inserts, multiple materials/colors, and printed films can eliminate post processing or assembly operations

Injection Moldings

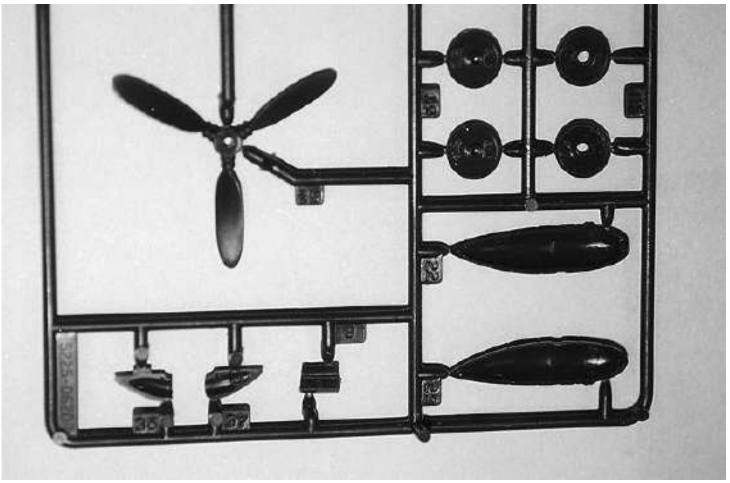
Injection Molding



Injection Molding



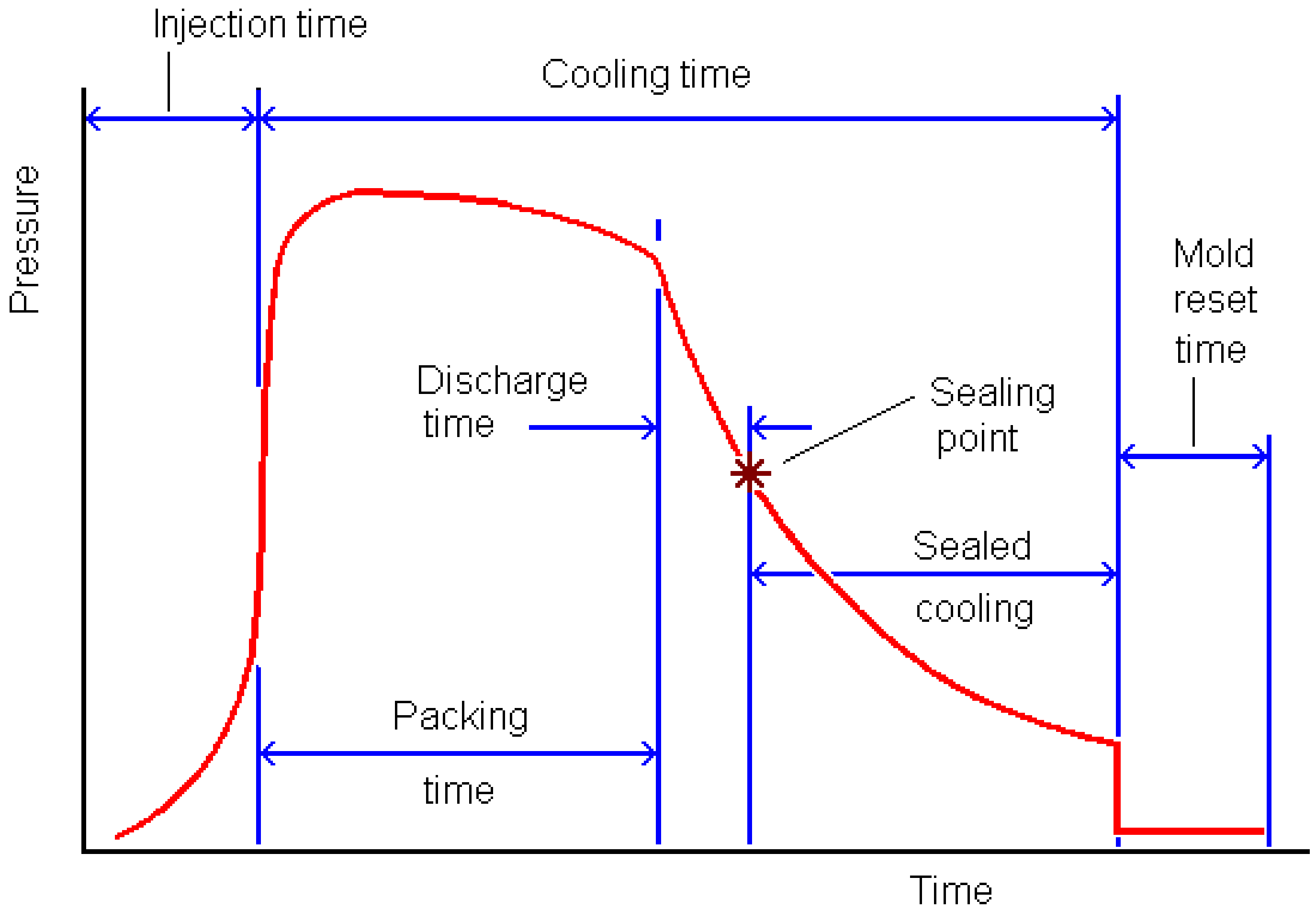
(c)



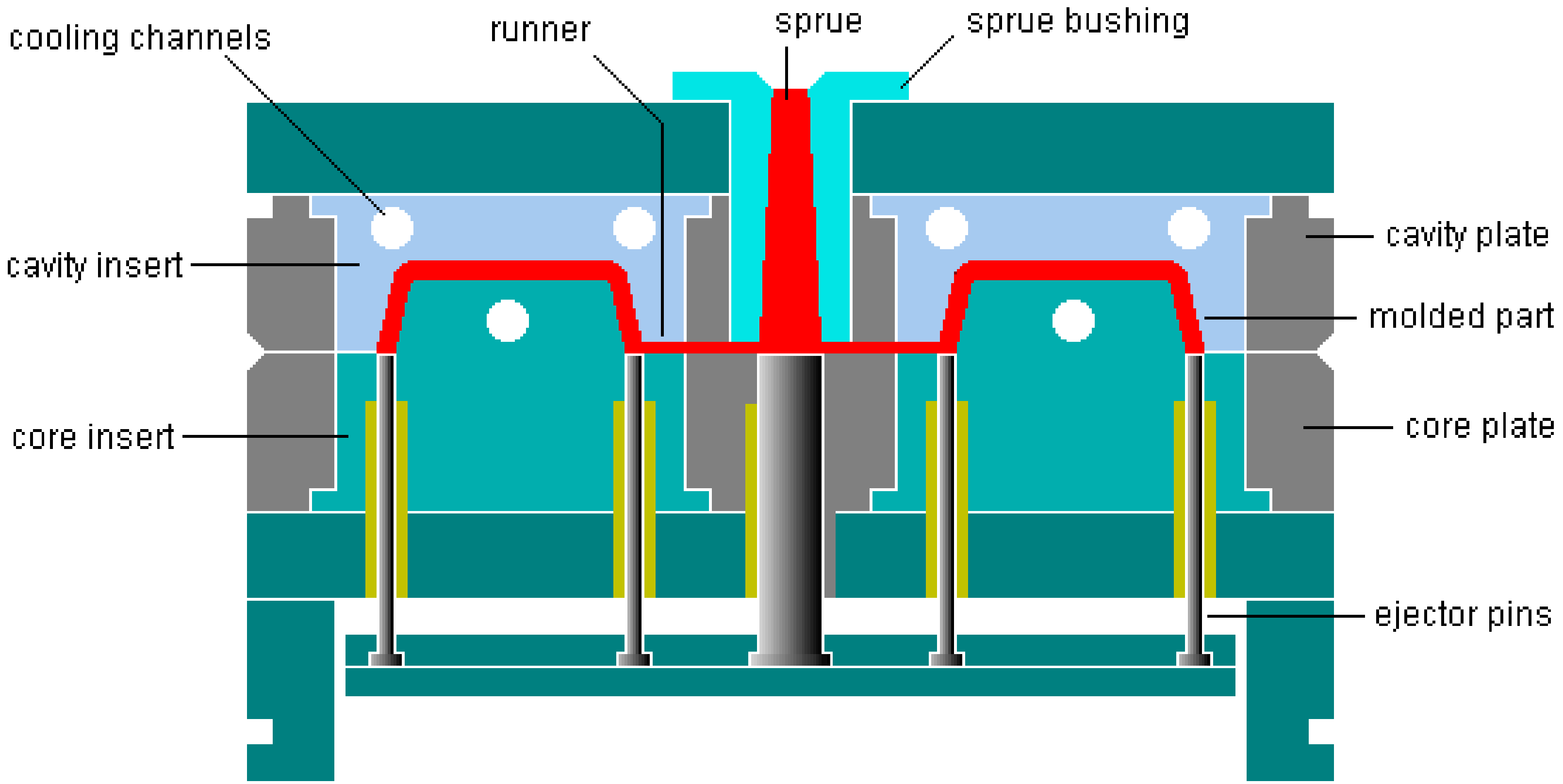
- Cold-runner molds are similar to metal casting
- More expensive hot-runner molds have no gates, runners, or sprues attached to final part

Plastic Injection Molding

Cycle Time Breakdown

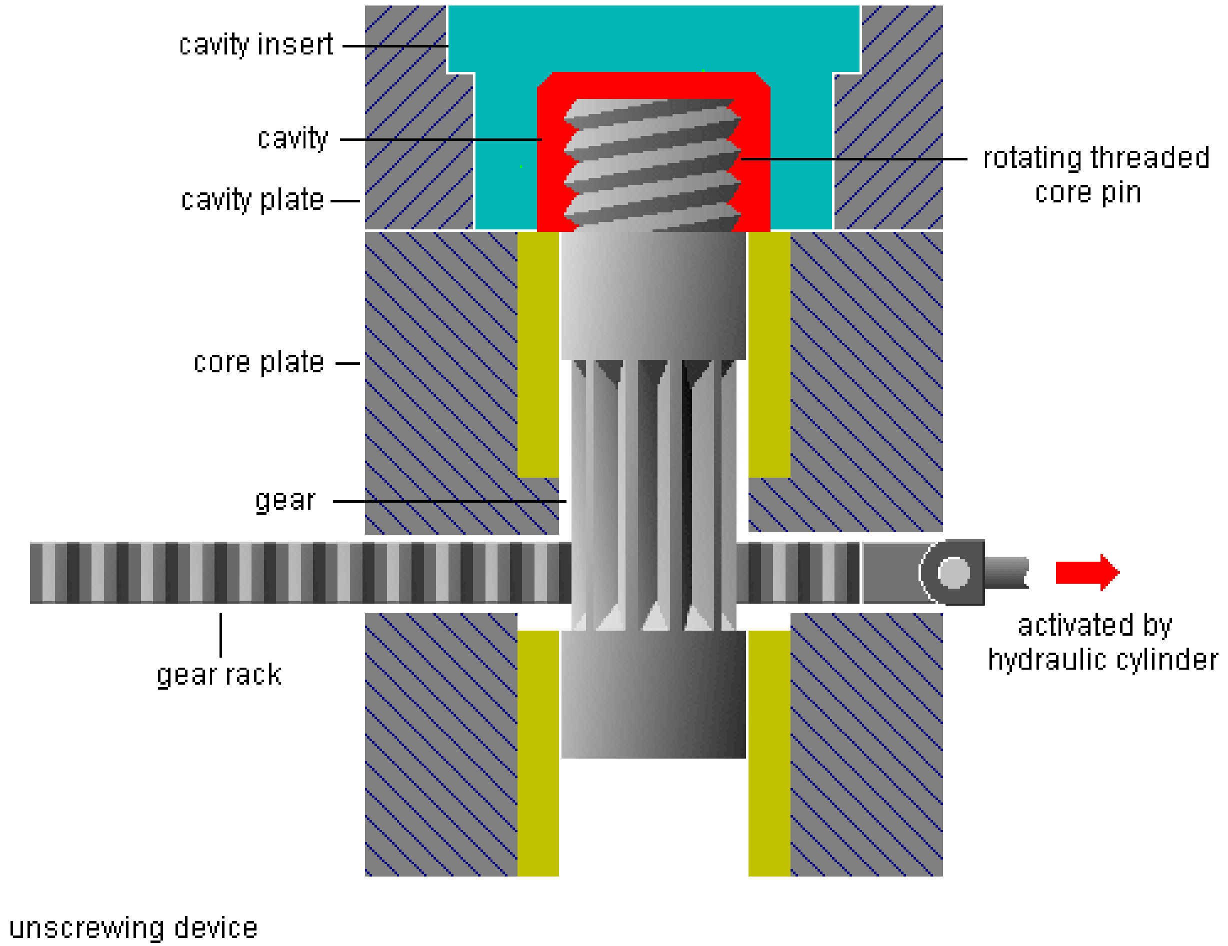


Injection Molding Two Plate Mold



two- plate and two-cavity mold

Injection Molding Die Mechanisms
Unscrewing Core



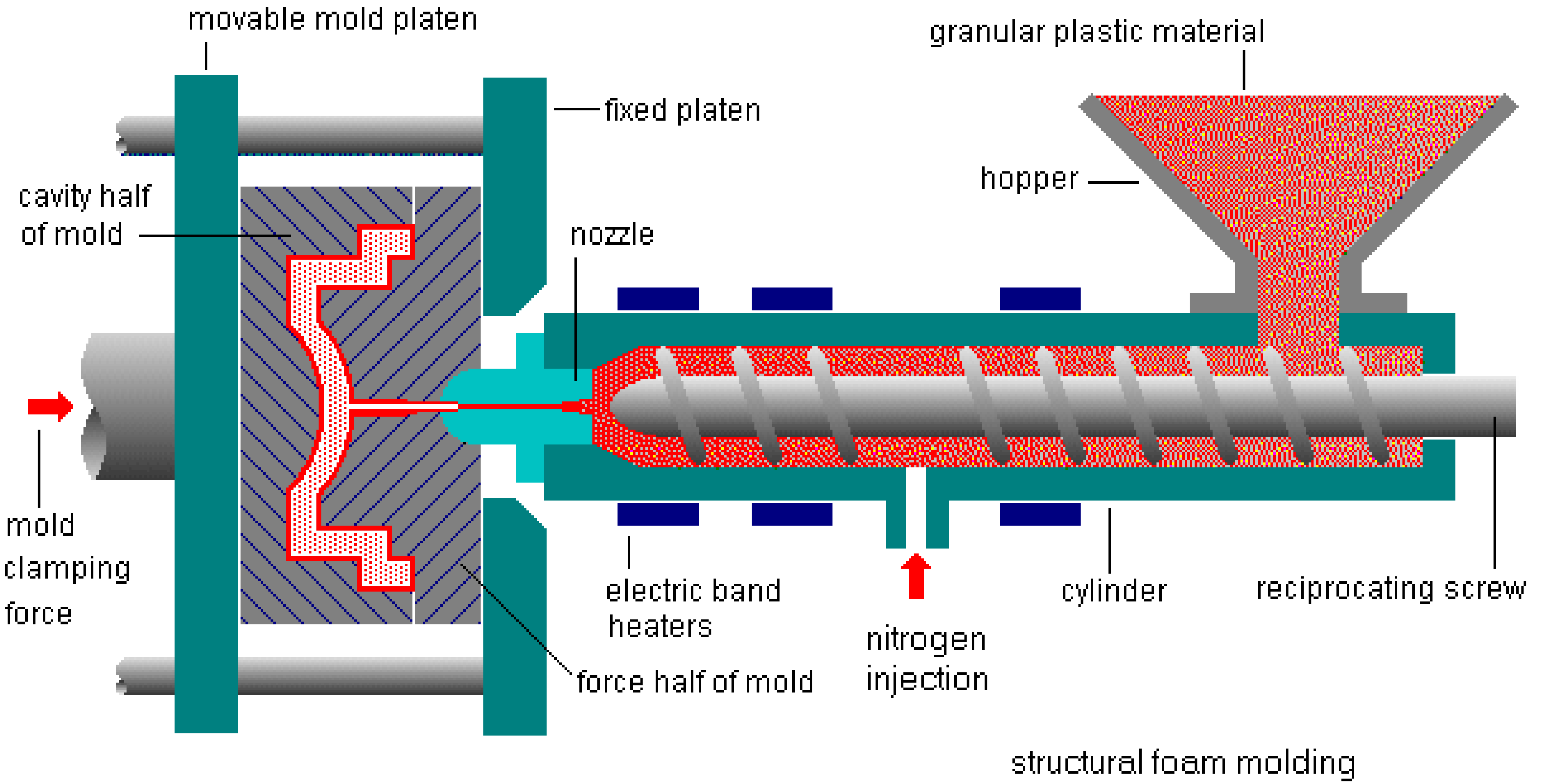
Injection Molding Capabilities

- High production rates
- Good dimensional control
- 5-60 second cycle times (or several minutes for thermoset materials)
- Molds with multiple cavities, made of tool steels (2 million cycles), aluminum (10,000 cycles), etc.
- Mold costs up to $20-200K
- Machines are usually horizontal with clamping forces 0.9-2.2 MN (100-250 tons)
- 100 ton machines cost $60-90K
- 300 ton machines cost $85-140K

Structural Foam Molding

- A variation of the injection molding process, developed for applications where stiffness is a primary concern, and particularly for large structural parts.
- Parts consist of a rigid, closed-cellular core surrounded by a continuous, solid skin.
- The polymer melt contains a dissolved inert gas; most commonly nitrogen, introduced in the extrusion screw.
- A predetermined shot size is injected into the mold cavity, the extruder valve is closed, and the foam material generates internal pressure and expands to fill mold cavity.
- A much lower pressure operation than the conventional injection molding system, which allows much larger parts to be molded.

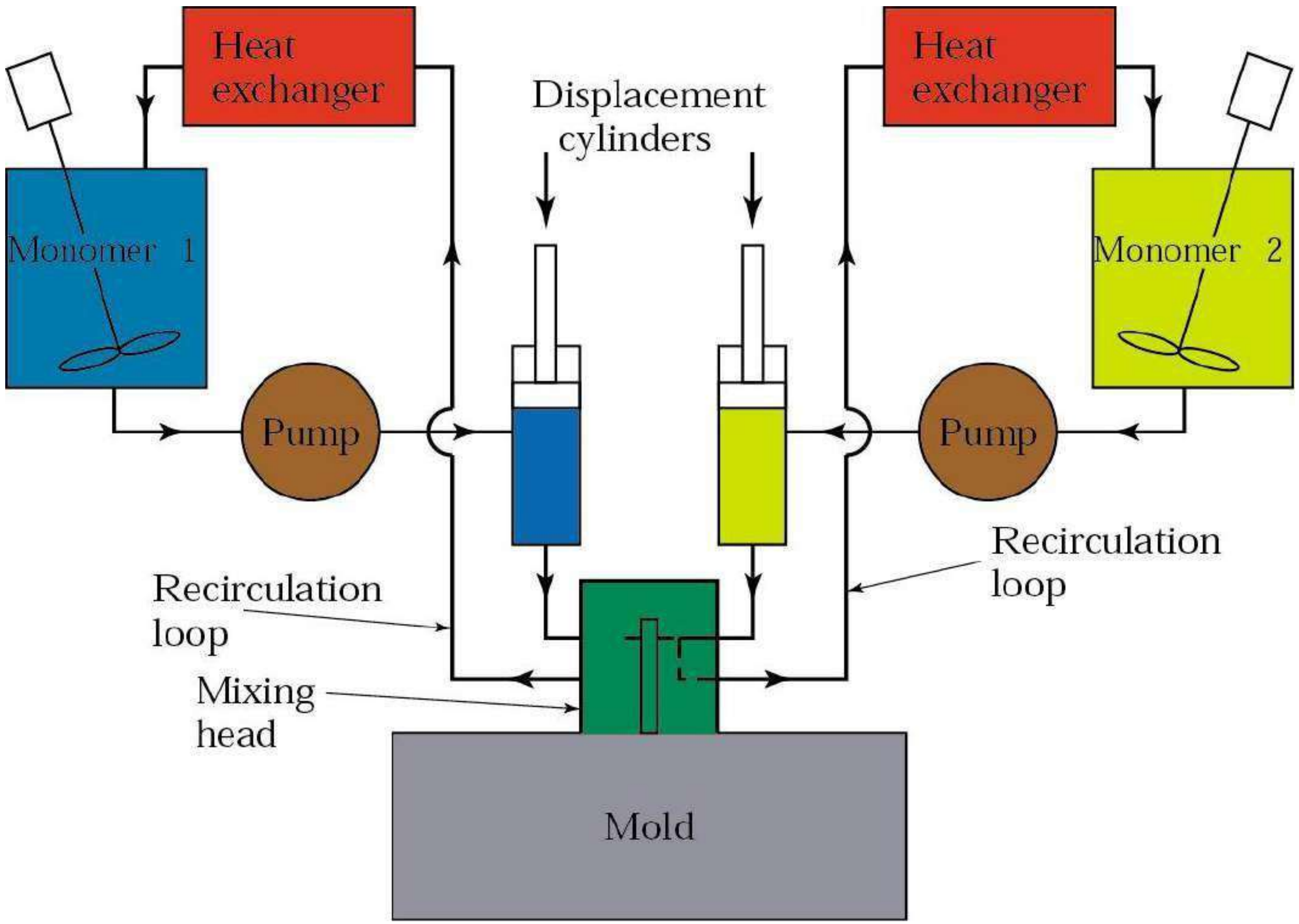
Structural Foam Molding



Structural Foam Moldings

Reaction Injection Molding

Chemical reaction between two polymer materials - thermoset



- Large parts
- Low tooling costs
- Car bumpers are good examples for this process

Reaction Injection Moldings

Blow Molding

- Modified extrusion and injection molding processes
- Extrusion Blow Molding
  - Small tube is first extruded, usually vertically, then clamped and air blown inside to expand it to fit a much larger diameter mold
  - Air pressures 350-700 kPa (50-100 psi)
  - Can be a continuous process (corrugated pipe and tubing)
- Injection blow molding
  - Short tubular piece (parison) injection molded, transferred to a blow-molding die
  - Plastic beverage bottles and hollow containers
- Multilayer blow molding
  - Uses coextruded tubes or parisons
  - Plastic packaging for food and beverages, cosmetics and pharmaceutical industries

Blow Moldings

Blow Molding

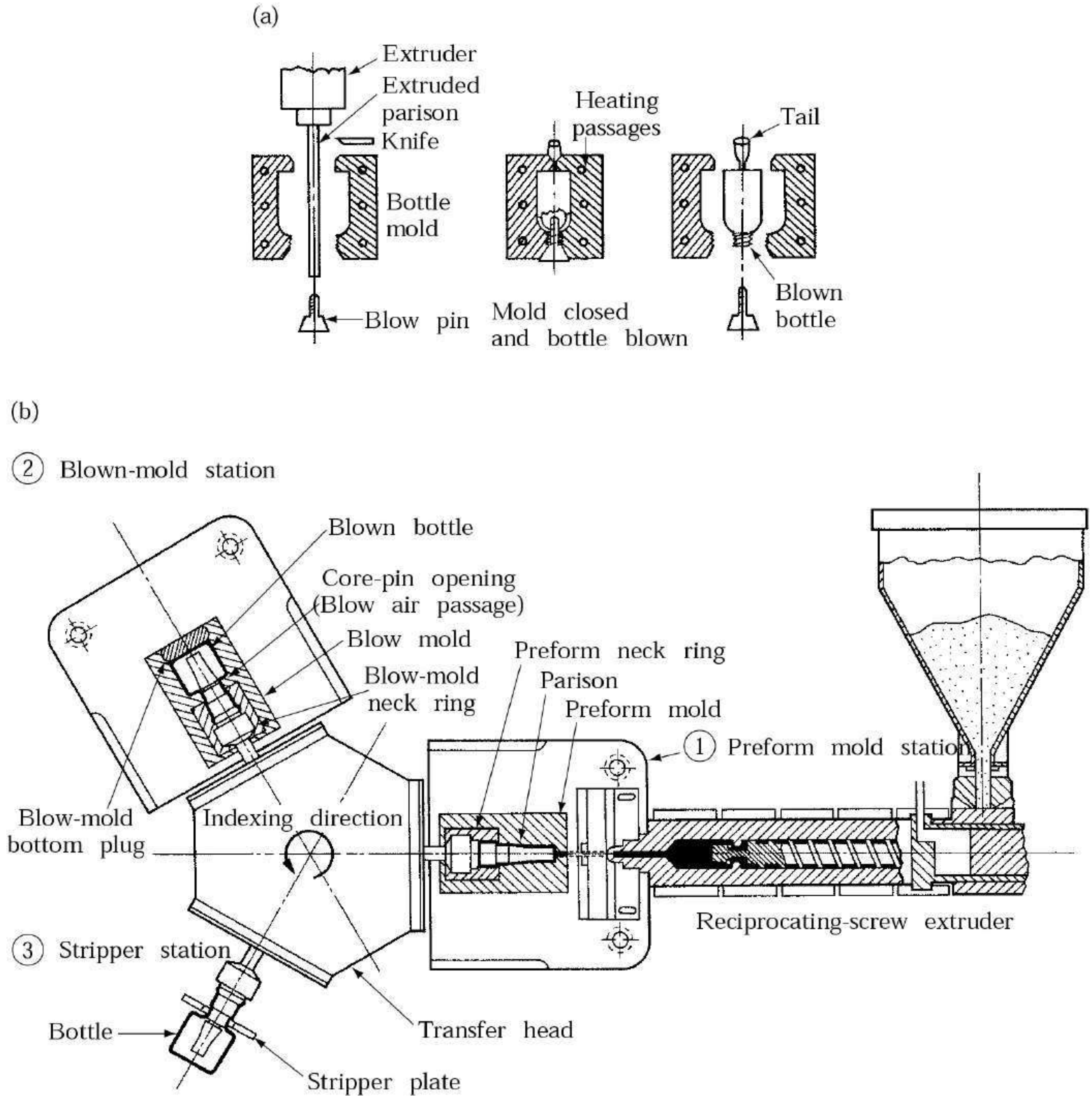
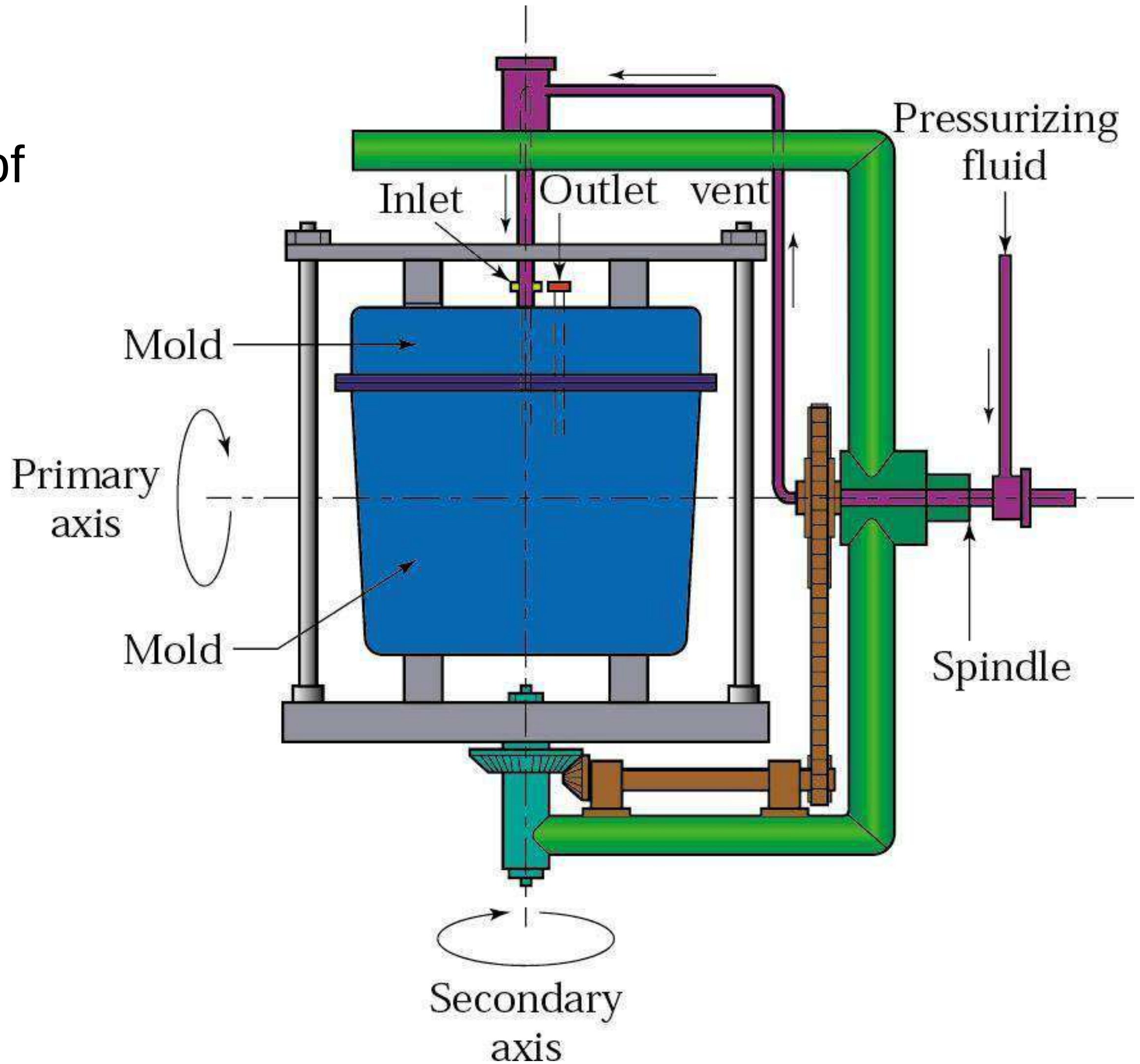


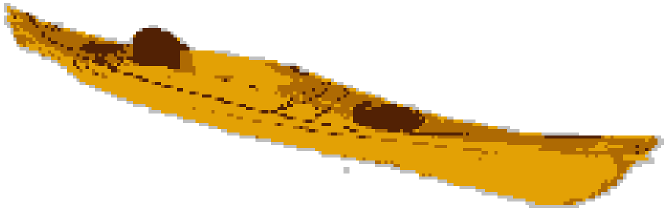
Figure 18.9 Schematic illustrations of (a) the blow-molding process for making plastic beverage bottles, and (b) a three-station injection blow-molding machine. *Source*: *Encyclopedia of Polymer Science and Engineering* (2d ed.). Copyright ©1985. Reprinted by permission of John Wiley & Sons, Inc.

Rotational Molding

- Premeasured quantity of powder placed inside warm mold
- Rotated on two axes inside a heated furnace
- Low equipment costs
- Longer process times
- Trash cans, boat hulls, buckets, toys, footballs
- 0.4 mm wall thickness possible
- Also, slush molding

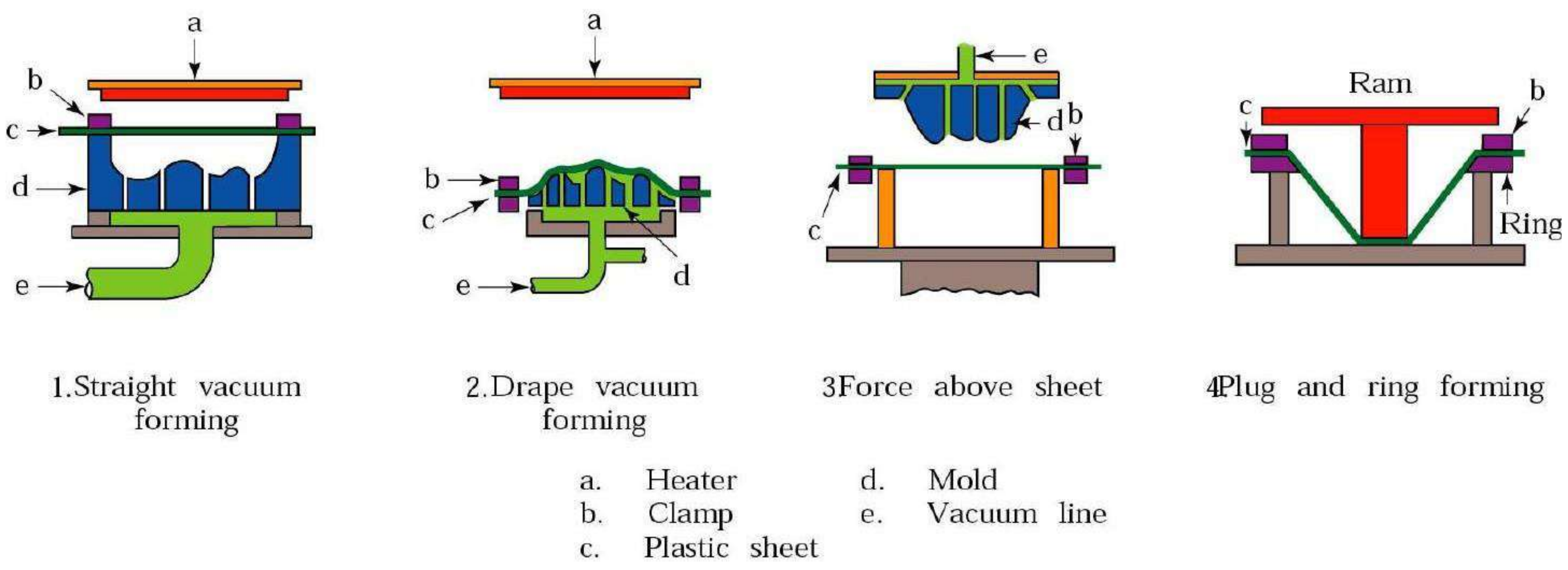


Rotational Moldings



Thermoforming

- Plastic sheet is heated to a sag point (softened, but not melted)
- Heated sheet placed over a room-temperature mold and forced against it by vacuum pressure
- Stretch forming process – material thickness variations
- Advertising signs, refrigerator liners, appliance housings, shower stalls, packaging



Thermo Formed Parts

Compression Molding

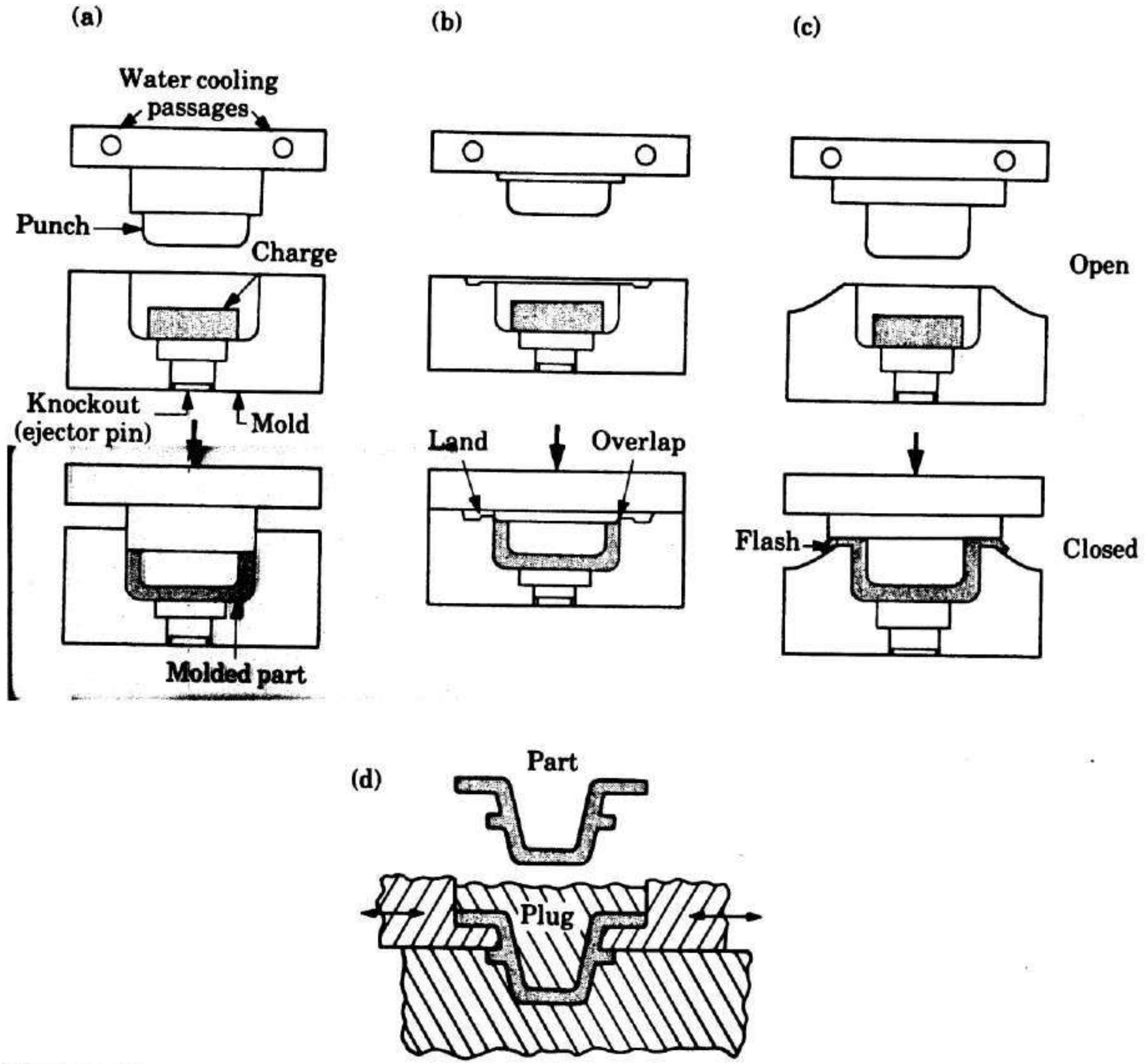


FIGURE 18.12

Types of compression molding, a process similar to forging: (a) positive, (b) semipositive, and (c) flash. The flash in part (c) has to be trimmed off. (d) Die design for making a compression-molded part with undercuts.

Compression Moldings

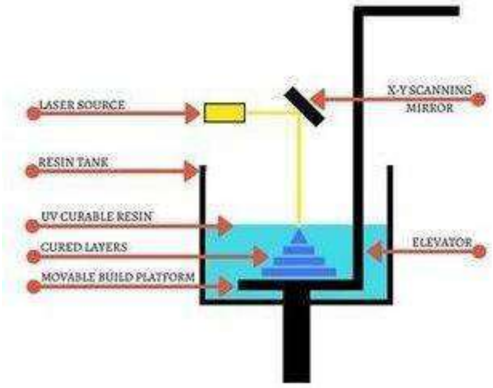
Rapid prototyping:

It is the fast fabrication of a physical part, model or assembly using 3D computer aided design (CAD). The creation of the part, model or assembly is usually completed using additive manufacturing, or more commonly known as 3D printing.

Different Types of Rapid Prototyping Processes:

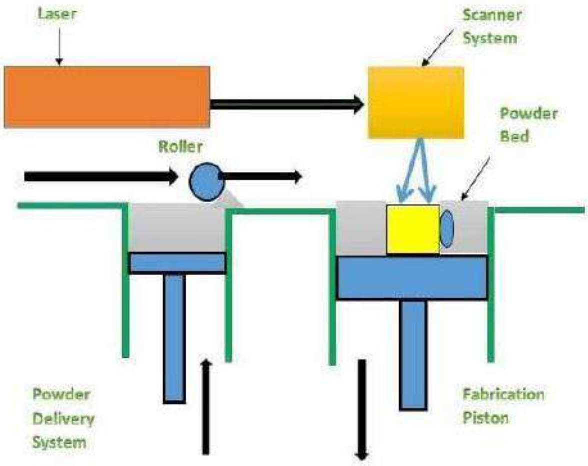
1) Stereolithography Apparatus (SLA) or Vat Photopolymerization:-

This fast and affordable technique was the first successful method of commercial 3D printing. It uses a bath of photosensitive liquid which is solidified layer-by-layer using a computer-controlled ultra violet (UV) light.



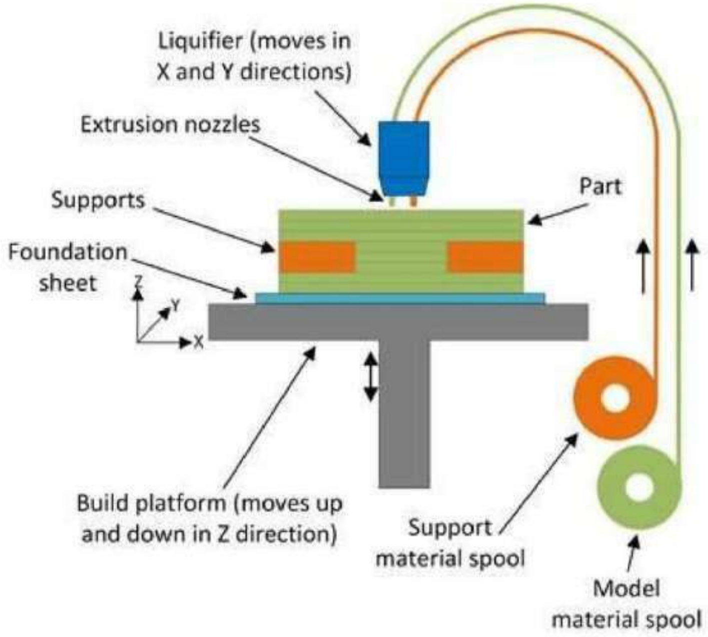
2) Selective Laser Sintering (SLS):

Used for both metal and plastic prototyping, SLS uses a powder bed to build a prototype one layer at a time using a laser to heat and sinter the powdered material. However, the strength of the parts is not as good as with SLA, while the surface of the finished product is usually rough and may require secondary work to finish it.



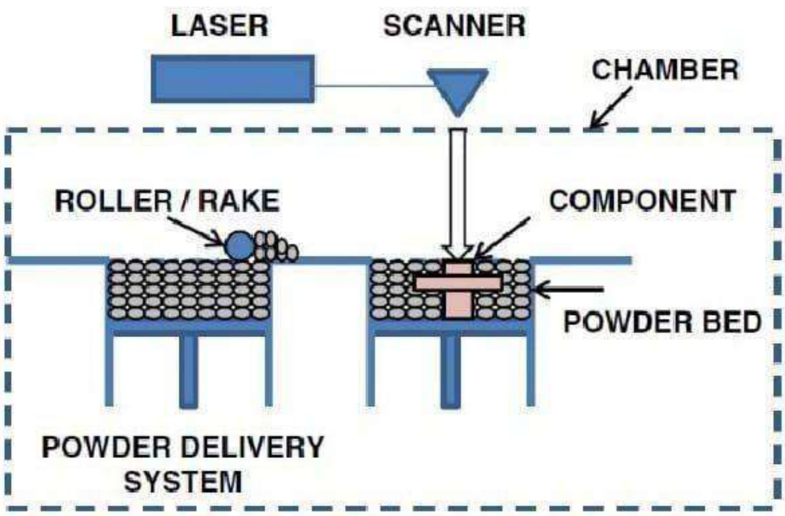
3) Fused Deposition Modelling (FDM) or Material Jetting:

This inexpensive, easy-to-use process can be found in most non-industrial desktop 3D printers. It uses a spool of thermoplastic filament which is melted inside a printing nozzle barrel before the resulting liquid plastic is laid down layer-by-layer according to a computer deposition program. While the early results generally had poor resolution and were weak, this process is improving rapidly and is fast and cheap, making it ideal for product development.



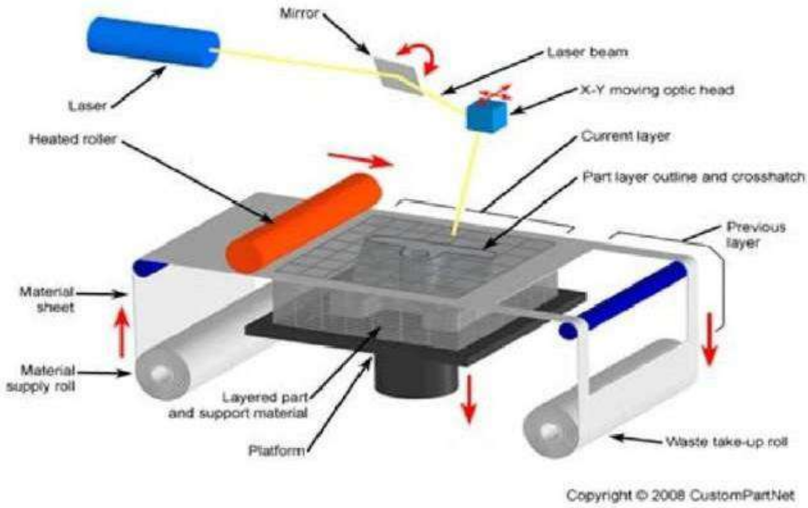
4) Selective Laser Melting (SLM) or Powder Bed Fusion:

Often known as powder bed fusion, this process is favoured for making high-strength, complex parts. Selective Laser Melting is frequently used by the aerospace, automotive, defence and medical industries. This powder bed based fusion process uses a fine metal powder which is melted in a layer by layer manner to build either prototype or production parts using a high-powered laser or electron beam. Common SLM materials used in RP include titanium, aluminium, stainless steel and cobalt chrome alloys.



5) Laminated Object Manufacturing (LOM) or Sheet Lamination:

This inexpensive process is less sophisticated than SLM or SLS, but it does not require specially controlled conditions. LOM builds up a series of thin laminates that have been accurately cut with laser beams or another cutting device to create the CAD pattern design. Each layer is delivered and bonded on top of the previous one until the part is complete.

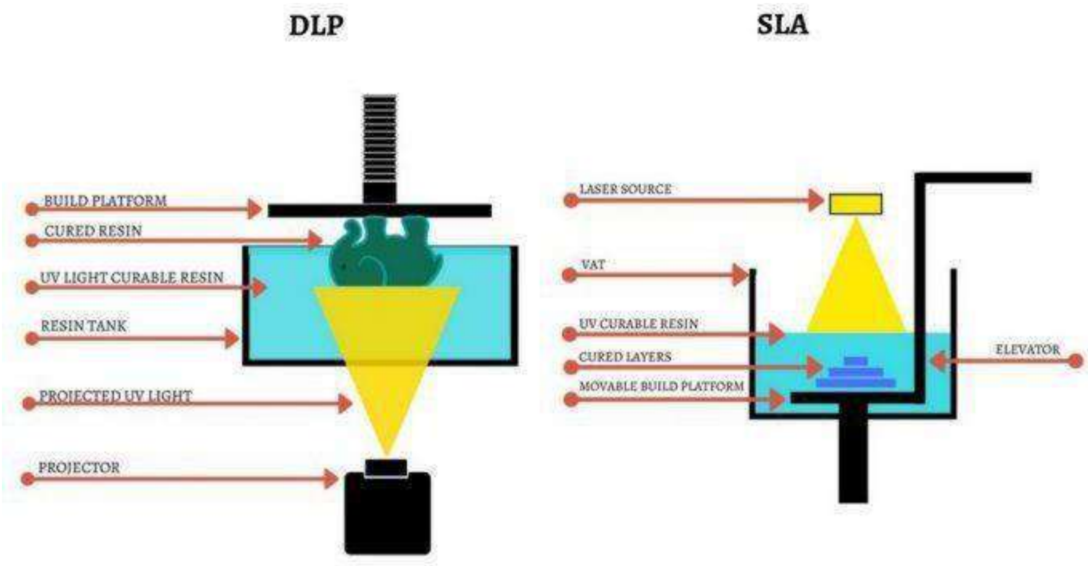


6) Digital Light Processing (DLP):

Similar to SLA, this technique also uses the polymerisation of resins which are cured using a more conventional light source than with SLA. While faster and cheaper than SLA, DLP often requires the use of support structures and post-build curing.
An alternative version of this is Continuous Liquid Interface Production (CLIP), whereby the part is continuously pulled from a vat, without the use of layers. As the part is pulled from the vat it crosses a light barrier that alters its configuration to create the desired cross-sectional pattern on the plastic.

Working Process:

The digital light projector is the light source of a DLP 3D printer. The DMD (Digital Micromirror Device) is a component which is made of thousands of micromirrors used for navigating the light beam projected by the digital light projector. Next up the line is the vat, which is basically a tank for the resin.
However, the vat needs to have a transparent bottom so that the light projected by the digital light projector reaches the resin and cures it. The build platform is simply the surface the printed objects stick to during printing. The z-axis is also a self-explanatory component, used for slowly lifting the build platform during the printing process.
Again next layer is formed until complete model gets ready.



7) Binder Jetting:

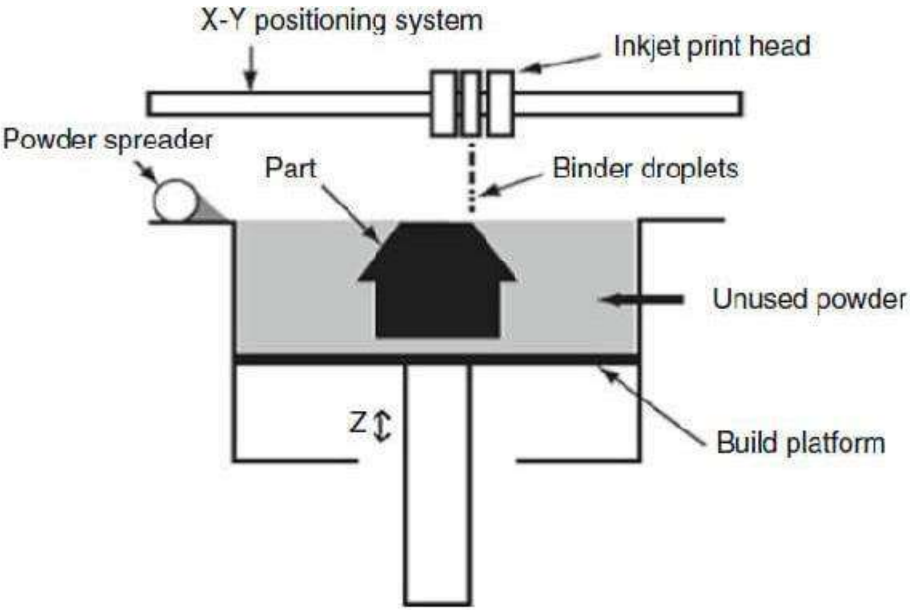
This technique allows for one or many parts to be printed at one time, although the parts produced are not as strong as those created using SLS. Binder Jetting uses a powder bed onto which nozzles spray micro-fine droplets of a liquid to bond the powder particles together to form a layer of the part. Each layer may then compacted by a roller before the next layer of powder is laid down and the process begins again. When complete the part may be cured in an oven to burn off the binding agent and fuse the powder into a coherent part.

Applications:

Product designers use this process for rapid manufacturing of representative prototype parts. This can aid visualisation, design and development of the manufacturing process ahead of mass production.

Originally, rapid prototyping was used to create parts and scale models for the automotive industry although it has since been taken up by a wide range of applications, as medical and aerospace. across multiple industries such

Rapid tooling is another application of RP, whereby a part, such as an injection mould plug or ultrasound sensor wedge, is made and used as a tool in another process.

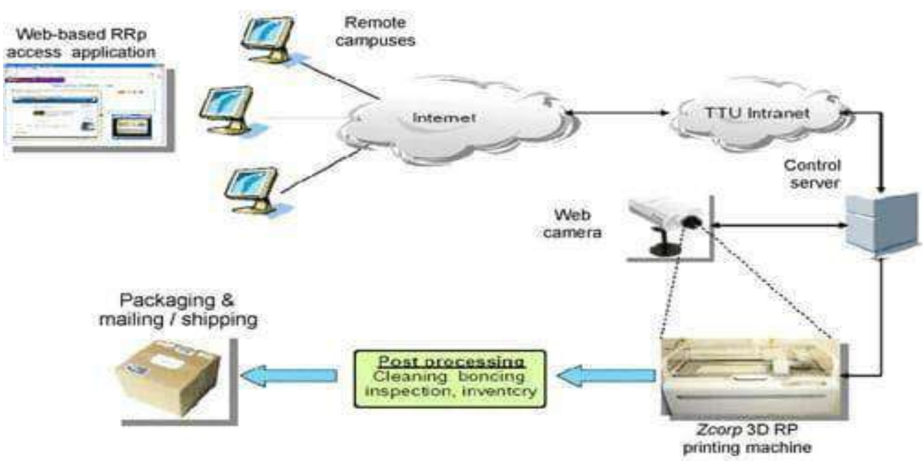


Web-based RP systems:

Rapid prototyping (RP) technique has shown a high potential to reduce the cycle and cost of product development, and has been considered as one of crucial enabling tools in digital manufacturing to effectively aid rapid product development.

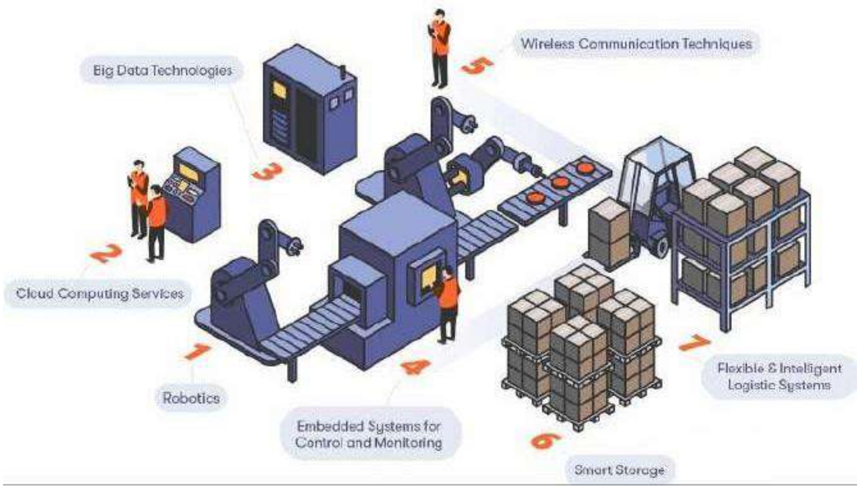
Manufacturing industry is evolving toward digitalization, network and globalization. The Internet, incorporating computers and multimedia, has provided tremendous potential for remete integration and collaboration in business and manufacturing applications. RP&M technique using the Internet can further enhance the design and manufacturing productivity, speed, and economy, as well as share the RP machines.

Web-based RP systems have been developed and employed to implement remote service and manufacturing for rapid prototyping, enhance the availability of RP facilities and improve the capability of rapid product development for a large number of small and medium sized enterprises.

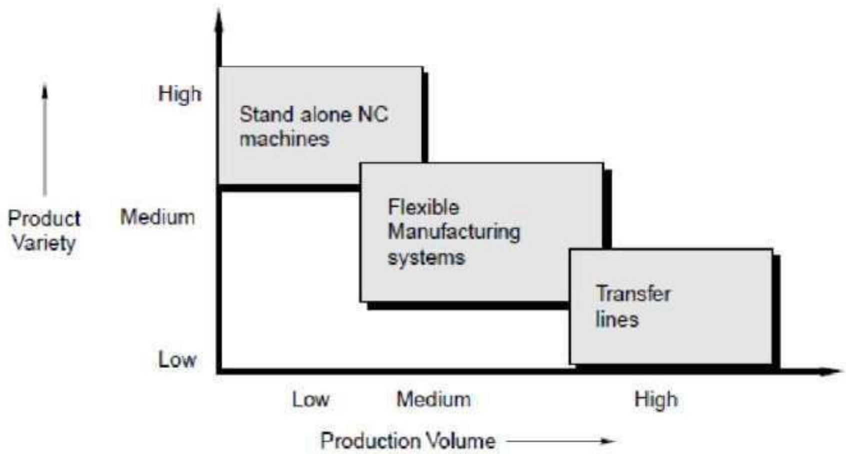


Flexible Manufacturing System:

A flexible manufacturing system is a automated machine cell, consisting of a group of processing workstations, interconnected with automated material handling and storage system.



The FMS is most suited for the mid-variety, mid-volume production range



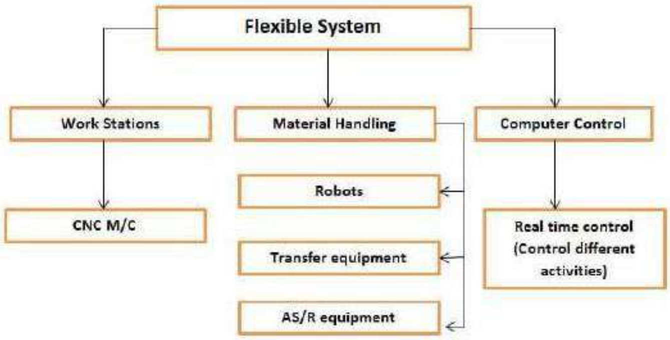
Benefits of FMS:

> It allows external changes such as change in product design and production system.
> Optimizing the manufacturing cycle time
>Reduced production costs
> Overcoming internal changes like breakdowns etc.

Three capabilities that a manufacturing system must possess to be a flexible.

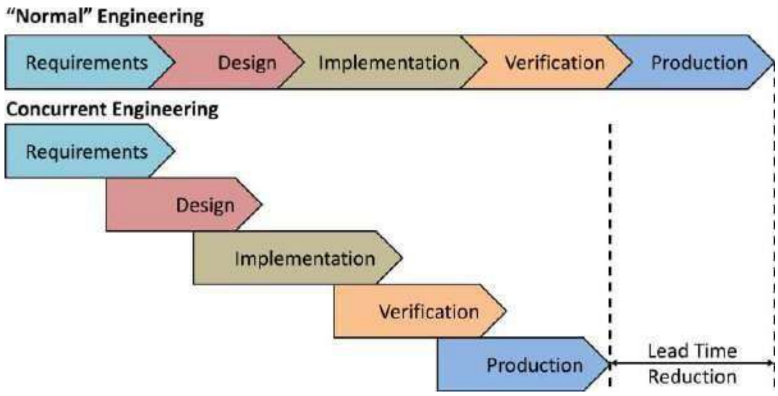
1.The ability to identify and distinguish among the different part styles processed by the system.
2.Quick changeover of operating instructions, and
3.Quick changeover of physical setup.

Basic components of FMS :
Workstations
Automated Material Handling and Storage systems
Computer Control System



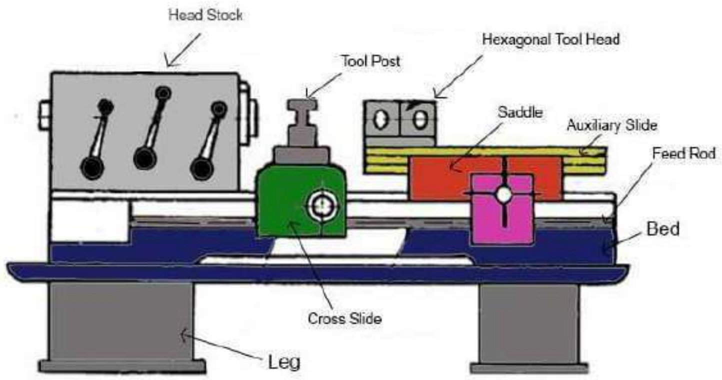
Concurrent Engineering

It is also known as simultaneous engineering. It is a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively. It decreases product development time and also the time to market, leading to improved productivity and reduced costs.



Capstan Lathe

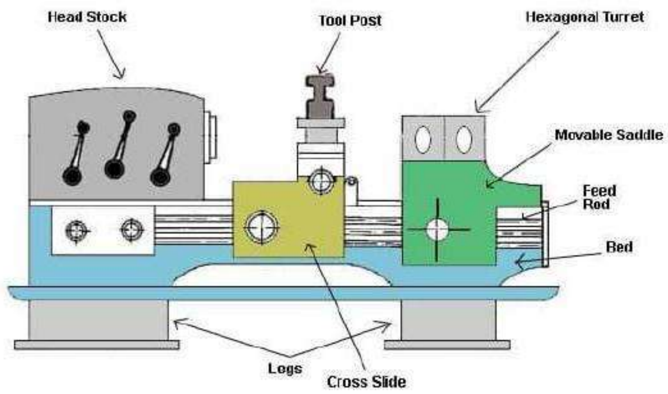
It is the modified form of Engine Lathe and Center Lathe in which the tailstock is replaced by a hexagonal turret tool head.



Turret Lathe:

A turret lathe is a semi-automatic lathe machine that is used for repetitive production of lathe parts. It is advance from the lathe machine produced earlier as it has a hexagonal turret.

Hexagonal turret is an indexable tool holder which can hold six tools at a time. With the help of hexagonal turret, multiple cutting operations can be performed each with different cutting tool in rapid succession without the need to replace or install and uninstall the tool in the lathe machine. In turret lathe, the tool can be switched automatically resulting in faster and more efficient production processes. The turret lathe can change to a different cutting tool in a few seconds but in a traditional lathe, it can take minutes for a human worker to manually change the cutting tool. When many operations are to be performed and the production has to be increased the turret lathe is used.



TURRET LATHE

CAPSTAN LATHE	TURRET LATHE
Turret head is mounted on a ram which slides over the saddle	Turret head is directly mounted on saddle. But it slides on the bed.
Turret movement is limited	Turret movement on the entire length of bed without any restriction
Shorter work piece can be machined	Longer work piece can be machined
Light duty application	Heavy duty application
Turret head can be moved manually	Turret head cannot be moved manually

SPECIAL PURPOSE MACHINE

Any machine which is used for mass production of particular component is called Special Purpose machine. SPM tools are developed for performing specific operation in mass production environment. SPM intended for manufacture of a special type of product. The machine will not have much variation but will have a small with in that vacinity. Ex. Hexagonal nuts, springs are some of the examples of product which am manufacture with the help of special purpose machines.

Advantage of Special Purpose Machines

> High accuracy
> Comprehensive tooling solutions
> Uniform quality
> Large production quantites.
> Repeatability
> Minimum possible time. Uncomplicated service or repair
> Short batch production

Elements of Special Purpose Machine

The elements that are used only in the specific type of machine are called as special purpose elements. For instance piston and connecting rods are used in the engines and compressors, while blades are used in the turbines and blowers. Some other examples are cam shafts push roads,crankshaft, cylinder etc.

The Elements of Special Purpose Machine are classified into two types fasteners and elements of rotary motion drive. These an described below:

1) Fasteners

The fasteners are the machine elements that connect or join various parts of the machine. The joints can be of permanent type or temporary type The permanent joints are the ones that cannot be separated or disassembled into individual elements without destroying or damaging them. The examples of permanent joints an welded joints, riveted joints etc. The temporary joints are the ones in which the individual elements of the assembly can be separated easily without destroying or damaging them. The joints obtained by nut and bolt, and the cotter joints are common and widely used examples of the temporary joints.

2) Elements of rotary motion drive

These are the elements that help transmit the motion or power to or from the machines. For example belt connected to the motor and pump helps running the them. The gear box helps transmit the motion and power from the engine to the wheels of the vehicles. Other examples of elements of the rotary motion drive are rope, chain, gear, worm drives, shafts, axles, couplings, bearings etc.

Principle of SPM design

Machine design and drawing are very important subjects of mechanical engineering No product can be manufactured without designing it. He some basic concepts of machine design or mechanical design have been covered.

The knowledge of machine design helps the designers as follows:
1) To select proper materials and best suited shapes,
2) To calculate the dimensions based on the loads on machines and strength of the material,
3) Specify the manufacturing process for the manufacture of the designed component of the machine or the whole machine.

Machine Design is the application of mathematics, kinematics, statics dynamics, mechanics of materials, engineering materials, mechanical technology of metals and engineering drawing. It also involves application of other subjects like thermodynamics, electrical theory, hydraulics, engines, turbines, pumps etc. Machine drawing is the integral part of the machine design, since all the components or the machines that have been designed should be drawn to manufacture them as per the specifications Without machine drawing the subject of machine design is Incomplete.

Here are some guidelines as to how the machine design engineer cas proceed with the design

1) Making the written statement
Make the written statement of what exactly is the problem for which the machine design has to be done. This statement should be very clear and

as detailed as possible If you want to develop the new produce write down the details about the project. This statement is sort of the list of the alms that are to be achieved from machine design.

2) Consider the possible mechanism

When we designing the machine consider all the possible mechanisms which help desired motion of the group of motions in your proposed machine. From the various options the best can be selected whenever required

3) Transmitted forces

Machine is made up of various machine elements on which various fores are applied. Calculate the forces acting on each of the element and energy transmitted by them.

4) Material selection

Select the appropriate materials for each element of the machine so that they can sustain all the forces and at the same time they have least possible cost.

5) Find allowable stress

All the machine elements are subjected to stress whether small or large Considering the various forces acting on the machine elements, their material and other facts that affect the strength of the machine calculate the allowable or design stress for the machine elements.

6) Dimension of the machine elements

Find out the appropriate diameters for the machine elements considering the forces acting on it, its material, and design stress. The size of the machine elements should be such that they should not distort or break when loads are applied.

7) Consider the past experience

If you have the past experience of designing the machine element or the previous records of the company, consider them and make the necessary changes in the design. Further, designer can also consider the personal judgment so as to facilitate the production of the machine and machine elements.

8) Make drawings:

After designing the machine and machine elements make the assembly drawings of the whole machines and detailed drawings of all the elements of the machine. In the drawings clearly specify the dimensions of the assembly and the machine elements,their total number required,their material and method of their production. The designer should also specify the accuracy, surface finish and other related parameters for the machine.

Productivity Improvement by SPM:

The special purpose machine are designed and manufactured to improve productivity. Productivity is generally defined as the ratio of aggregate output and aggregate input. In any firm or industry, productivity is a concept that measures the efficiency with which inputs are transformed into valuable output in a production process. Similarly, it can be defined as the combination of efficiency and effectiveness of a production process that aims to maximize output while minimizing the use of inputs. Productivity measures the relationship between outputs such as goods and services produced, and inputs that include labor, capital, material and other resources.

Some major considerations in developing a special purpose machine

Specific operations on the job and produce components at shortest possible time

> Work automatically, to the extent possible Involve

> Involve only the barest minimum of operator's involvement

> Should set up and run machine in the shortest time.

Special purpose machine are aimed at reducing the cycle times and control unnecessary costs thus increasing the profits. Special purpose machine should work automatically, to the extend possible. This sentence reveals the study of Burnham that productivity improvement can be accomplished via People and technology. Special purpose machine are designed and manufactured keeping in focus that it must have barest minimum of operator's involvement.

In addition to technology, there are also other means for improving productivity like, re-organization of resources, effective management of human resources Improving the quality work, reducing the amount of maintenance needed, making sure that delays do not occur ete are only some examples.

Some of the Improvement by SPM are given below:

1. New developed machine saves a considerable amount of time which ultimately results in production of more components
2. Reduced cycle time has resulted the company in manufacturing of components of a higher rate
3 Previously the component was machined on conventional setape which were associated with more cycle time, harulling skilled labor, inspection of components. In newly SPM manufactured machine the component is machinel and finished to required dimensional accuracies with an unskilled labor.
4. The direct labor cost for component has been reduced with saving in time
5. Loading and unloading of the component on the machine does not require skill. An unskilled labor can do the loading and unloading of component.

MAINTENANCE OF MACHINE TOOLS

Machine maintenance can include regularly scheduled service, routine checks, and both scheduled and emergency repairs. It also includes replacement or realignment of parts that are worn, damaged, or misaligned. Machine maintenance can be done either in advance of failure or after failure occurs. Machine maintenance is critical at any plant or facility that uses mechanical assets. It helps organizations meet production schedules, minimize costly downtime, and lower the risk of workplace accidents and injuries.

Types of machine maintenance:

There are different types of machine maintenance. Each one has its pros and cons (except reactive maintenance, which is all cons), and can be mixed and matched with assets to create a balanced maintenance program.

Reactive maintenance:

Reactive maintenance refers to repairs done when a machine has already reached failure. Since it's unexpected, unplanned, and usually leads to rushed, emergency repairs, It's often called "fighting fires."

Run to fail maintenance:

Run to fail maintenance is very similar to reactive maintenance. It involves letting a piece of equipment run until it breaks down. However,run to fail is a deliberate choice, whereas reactive maintenance is not. A plan is in place to ensure parts and labour are available to get the asset up and running, or replaced, as soon as possible.

Routine maintenance:

Routine maintenance consists of basic maintenance tasks, such as checking, testing, lubricating, and replacing wom or damaged parts on a planned and ongoing basis.

Corrective maintenance:

Corrective maintenance is any work that gets assets back into proper working order, although it's most commonly associated with smaller, non-invasive tasks that fix a problem before a complete failure occurs. For example- realigning a part during a routine inspection.

Preventive maintenance:

Preventive maintenance refers to any regularly scheduled machine maintenance intended to identify problems and repair them before failure occurs. Preventive maintenance can be split up into two predominant types:

a) Time-based preventive maintenance and

b) usage-based preventive maintenance. Time-based preventive maintenance are tasks scheduled at a certain time interval, such as the last day of every month. Usage-based preventive maintenance is when work is scheduled based on the operation of equipment, such as after 30 production cycles.

Condition-based maintenance:

Condition-based maintenance depends on monitoring the actual condition of assets in order to perform maintenance when there is evidence of decreased performance or upcoming failure. This evidence can be obtained through inspection, performance data, or scheduled tests, and it can be gathered either on a regular basis or continuously, through the use of internal sensors.

Predictive maintenance:

Predictive maintenance builds on condition-based maintenance, using tools and sensors to track machinery performance in real-time. This enables the identification of potential problems so they can be corrected before failure occurs.

Prescriptive maintenance:

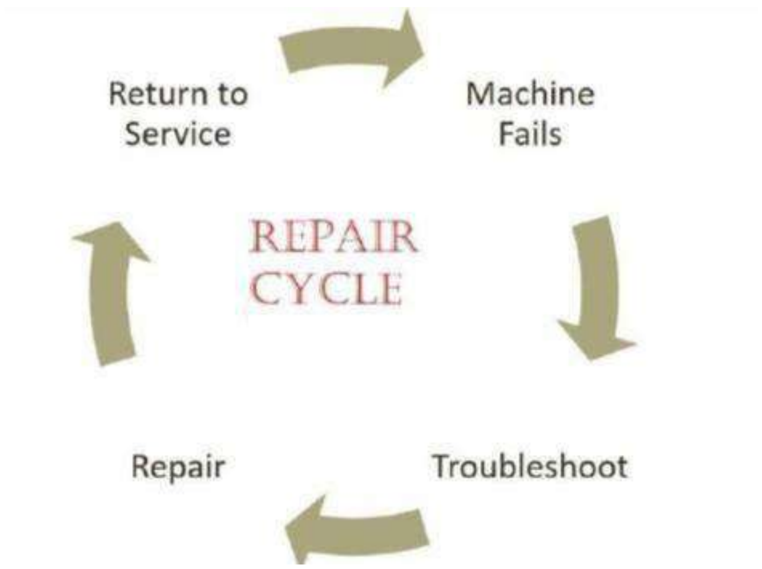
Prescriptive maintenance automates the maintenance process even further through the use of machine learning and artificial intelligence (AI). With a prescriptive maintenance strategy in place, sensors track machinery performance in real-time and uses AI to let you know what maintenance work needs to be done and when.

REPAIR CYCLE ANALYSIS

The stages through which a reparable item passes from the time of its removal or replacement until it is reinstalled or placed in stock in a serviceable condition. Level of repair analysis (LORA) is a process used to determine when and where an asset should be repaired. Level of repair analysis is intended to optimize repair decisions in order to minimize the overall life cycle costs of assets. The Level of repair analysis process takes into account numerous factors, including:

> The costs of different types of repairs, including diagnostics, parts, and labor The impact asset failure could have on operations
> The skills and equipment needed to complete specific repairs

After assessing what it would take to repair specific issues and how necessary those repairs would be, Level of repair analysis determines the type of repair work that should be done and who should do it..



MAINTENANCE MANUAL

It is a comprehensive document that provides all the details necessary about a physical plant as well as individual pieces of equipment to help the maintenance staff keep everything running smoothly.

Components of maintenance manual:
A comprehensive operations and maintenance manual have several common parts:

Overview: This section provides a general overview of the physical plant being discussed as well as the components covered in the manual. It includes personnel information, organizational charts, company history, or other background information.

Physical building: This section details important information about one specific facility. Ideally, this information is collected during the construction of the facility itself and contains floor plans, building materials, finish data, building code and specification information, and site survey.

Operating procedures: A comprehensive, detailed explanation of all major operating procedures should be documented so that a new employee can learn quickly and a seasoned technician can double-check work.

Maintenance procedures: The preventive and corrective maintenance programs should be explained thoroughly including schedules, procedures, responsibilities, trouble-shooting and test requirements.

Emergency procedures: It's important to think through emergency situations before they happen because it can be difficult to remember details in the middle of a chaotic situation. This section outlines all the people, steps, agencies, and other organizations that need to be notified as well as a primer on how to handle crisis communications internally and externally.

Maintenance records:

It is a document that includes information regarding each repair and maintenance work that is done on asset or equipment. In simple words, it keeps tracks of assets failures and repairs. It is one of best way to maintain health and safety management.

HOUSEKEEPING

Lubrication: Regular lubrication, as part of your regular machine tool maintenance routine, will ensure moving parts are protected reducing wear and tear. This includes greasing internal and external moving parts and visual inspection.

Cleanliness: Cleanliness is a simple, but often overlooked maintenance step. However, it can go a long way in reducing grime accumulation and rust.

Proper maintenance of machine tool accessories and parts: Routine inspection can sharpen operators' ability to detect developing issues beforehand. Keeping a checklist and a detailed log of all machine tool maintenance procedures can also help catch possible problems.

TOTAL PRODUCTIVE MAINTENANCE

It is the process of using machines, equipment, employees and supporting processes to maintain and improve the integrity of production and the quality of systems.

In other word it is the process of maximizing equipment effectiveness through the active involvement of all supporting departments. The goal of Total Productive Maintenance (TPM) is to improve overall productivity by optimizing equipment availability.

The 8 Pillars of Total Productive Maintenance (TPM): Traditional total productive maintenance was developed by Seiichi Nakajima of Japan. The results of his work on the subject led to the TPM process in the late 1960s and early 1970s. Nippon Denso a company that created parts for Toyota, was one of the first organizations to implement a TPM program.

TPM is built on eight pillars based on the 5-S system. The 5-S system is an organizational method based around five Japanese words and their meaning.

1) Seiri (organize): eliminating clutter from the workspace
2) Seiton (orderliness): ensure order by following "a place for everything and everything in its place"
3) Seiso (cleanliness): clean the workspace and keep it that way
4) Seiketsu (standardize): standardize all work processes, making them consistent
5) Shitsuke (sustain): constantly reinforcing the first four steps

a) Sort tools, equipment, and materials to identify which of these can be discarded.
b) Straighten and set things in the proper order to reduce unnecessary motion and efficiently travel between working groups and locations.
c) Shine refers to performing necessary housekeeping to clean up the work area.
d) Standardize and schedule activities to systematically form the habits to keep the workplace organized.
e) Sustain the process and principles for long-term applications

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

ENGINEERING MATERIAL

3RD SEMESTER

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ENGINEERING MATERIAL

Material:

(i) Material is that out of which anything may be made.

(ii) Engineering materials are those which are design structurally develop specific property for a given appreciation.

Material Classification:

(i) According to physical, chemical & mechanical properties solid materials have usually been group into two basic types

(i) Metals & Alloys

(ii) Non-metal

(ii) Further for engineering application metals and alloy are classified as

Ferrous and Non-ferrous.

(iii) Similarly non-metals are classified as :

- Polymer
- Ceramics
- Organics
- Composite
- Semiconductor

Metals:

– Metals are composed of elements, which give up electrons to provide a metallic bond and achieve thermal or electrical conductivities.

– The metals are characterized by high thermal and electrical conductivity. Strong yet deformable under applied mechanical loads. Opaque to light.

– Metals also possess the following properties hardness. Strength, ductility, brittleness, mechanical ability, weld ability, cast ability, formability, stiffness etc.

Ferrous material:

(i) Ferrous metals are those in which the best constituents or main constituents is iron, at though other constituents are carbon, sulpher, phosphorous manganese etc. also exists in different proportion.

(ii) Properties or characteristics of ferrous material are hardness, strength, ductility, good conductor of heat and electricity, machine ability etc.

Ex.: Pig iron, wrought iron, cast iron.

Non-Ferrous metals:

(i) Non-Ferrous metals are those which do not contain iron constituents.

(ii) Metals like aluminum, copper, zinc, lead tin, gold etc. and their alloys falls under this category for metals classification.

(iii) Non-ferrous metals posses for special character like good conductivity of heat and electricity, light weight, high resistance to corrosion etc.

Non-metals:

(i) Non-metals are not able to conduct electricity or heat.

(ii) The Non-metals exists two of the three states of metal at room temperature, gases (such as oxygen) solid (such as carbon)

(iii) The non metal have non-metallic, luster are do not reflect light.

(iv) Non-metallic elements are brittle and cannot be rolled into wires or form into sheets.

Ceramics:

(i) Ceramics are usually consist of oxides, carbides, nitrides, silicate of various metals.

(ii) Ceramics are any in organic, non metallic solids proceed at high temperature.

(iii) Ceramics are partly crystalline and partly amorphous.

(iv) Ceramic materials are rock like or clay mineral materials.

Characteristics:

(i) Brittleness, abrasiveness, hardness, corrosion resistance, opaque to light, high temperature strength, rock line appearance.

Ex- Sand, brick, concrete, abrasives etc.

Organic materials (polymer):

(i) Organic materials (Polymer) are polymeric material, that are chemically based on carbon hydrogen and other non-metallic elements.

(ii) The polymers composited of a large number of repeating units (small molecules) called monomer.

(iii) A polymer is made of thousands of monomers Joint together to form large molecules of specific dimension called macro molecules.

(iv) The unique feature of a polymer is that each molecule is either a long chain or networking of repeating units. All molecules are covalently bonded together.

(v) Polymers in the form of thermo plastic (pvc, rubber, Polyethylene etc) consists of molecules that have covalent bonding within each molecule. Polymer in the form of thermo sets (Bakelite) consists of a network of covalent bonds.

(vi) Due to the kind of bonding polymers are typically eclectically or thermal insulator.

Important Characteristics :

(i) Light weight, combustion, soft, poor conductor of heat and electricity, poor resistance to temperature.

Ex- Polyethylene, Rubber, Fiber, PVC etc.

Composite :

(i) Composite materials are mixture of two or more different materials that are mechanically or metallurgical bonded together.

(ii) Usually the components do not dissolve in each other and can be physically identify by an interface between the components.

Characteristics :

(i) Strength	(iv) hardness
(ii) Stiffness	(iv) insulation etc
(iii) Corrosion resistance	

(iii) The best example is fiber Glass a composite of Glass embedded with polymer matrices.

Semi Conductor:

– Semi conductors have electrical properties that are intermediate between the electrical conductors & insulators.

– Semi conductors are covalent in nature

– The electrical characteristic of these material are extremely sensitive to the presence of very small concentration of impurity atoms which concentration may be controlled very small vision.

For example :

Silicon, Germanium, Gallium, arsenide.

– Semi conducting material are basically are used of manufacturing of different electrical & electronics components.

Factors affecting the selection of materials for engineering application :

– Following factors are affect the selection of material for engineering purpose directly & indirectly.

– (i) Properties of material

(ii) Environmental condition

(iii) Availability

(iv) Disposability

(v) Economic factors

(vi) Physical attributes

(vii) Performance Requirement

(viii) Material reliability

(ix) Safety

Performance Requirement:

– The material of which a part is manufactured must be capable of performing its function without failure.

– For example - a component to be used in the furnace must have been of that material which can withstand high temperature.

Material Reliability:

– A material a given application must be reliable. Simply states that reliability is the degree of probability that a product and the material of which It is made will remain stable enough to function in service without failure.

Safety:

– a material must perform its function otherwise the failure of the product made out of it may be catastrophic as in air planes, turbines etc.

Properties of materials :

– Property of a material is a factor that influences qualitatively or quantitatively the response of a given material to the applied constraints like force, temperature etc.

– engineering properties of the materials are classified into different categories :

Mechanical property :

Mechanical properties give us information about the behavior of the material under the action of external force.

Ex- Strength, ductility, brittleness, creep, fatigue. Impact resistance etc.

Electrical property :

– Electrical property gives up information about the behavior of material when electric current flows through them.

Ex- Restively, conductivity, dielectric strength etc.

Thermal Properties :

Thermal property gives us information about the behaviors of the material under the action of heat.

Ex- Specific heat, thermal conductivity melting point thermal expansion.

Magnetic property :

Magnetic property gives us information about the behavior of the material under the action of magnetic field.

Ex- Permeability, Hysteresis etc.

Physical property of a material :

– Physical properties are employed to describe a material under condition in which external forces are not concerned.

– Physical property includes. Dimensions of the material - Dimensions implies that length, breadth height, diameter etc of rectangular, square ,circular or any other section.

(ii) Porosity - A material is said to be porous. If it has poros within it.

True porosity =Total pore volume/ Bulk volume

(iii) Structure: Structure means geometrical shapes of material or components, such as circular rectangular etc.

(iv) density : The density is the weight or mass of unit volume of material expressed in metric units.

Chemical property:

Most of the engineering materials when they come in contact with other substances, with which they can react, tend to suffer chemical deterioration. This necessitates the study of chemical properties of material.

– Some of the chemical properties are :

(i) Corrosion resistance: It is the loss of material by chemical reaction with the environment. Corrosion degrades material properties and reduced economic value of the material.

(2) Chemical composition

(3) Acidity

<u>Ferrous materials</u>

– Ferrous materials are those in which the main constituent is iron, although other constitutes like carbon, sulpher, manganese, phosphorus etc. also exist in different proportions.

– Iron, steel and their alloys fall under this category.

– Ferrous materials are the most important metals or alloys in the metallurgical& mechanical industry because of their extensive use. The wide spread use of ferrous material is accounted by three factors.

(i) Iron containing compound are exist in plenty quantity is the earth crust.

(ii) Iron, steel & there alloys may be produced by using relatively economical extraction, refining, fabrication technique.

(iii) Ferrous alloys have a wide range of mechanical & physical property

– The main disadvantages of ferrous alloy is less resistance to corrosion.

Ferrous materials are:

– Pig iron

– wrought iron

– cast iron
  - gray cast iron
  - white cast iron
  - malleable cast iron

– carbon steel

Carbon steel :

– It is an alloy of iron & carbon and It is malleable.

– Carbon steels are differing from cast iron. As regards the percentage of carbon.

– Carbon steels contain from 0.10% to 1.5% carbon where as cast iron posses 1.8% to 4.2% carbon.

– Carbon steels can be classified as

(1) Low carbon steel

(2) Medium carbon steel

(3) High carbon steel

Low carbon steel or mild steel:

– Low carbon steel or mild steel contain carbon form 0.05% to 0.3% carbon.

Steels containing 0.05 to 0.15% carbons are used for making steel wires sheets, Rivets, Screws, nails, chains, etc.

– It is also known as dead mild steel & It has a Tensile strength of 390N/mm^2& a hardness of about 115 BHN (brinel hardness number)

– Mild steel containing 0.15% to 0.20% carbon has a tensile strength of 420 N/mm^2 and hardness of 125 BHN. It is used for making sheets, strips for fan blades, welded turbines forgings cam shafts.

– Mild steel containing 0.20% to 0.30% carbon has a tensile strength of 555 N/mm^2& a hardness of 140 BHN.

- It is used for making valves making, connecting rod, crank shafts, railway axle etc.

Medium carbon steel:

- Medium carbon steels contain carbon form 0.30 to 0.70%.
- Steels containing 0.35 to 0.45% carbons have a tensile strength of about 750 N/mm^2. They are used for making wire rods, connecting rods, shafts and break levers, gear shafts etc.
- It maintained hardness 200 to 300 BHN.
- Steels containing 0.45 to 0.55% carbon have a tensile strength of about 1000N/mm^2& a hardness of 300 to 400 BHN.
- They are used for making parts those are to be subjected to shock & heavy reversal stress.
- They are used for making crank shafts, axle, splines shafts etc.
- Steels containing 0.6 to 0.7% carbons have a tensile strength of 1230N/mm^2& a hardness of 400-450 BHN.
- They are used for making drop forging dies, Die blocks, Set screws, valve springs and thrust washer etc.

High Carbon Steel :

- High carbon steels contain carbon form 0.7% to 1.5%.
- Steels containing 0.7% to 0.8% carbon have a tensile strength of about 1400N/mm^2 and a hardness of 450 to 500 BHN.
- These steels are used for making cold chisels, Jaws for vices, wheels for Railway service, Hack saws etc.
- Steels containing 0.8% to 0.9% carbon have a tensile strength of about 360 N/mm^2 and hardness 500 to 600 BHN.
- These steels are used leaf spring, punch & die circular saws, machine chisels, Railway rails etc.
- Steels containing 0.9 to 1.0% carbon (High carbon tool steel) have a tensile strength of 580 N/mm^2& a hardness of 550 to 600 BHN.
- They are use for making keys, leaf springs. Punches& dies, pins etc.
- Steels containing 1.0% to 1.5% carbon are used for making taps, machine tools mandrels, railway spring etc.

– Steels containing 1.1% to 1.2% carbon are used for taps, knifes, twist drills etc.

– Steels containing 1.2 to 1.3% carbons are use for making files, reamers, metal cutting tools etc.

– Steels containing 1.3% to 1.5% carbon are used for making metal cutting saws, paper knives, wire drawn dies etc.

ALLOY STEELS:

– The usefulness of plain carbon steel is limited by its poor corrosion resistance to property and loss of strength at elevated temperature.

– This deficiency of plain carbon steel overcomes by employing alloy steel.

– Alloy steels are steel containing various alloying elements like ni, cr, mn, w, Mo, v, Co. etc.

– The objectives in adding alloying element to steel is not only to improve and extend the property of plain carbon steel but also to introduce new property that are not available in plain carbon steel.

Purpose:

– The purpose of using alloying elements are:

(i) To increase harden ability.

(ii) To increase strength at ordinary temperature.

(iii) To increase resistance to corrosion.

(iv) To increase wear resistance.

(v) To improve toughness.

(vi) To improve electric and magnetic properties.

Classification:

– Alloy Steels are classified as

Based on total alloy content:

(i) Low alloy steel: up to and including 5% alloying element.

(ii) Medium alloy steel two more than 5% but up to including 10%

(iii) High alloy steel more than 10% alloying element.

Based on Engg application:

(i) Structural grade alloy steel used in construction, transporting, Production and industrialization.

(ii) Stainless steel used in corrosion and heat resistance application.

(iii) Tool and die steel used in making forming and machining tools.

(iv) Special alloy steel used in special application.

Tool Steel:

– Tool & Die steels may be defined as special steel which have been developed to form to cut or otherwise change the shape of material into finished or semi finished product.

Properties of tool steel:

– Good toughness
– Good wear resistance
– Very good machine ability
– A definite hardening temperature
– Little risk of cracking
– A definite cooling rate.

Types of tool steel :

Symbol	**tool steel**
T	T- High speed steel
M	MO. High speed steel
D	High C. Higher Steel
A	Air hardening steel
O	Oil hardening tool steel
W	Water hardening tool steel
H	Hot work steel
S	Soft resisting steel

Effects of alloying elements:

– **Nickel:**

(i) Increases toughness & resistance to impact.

(ii) Strengthen steels.

(iii) Lowers the critical temperature of steel.

(iv) Widen the range of heat treatment.

(v) Does not unite with carbon.

(vi) Less distortion in quenching

Chromium:

(i) Chromium joints with carbon to form chromium carbides. Thus adds depth harden ability with improve resistance to abrasion & wear.

Manganese:

(i) It increases strength & hardness of the material.

(ii) It resists brittleness of the material.

(iii) Lowers ductility & weld ability If it is present in 5% of carbon contained in steel.

Molybdenum:

– It promotes harden ability of steel
– It makes steel fine grained.
– It makes steel tough of at various level
– It resists brittleness of steel.
– Enhances corrosion resistance in stainless steel.
– Increase tensile & creep strength at high temperature.

Vanadium:

– Promotes fine grains in steel.
– Increases harden ability when dissolved.
– Imparts strength & toughness to the steel

Tungsten:

– It increase hardness
– Promotes Fine grains
– Resists heat
– Promotes strength at elevated temperature

Stainless Steel:

- When 11.5% or more chromium is added to iron, a thin surface of chromium oxide forms on the iron surface exposed to air or presence of air.
- This chromium oxide surface acts as a barrier to retard oxidation, ,rust, stains &corrosion.
- As this steel cannot be stained easily It is called stainless steel
- All stainless steel can be group into 3 metallurgical classes

  (1) Austenitic

  (2) Martensitic

  (3) Ferrite.

Crystal imperfection

- A crystal is a solid composed of atoms, iron or molecules arranged in a pattern which is a repetitive in three dimensions.
- The regular repetitive arrangement of atoms are described by a three dimensional network (Space lattice)
- Space lattice is a three dimensional pattern of points called lattice point.
- Each point in the space lattice has identical surroundings. The size and shape of an unit cell is described by three edge length (a,b,c) and the angles (α,β,γ) known as lattice parameters.

Metal crystal structure:

- The crystal system found in most elements metals are either

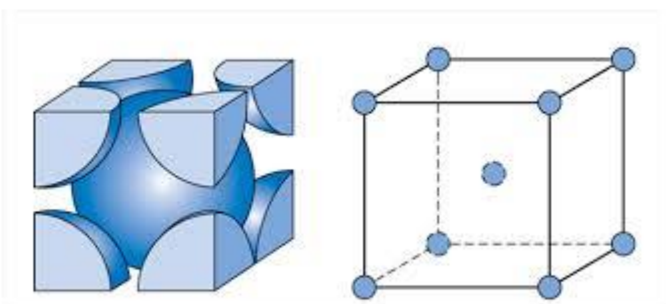
- BCC (Body centered cubic)
- FCC (Face centered cubic)
- HCP (Hexagonal closed pack)

– In BCC the unit cell has one atom at each corner and one atom at the center of the cube.

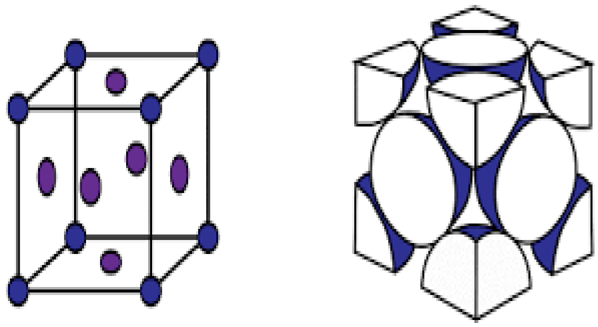
– In FCC there is one atom at each corner of the cube and one at the center of each face.

– In HCP there are two lattice basal planes in the form of regular hexagon with an atom at each corner of the hexagon and one atom at the center of Basel plane another plane that provides three additional atoms to the unit cell is situated between the top & bottom plane.

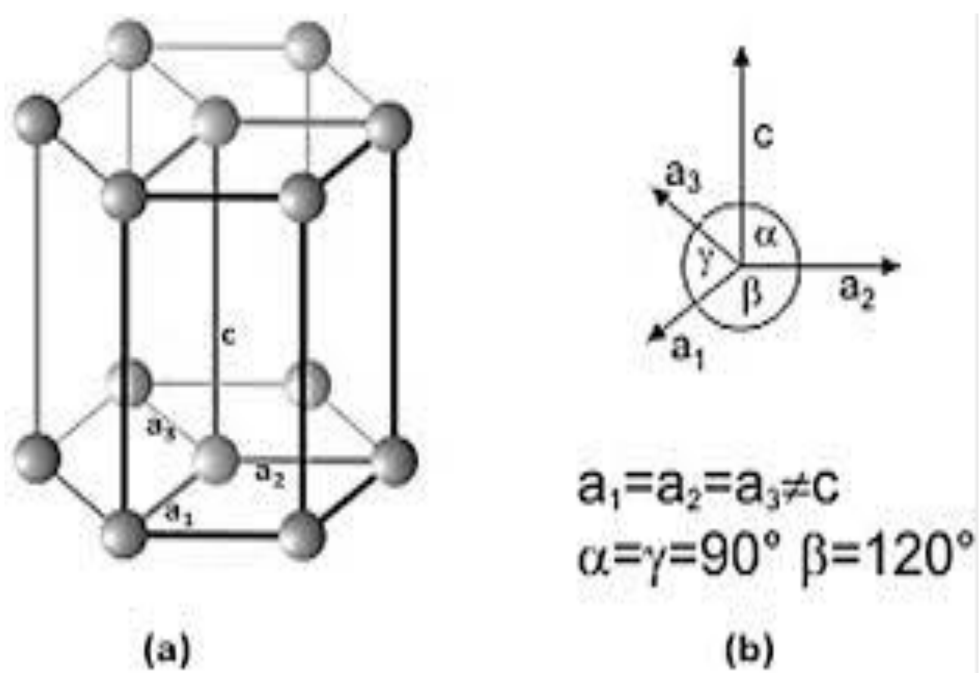
BCC (Body centered cubic)

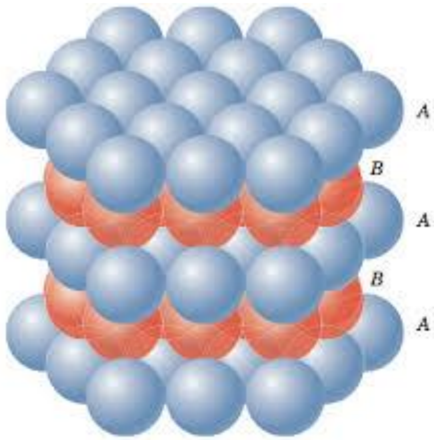


Two representations of FCC Crystal Structure



HCP (Hexagonal closed pack)





Types of crystals

– Briefly crystal are two types :

– (1) Idle crystal:

An Ideal crystal the atomic arrangement is perfectly regular &continuous throughout.

– (2) Real crystal:

Real crystal as in cast or welded object is never perfect.

Lattice Distortion, various Imperfections, irregularities and other defect are generally present in them.

Crystal defect:

– Crystal defect as meant as lattice irregularities having one or more of its dimensions.

– The crystal defect affects the mechanical properties of material. Such as strength, hardness, ductility, toughness etc.

Classification of crystal defects:

– All defects and Imperfection of crystal can be confidently classed under 4 main division namely

(i) Point defects:	Vacancy
	Impurity
	Electronic defect
(ii) Line defects:	Edge dislocation

Screw dislocation

(iii) Surface defects: Gain Boundary

Tilt Boundary

Twin Boundary

(iv) Volume defects:

Point defect:

– Point defects are localized disturbances of the crystal lattice involving one or several atoms.

– These imperfection are introduced by the movement of atoms. When they gain energy by heating.

– In a crystal lattice point defect is one which is completely local in it's effect.

– In a crystal lattice point defect is one which is completely local in its effect. For example vacancy, impurities, interstitial etc.

– The introduction of point defect into a crystal increases its internal energy as compare to that of idle crystal.

_ Following are the types of point defects.

Vacancy:

– A vacancy is produced when an atom is missing from a normal size.

– Vacancies are introduced into the crystal during solidification at high temperature.

– At temperature very few vacancies are present on crystal but these number increases as temperature is increased.

– A vacancy implies an unoccupied atom position within crystal lattice.

– Vacancies may occur as a result of imperfect packing during the original crystallization or they may arise from the thermal vibration (Randomly movement of atoms by thermal equilibrium) of atoms at temperature, because as thermal energy is increased there is a higher probability that individual atoms will sump out there position of lowest energy.

– The atoms surroundings a vacancy tend to be closed together there by disturbing the lattice pattern.

Schottky defect:

– Scotty defect is pair of vacancy in an ionic bonded material that is both an anion and a action are found missing from the lattice.

Frankel defect:

– In an ionic solid structure sometimes an ion jumps from a normal lattice point to one interstitial side lining behind a vacancy this results in a vacancy interstitial pair called frankel defect.

Impurities

– Impurities give rise to compositional defect.

– Impurities may be small particles (such as slag inclusion in metal) embedded in the structure or foreign atoms in the lattice.

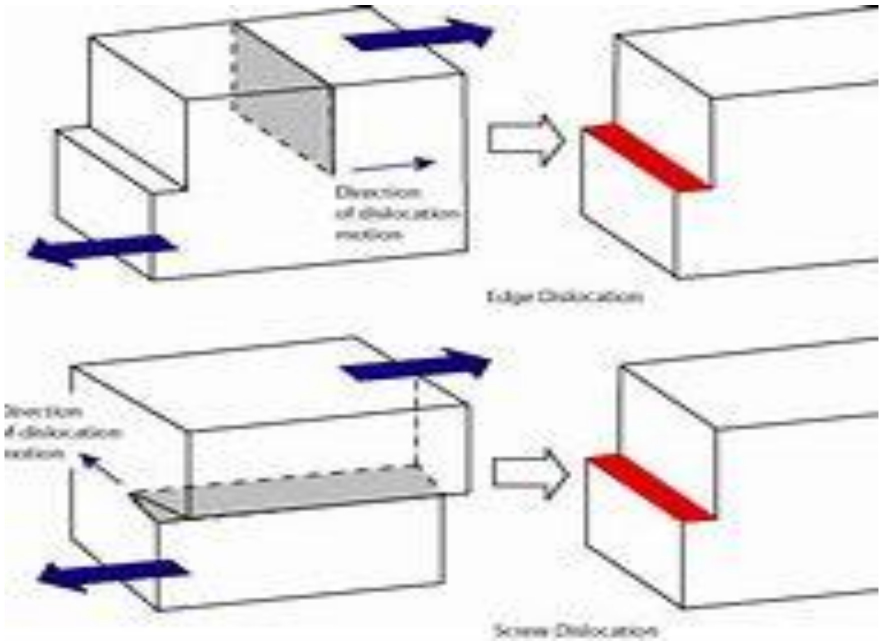
– Impurity or foreign atoms are introduced into crystal structure as substitution or interstitial atoms that is foreign atoms either occupied lattice side from which the regular atoms are missing or they occupied position between the atoms of the Idle crystal. Impurities may considerable disturbed the lattice.

– A controlled addition of impurity to a very pure crystal is the basic of producing many electronic devices.

– Impurities defects occur in metallic co-valiant& ionic bonded solids & play a very impotent role in much solid state process. Such as electrical & thermal conductivity, phase transformation etc.

Line Defect or dislocation:

– Line defects in crystalline solids are defects that cause lattice distortion around a line. A part of the line of atoms will be missing from its regular site & this missing row at atoms is called as a Dislocation.



- A dislocation may be defined as a disturbed region between two substantially perfect parts of crystal.
- Dislocation is a line defect in a crystal structure where by a part-plane of atoms is displaced from its symmetrically stable position in the array.
- The dislocation is responsible for the phenomenon of slip, by which most metals deform plastically.

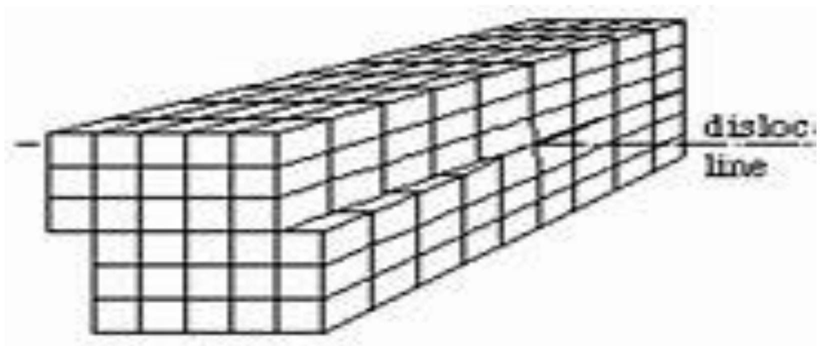
– The two basic types of dislocation are edge dislocation & screw dislocation.

– Dislocations are created during the solidification of the material or when the material is deformed.

Edge dislocation:

– An edge dislocation as created in the crystal due to the insert of extra half plans of atoms.

– The atoms above the edge of the extra plane as squeezed together and are in a state of compression.



– Just below the extra plane the atoms are pulled apart and are in a state of tension.

– There is an extra energy due to the distortion in the region immediately surrounding the edge of the incompletely plane.

– The edge dislocation is said to be positive denoted by '⊥' with the entry of extra plain from the top of the crystal 'T' indicates negative dislocation in which the entry of extra plane from the bottom of the crystal.

– The dislocation line is characterized by a vector called burgers vector.

– The burger's vector of a dislocation is determined as follows:

Burgers vectors (b) :

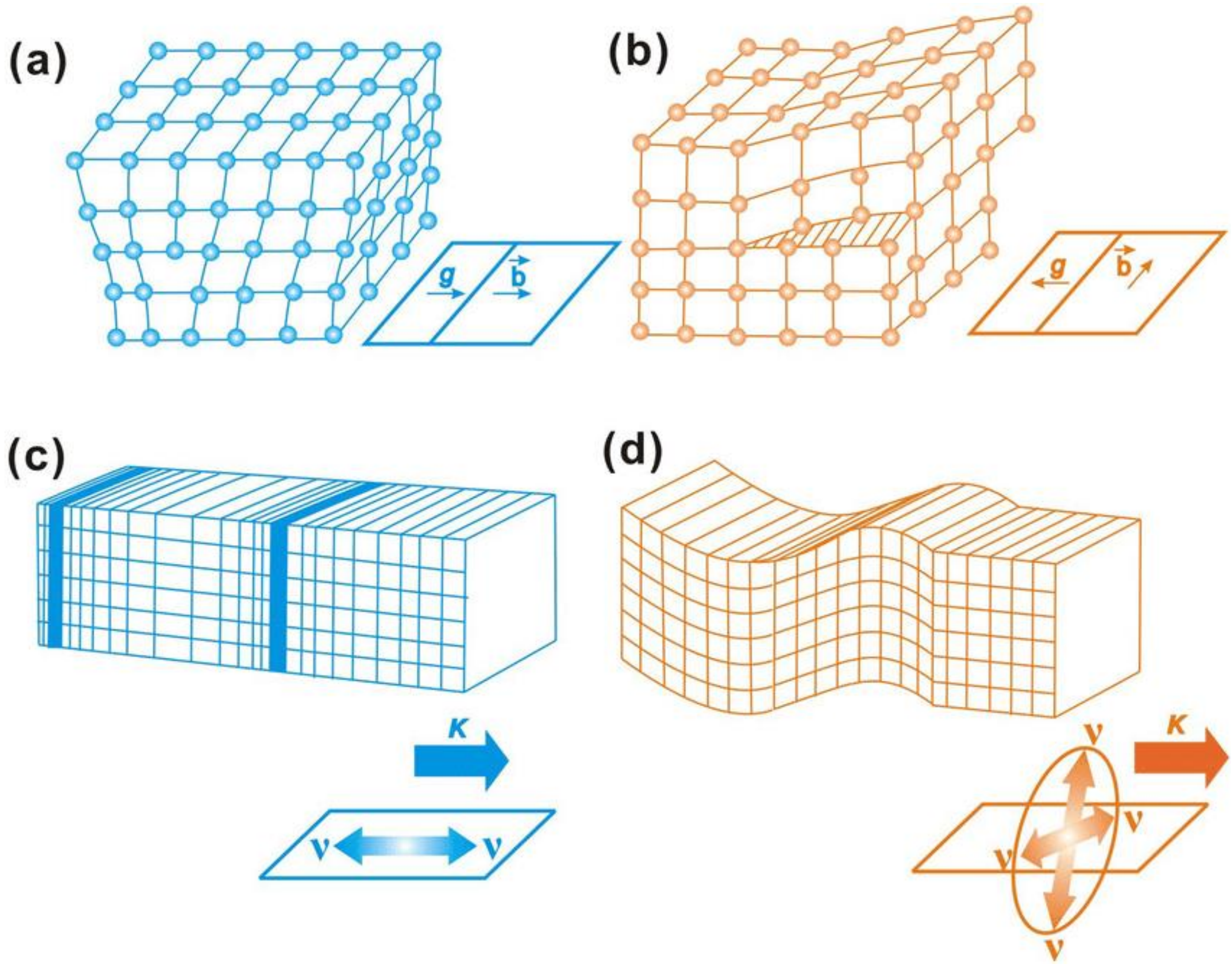
– Starting from a point to make a loop around the dislocation, we go by m number of steps right then M steps down then m steps left and finally m steps up but the loop does not closed we need an atomic step distance to close the loop. This displacement vector required to close the loop burger's vector (b). Burgers vector is always perpendicular to the edge dislocation line.

Screw dislocation:

– A screw dislocation is imaginary by cutting a part way through prefect crystal then skewing by one atom spacing.

– The name screw dislocation is given, because it transfers an atomic plane into the surface of a helix around the dislocation line.

– In screw dislocation a region of shear strain is created along the dislocation in which energy is stored.



- The screw dislocation is represented by (or) according to it's helical screw path direction.
- The burgers vector is screw dislocation is always parallel to the dislocation.

Causes of dislocation:

- Slip is the most important factor that causes dislocation.
- Mechanical phenomena such as strain hardening, yield point, creep, fatigue causes dislocation.
- Thermal vibration.
- Tensile, compressive and shear stress may cause various dislocations.
- Corrosion fatigue
- Crystal growth.

Deformation by slip:

– The usual methods of plastic deformation in metal is by sliding of blocks of the crystal over one another along definite crystallographic plain called slip plains.

– Slip occurs when the shear strain exceeds a critical value.

– In this phenomenon the atoms move an integral number of atomic distances along the slip plain & a slip is produced in the polished surface.

– When we view the polished surface from above with a microscope the step sources of as a line which we called slip line.

Effect of imperfection on metal properties :

– The property of engineering material safely depends upon the imperfection present within it.

– Imperfection affects material property both positively &negatively.

– The presence of imperfection is most necessary For any engineering material without which we cannot Generate deferent shapes and size.

– The imperfection which is responsible for the following characteristic of the material.

(i) Crystal Growth

(ii) Flow & Fracture characteristic

(iii) Diffusion mechanism

(iv) Electrical properties including semi-condemn behavior

(v) Creep characteristic of real metal

(vi) Oxidation & corrosion.

(vii) Plasticity

(viii) Thermal conductivity, yield strength etc.

Bearing Material

- Bearing supports moving parts such as shafts, spindles of a machine or mechanism. Bearing may be classified as

  (i) Rolling contact bearing

  (ii) Plain bearing or Flat bearing.

- Rolling contact bearing are almost made of steel that can be harden after machining. Both plain carbon steel and alloying element (Nickel, Chromium etc) are employed for different application.
- For making plain bearing an extremely wide range of different materials is Available.

Properties:

- Bearing material should have low coefficient of friction.
- It should provide good wear resistance.
- It should have ability to withstand bearing pressure.
- It should have high compressive strength.
- It should have fatigue strength.
- It should possess adequate strength at high temperature.
- Be such that it can be easily fabricated.
- It should have high thermal conductivity to dissipate heat generated due to friction between the bearing shaft & rotating shaft.
- It should have good casting.
- It should have non corrosive properties.
- It should be economical in cost.

Types of bearing material:

The following are widely used bearing material :

(i) Copper Base Alloy

(ii) Cadmium Base Alloy

(iii) Tin Base Alloy

(iv) Lead Base Alloy

(i) Copper Base Alloy:

(i) The copper based alloys are the most impotent bearing alloys. These alloys are harder and stronger than white metals (lead base & tin base alloys)

(ii) Copper based alloys generally used for bearing which is subjected to heavy pressure.

(iii) The copper alloys are broadly classified into the following two groups.

(i) Copper zinc alloys (Brass) in which zinc principle alloying metal.

(ii) Copper tin alloys (Bronze) in which tin is principle alloying metal.

Brass:

(i) The most widely used copper zinc alloys is Brass. This is fundamentally a Binary alloys of copper with zinc is 50%.

(ii) By adding small quantities of other element. The proportion of brass may be gradually changed. For example the addition of lead (1% to 2%) improves the machining quality of Brass.

(iii) It has a greater strength than that of copper But has a lower thermal and electrical conductivity.

(iv) Brasses are good resistances to atmospheric corrosion.

(v) It can be easily fabricated.

Bronze:

(i) The term bronze covers a large number of copper alloys with varying percentages of tin, zinc & lead.

(ii) Bronze is one of the oldest known bearing materials.

(iii) Bronze is easily worked.

(iv) Bronze has good corrosion resistances.

(v) Bronze is resalable hard.

Composition:

	(I)	(II)
Cu	80%	85%
Sn	10%	15%
PB	10%	–

(vi) Tin Bronze (10 to 14% remaining copper) is used in the machine and engine industry for bearing bushes made from thin world drawn tubes.

(vii) Copper based alloys are employed for making bearings required to resist heavier pressure such as in railway.

Cadmium based alloys :

(i) Cadmium based alloys bearing are not very popular because high price of cadmium.

(ii) These bearing alloys poses greater compressing strength than tin base alloys.

Composition :

	(i)	**(ii)**	**(iii)**	**(iv)**
Cd	98	98	98.5	94.75
Ni	2	–	–	3%
Ag	–	1%	1%	1.50
Cu	–	1%	0.5	–
In	–	–	–	0.75%

Properties :

(i) Low coefficient of friction.

(ii) High fatigue strength

(iii) High load caring capacity

(iv) Low wear poor corrosion resistance.

Uses :

(i) Cadmium based alloys are used in automobile and air craft industries.

Lead or tin base alloy :

(i) The lead base or tin base alloys are known as white metal & are usually referred to as Babbitt.

(ii) They may be divided as

(i) The high tin alloys with more that 80% tin & No lead.

(ii) The high lead alloys which more than 80% lead & 1 to 12% tin.

(iii) The alloys with intermediate percentage of tin and lead.

(iv) In addition to tin & lead these Babbitt metal or white metal also content antimony & copper also.

Tin base alloy :

Tin (Sn)= 88%

Antimony (Sb) = 8%

Copper (Cu) = 4%

Property :

(i) Tin base alloy low coefficient of friction.

(ii) Tin base alloys are preferred for heavier load.

(iii) Tin base alloys poses good resistance to corrosion.

(iv) Tin base alloys are costly and find application in steam turbines high speed engine generators etc.

Lead based alloys:

Composition:

Lead (pb) - 75%

Tin (sn) - 10%

Antimony (sb) - 15%

Properties:

(i) Lead based alloys are softer and brittle.

(ii) Lead based alloys are chipper than tin base alloy.

(iii) Lead base alloys are suitable for light & medium loads.

(iv) Lead base alloys find application in manufacturing collapsible, automobile industries, rail road construction etc.

<u>Spring Material</u>

(i) Spring stores mechanical energy therefore the spring material remains under highly internal stressed.

(ii) The choice of material for springs depends upon the operating condition. For example most heavily loaded springs are made up of steel piano wires, springs of which have to corrosion at fabricated of stainless steel & phosphorus bronze etc.

Types :

The commonly employed spring materials are

(i) Copper based spring material

(ii) Iron based spring material

(iii) Nickel based spring material

(iv) Special based spring material

Copper based spring material:

(i) Copper based spring material posess :

(i) High electrical conductivity

(ii) Good resistance to corrosion.

(iii) Lack of magnetic properties.

(ii) Copper based spring material can be classed on

(i) One Which can be hardened by cold forming

(ii) Others which can be hardened by heat treatment

(iii) Various copper based spring materials are

Phosphorus Bronze

(Cu – 92%, Sn-8%)

Uses :

High quality springs forSwitches, relays& Contact etc.

Brass:

(cu-67%, zn-23%)

Uses: switches and contacts

Nickel Silver:

(Cu-56%, Ni-18, Zinc - 25%)

Uses:

High quality spring for switches, contacts and other electrical equipments.

Beryllium copper:

(Cu -98, Be-2%)

Uses :

Brush, relays, switches etc. with relatively good resistance to wear good conductivity good resistance to corrosion.

Iron based spring material :

(i) A good spring steel posess high

(i) modulus of elasticity

(ii) elastic limit

(iii) fatigue strength

(iv) creep strength

(ii) Steel is used for making deferent types of spring such as

(i) Helical spring

(ii) Leaf spring

(iii) Plate spring

(iv) Cone spring

(v) Torsional spring

(iii) Iron based spring materials are

(i**) Stainless steel**

Composition: Cr=18%

Ni = 8%

C =0.1% - 0.2 %

Fe = Remainder

Uses:

(i) It is used in application requiring high resistance to corrosion.

(ii) Also used as valve springs in flow meter

(2) **Steel piano wire** :

C = 0.7% to 1.0%

Mn = 0.3% to 0.6%

Fe = Remainder

Uses:

(i) Small size helical spring

(3) Oil hardened spring wire :

C = 0.55 – 0.75%

Mn = 0.3% – 0.9%

Fe = Remainder

Uses :

Weighing machines, cars, truck & automobiles.

Hard drawn tube spring wire :

C= 0.5% – 0.75%

Mn = 0.6% – 1.2%

Fe = Remainder

Uses :

Where the stresses are low or where the high degree of uniformity is not essential or where fatigue loading is not involved.

Chromium vanadium spring steel:

Composition:

C = 0.5%

Cr = 0.2 – 0.9%

Mn = 0.8 – 1.1%

V = 0.07 – 0.12%

Fe = Remainder

Uses:

Railway carriages, engines, automotives valves etc.

POLYMER

– Polymerization may be defined as the process of growing large molecules for small ones.

– Polymerization links together monomers. Monomers are small molecules which combined end to end to form a large molecule known as polymer.

– The word "mer means a unit", monomer stands for a single unit & polymer means many unit joint together by a chemical reaction. Known as polymerization reaction.

– Examples of polymers are:

(i) Wood

(ii) Starch

(iii) Resin

(iv) PVC

(v) Polyethylene

(vi) Epoxiesetc.

– An example of polymerization reaction is the joining of ethylene molecules into a large molecule resulting polyethylene called polythene.

Characteristics:

(i) Good corrosion resistance.

(ii) Low coefficient of friction.

(iii) Good mold-ability

(iv) Excellent surface finish

(v) Poor tensile strength

(vi) Poor temperature resistance

(vii) Low mechanical properties

(viii)can be produced transparent and in different colors.

Classification of Polymer :

– According to the mechanical response at elevated temperature polymers may be classified as :

(i) Thermoplast or thermo plastic polymer

(ii) Thermosets or Thermo setting polymer.

Thermo plats or Thermo plastic polymer :

– Thermo plastic polymers soften when heated (and even liquify) & hardened when cooled this process is totally reversible and may be repeated.

– Thermoplasts have low melting temperature & can be repeated by molded & remolded to the desired shapes. They have a resell value.

– Thermo plasts are relatively soft & ductile.

– These materials are normally fabricated by the simultaneously application of heat & pressure.

– Some commercially available thermo plasts are:

PVC (Poly Vinyl Chloride)

– The polymers are produced by polymerizing vinyl compound.

– It is relatively low in cost.

– It offers good toughness strength & abrasion resistance.

– It is self extinguishing with low moisture absorption.

– They have good electrical insulation property

– They are widely used to manufacture, rain courts, hand bags, tubes, pipes etc.

Poly Ethylene:

– These polymers are produced by polymerization ethylene molecules.

Properties:

(i) It is light and odorless. It offers chemical resistance &don't absorb moistures.

(ii) It is an excellent electrical insulator.

Uses :

(i) These are widely used as insulating coating for electric wires, pipes, bottles, buckets, carry bags, etc.

Polystyrene:

(i) The polymers are produce by polymerizing styrene compounds. They have high resistance to chemicals. It is low cost and ability to be made crystal cleared hard & Glossy surface.

Uses:

(i) They are widely used as refrigerator door liner, Radio & television cabinet, food container.

Thermo setting polymer :

(i) These polymers become soft during their 1st heating & become permanently hard when cooled. They don't soften upon subsequent heating.

(ii) They cannot be recycle & don't melt, so that they don't have resell value. If heated to excessive temperature. The polymer Degradation takes place.

(iii) Thermo sets are generally harden stronger & more brittle.

(iv) Some commercially available thermo sets are:

Phenol :

(i) Phenolic or phenols are produced by the poly condensation of phenol and thermal dehyde.

(ii) It offers excellent strength, resistance to heat.

(iii) It shows chemical resistance property & relatively low on cost.

(iv) They are widely used for making electric iron handles, fan motor, switch covers etc.

Melamine:

(i) These polymers are produced by the co polymerization of melamine's and formal dehyde.

(ii) They have excellent tensile strength.

(iii) It is the hard set plastic known & dimensional stability

(iv) It offers low moisture absorption & Flame resistance.

(v) It is moderate in cost.

Uses:

(i) Melamine's are used for plastic crockery, automobile parts etc.

Epoxies:

(i) These polymer is produced by the condensation of epochlrohydrin &

Dioxy diphenyle propane.

(ii) They have excellent adhessive property.

(iii) It offers chemical resistance & low moisture absorption.

(iv) It offers good toughness and electrical insulation property.

(v) It is relatively expensive.

(vi) They are widely used for bonding the material together such as wood, plastic, metal etc.

(vii) They are also used the manufacturing of high voltage, insulating material, laminates, varnish.

Elastomer :

(i) Elastomers commonly referred to as rubber are hydrocarbon & polymeric materials, Similar in structure like plastic.

(ii) The American society for testing and materials ASTM defines as elastomeric is a polymeric material which at room temperature can be stressed to at least twice of its original length & immediate release of the stress will return quickly to approximate its original length.

Characteristics:

(i) They are non-crystalline in structure. They are non-conductors of electricity.

(ii) They are high resistance to chemical & corrosion.

(iii) They have relatively low soften temperature.

Properties of Elastomer :

(i) High resilience or energy storing capacity.

(ii) Good tensile strength.

(iii) Excellent abrasion resistance & oil resistance.

(iv) Good compression strength & hardness.

Non-ferrous metal

Pure aluminum

Aluminum is a silver white metal & It poses the following characteristics:-

(i) It is a light metal.

(ii) It is very good conductor of heat & electricity

(iii) Aluminum has higher resistance to corrosion

(iv) Aluminum is non-magnetic in nature

(v)Aluminum has soft and ductile

(vi) Aluminum&its alloy can be cast, forged, welded, extruded, rolled etc.

Uses :

(i) Transformation industries

(ii) Structural frame work

(iii) Engine parts, doors, window frames decorative parts components of automobile parts, beat parts, refrigeration, food preparation equipments, storage container, wires, tubes, pipes, etc.

AluminumAlloys:

(i) Aluminum forms a wide range of Alloy with alloying element like copper manganese, silicon, magnesium, zinc, titanium etc.

(ii) The most commonly used aluminum alloys are Duralumin & Y-alloy

Duralumin :

Composition :

Cu = 3.5 – 4.5%

Mg = 0.4 – 0.7%

Mn = 0.4 – 0.7%

Si = 0.7%

Al = Remainder

Properties:

(i) High tensile strength after heat treatment.

(ii) High machinability.

(iii) It shows excellent hardness property.

(iv) Non-magnetic & corrosion less

(v) Excellent casting & forging properties.

Uses :

(i) It is used for making air craft & automobile parts,

(ii) It is used as bars, sheets tips, tubes, rivets etc.

(iii) It is used for making cables.

(iv) It is used in surgical & orthopedic works.

(v) It is used for non-magnetic instruments.

Y- alloy :

Composition:

Cu- 4%

Ni- 2%

Mg- 1.5%

Al- Remainder

properties

(i) It shows better strength than aluminum.

(ii) It maintains excellent strength & hardness at elevated temperature.

(iii) It can be easily casted & hot worked.

Uses:

i) It is extensively used for IC engine components, like piston, cylinder heads, crank case, engine head.
ii) It is also used for die casting pump & pump rod.

IRON-CARBON SYSTEM

– The iron carbon diagram is the most important subject in the study of ferrous metallurgy; it provides the basis understanding the properties & the heat treatment of the steel including the effect of alloying element in alloy steel.

Equilibrium phase diagram:

– The important metallurgical changes that takes place when a mixture of different material or metals, is gradually cooled from liquid state to solid state are best described with the help of an equilibrium phase diagram.

– Phases are characterized by the boundaries across which discontinuity exist in the physical property. Even a pure metal can exist in different phases like solid, liquid & gases, at different temperature & pressure.

– A convenient way of describing this phase Transformation diagrammatically, where the phases are different combination of temperature & composition is indicated such a diagram is called an equilibrium phase diagram.

– Phase diagrams are graphically representation of phases in the system at various temperature pressure & composition.

– The phase diagrams are constructed by using equilibrium condition. The word equilibrium means that the process are carried out of slow cooling slow heating

– Depending on the number of components are called as Unary, Binary, and Ternary**.**

Classification of phase diagram :

– The phase diagrams are widely used as binary diagrams.

– Binary phase diagram are constructed when only two elements are present in the alloy.

– The most important Binary alloys system are classified as

(1) Components completely soluble in liquid state.

– Completely soluble in the solid state

– Insoluble in the solid state.

– Partially soluble in the solid state

– Peritectic system

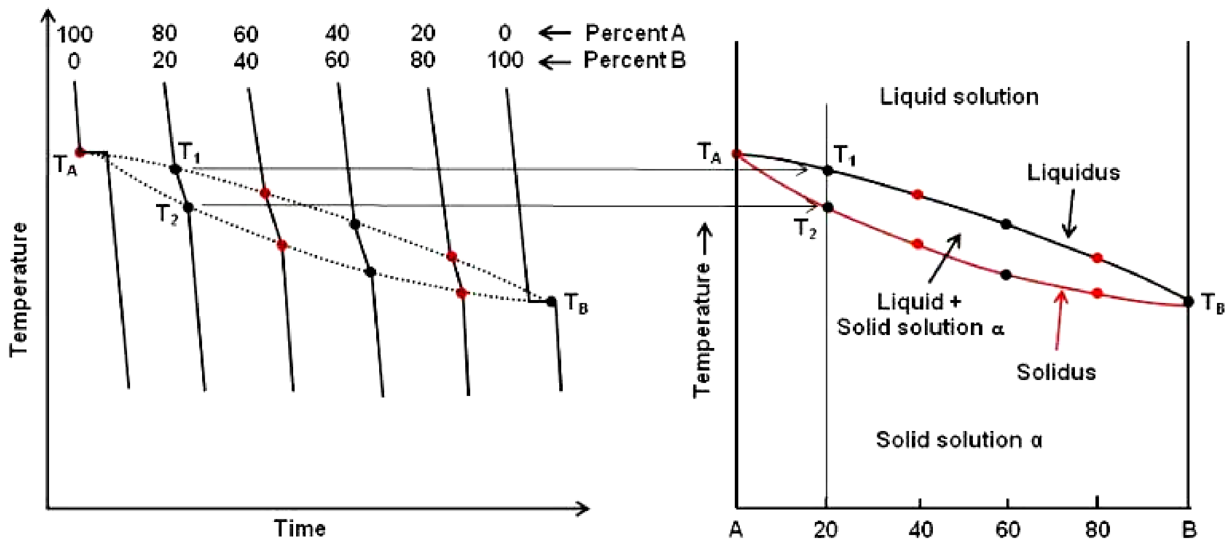
(2) Transformation in solid state

– Eutectic Reaction

– Periotectoid Reaction

Cooling Curves :

– A method to determine the temperature at which phase changes (liquid↔ solid) occur in an alloy system consist of following the temperature as a function of time as times different alloys in the system are very slowly cooled. The data obtain in this manner from a cooling curve for each of the alloy.



Series of cooling curves for different alloys in a completely soluble system both in the liquid and solid states

Phase diagram of two metals completely soluble in the liquid and solid states

Construction of Phase Diagram from Series of Cooling Curves

Cooling curve for pure metal:

(i) Liquid metal cools for cooling's from P to Q 1st crystal begin to form at point Q.

(ii) From Q to R the melt liberates latent heat in such amount that the temperature from Q to R remains constant until the whole mass has entirely solidified between Q to R. The mass is partly liquid and partly solid on further cooling from R to S the metal cools & solidified & tends to rich at room temperature.

(ii) The slope of P-Q. &R-S lines depend upon the specific heat of liquid and solid metal respectively.

Cooling curve from a binary solid solution:

(i) Curve portion P-Q is similar to pure metal, this binary systems consisting of two metals forming a solid solution.

(ii) However in a binary system during phasing period the temperature does no remain const.

(iii) Rather it drops along line Q-R till the whole mass is solid at point R

(iv) The dropping trend indicated that the alloy does not solidify. It possess a phasing does not maintain range which is due to the changes in the composition of solid & liquid phases.

(v) The solid cools along R-S to attempt the room temperature.

Cooling curve for a binary eutectic system.

(i) In this system the two components are completely soluble in liquid state, but entirely in the insoluble in the solid state.

(ii) Liquid cools along P-Q until temperature Q is reached.

(iii) At Q the component that is in excess will crystallizes & the temperature will draw along Q-R.

(iv) At point R the liquid compositions have been reached at which the two components crystallizesimultaneously from the solution (R-S).

(v) Then It cooling from S to T as usual in solidify Figure

Iron allotropy:

– Iron is relatively soft & ductile in nature. Iron has meting point of 1539^0C.

– Iron is allotropy metal which means it exists more than one types of lattice structure (BCC/ FCC) Depending upon temperature.

– In normal room temperature iron is BCC in lattice arrangement where as at 908^0C. it changes to FCC & then at 1403^0C. It backs to BCC & again vice versa.

– Another change occurs at about 770˚C (Curie point) at which the magnetic property of iron disappears& It becomes non-magnetic.

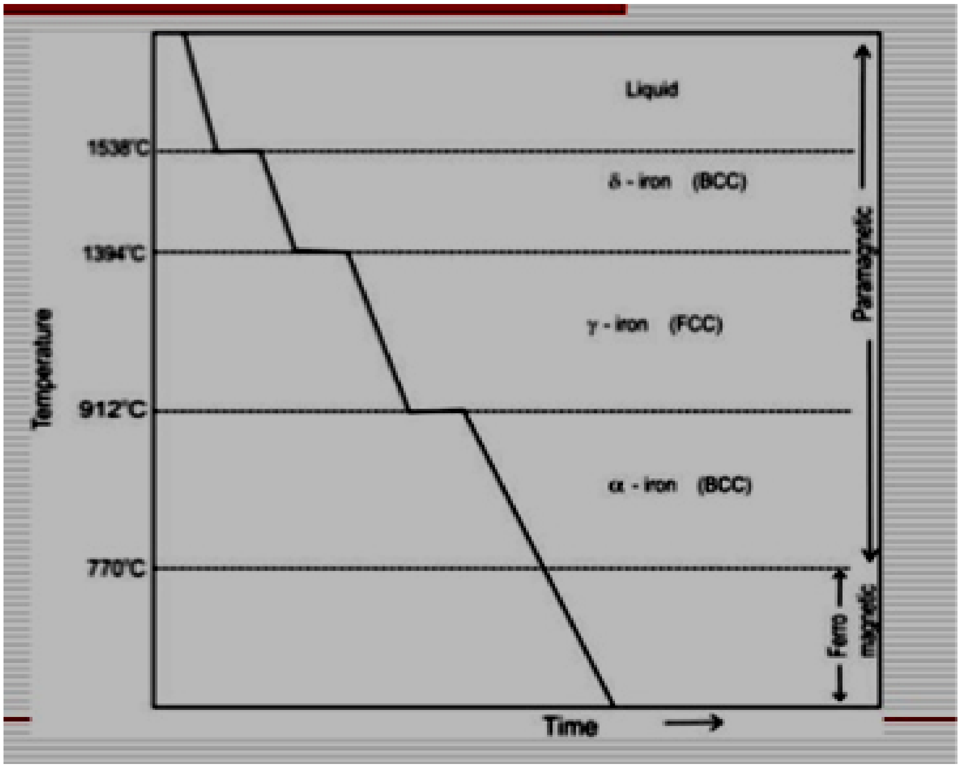
– The iron remains Non-magnetic until the temperature drops back below the Curie point upon which it's magnetic property reappear.

– In the figure iron is molted above 1539^0C & it solidify in the BCC б-form.

– On further cooling at 1400^0C a phase change occur & the atoms rearrange themselves into ᵞ-form which is FCC. Structure and non magnetic in nature.

– On steel further cooling at 910^0C another phase change occurs from FCC Non-magnetic ᵞ iron to BCC Non magnetic α iron.

– Finally at 768^0C the α iron BCC. Becomes magnetic without change in lattice structure.



(Cooling Curve for Pure Iron)

α – ferrite

γ– Austenite

б – ferrite

Fe_3C – Cementite

Iron carbon Alloy:

– Iron carbon alloys are widely used in practical application because it gives mechanical properties.

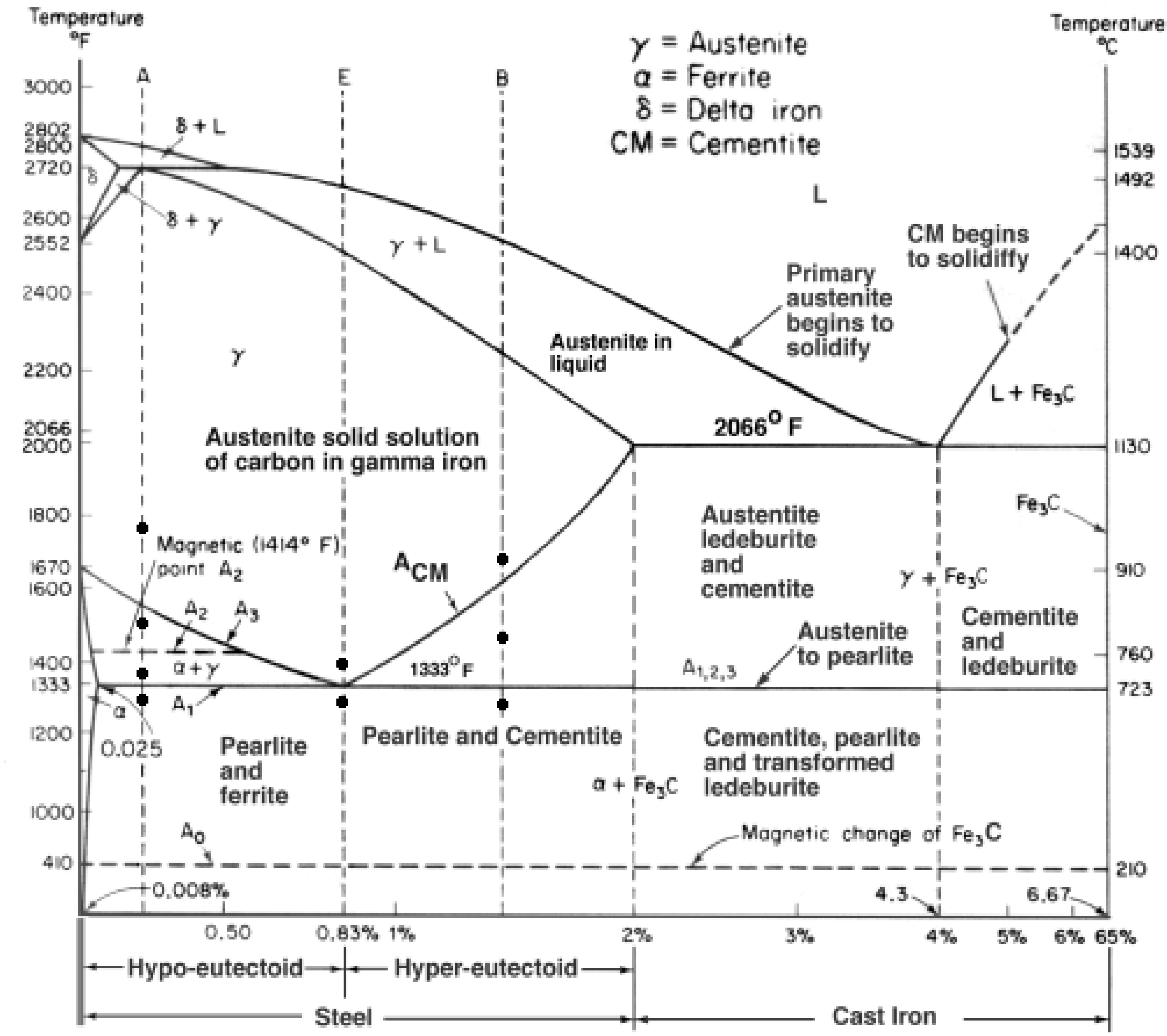
– The alloying elements in carbon, chromium, Nickel, silicon, manganese, etc. But the most important alloying element is carbon.

– Carbon forms solid solution & inter metallic compound with Iron.

– The internal compound of iron and carbon is carbide or cementite, which contains 6.67% carbon by weight.

– The phase diagram which shows iron carbon alloy is drawn by taking Iron, carbide, as components and the diagram is known iron carbide equilibrium diagram.

– In diagram the vertical time at the left represents the pure Iron.



– Various phases exiting in Iron carbon equilibrium diagram are:

(a) Alpha (α)ferrite:

(i) Ferrite is the name given to the interstitial solid solution of carbon in α-ferrite.

(ii) It has BCC crystal structure.

(iii) The solubility of carbon in α-ferrite is 0.008% at room temperature which increases 0.025% at 723 C.

(iv) It is the softest structure & ductile in nature that appears in iron carbon diagram.

(v) It is strongly ferromagnetic up to 768^0C after which it becomes Non-Magnetic in Nature. This temperature is called curie temperature.

(b) Austenite or (γ) iron:

(i) It is the solid solution of carbon in γ-iron.

(ii) The maximum solid solubility carbon in γ-iron is 2% at 1130^0C.

(iii) It is a soft, ductile & Non-magnetic in nature.

(iv) It has FCC crystal structure.

(v) It is stable above 723^0C.

(c) б- Ferrite

(i) It is an interstitial solid solution in carbon in б- iron.

(ii) It is stable between the temperature 1400^0C to 1539^0C..

(iii) The maximum solubility of carbon is б-iron is 0.012% at 1497^0C.

(iv) It has BCC crystal structure.

(d) Cementite : (Fe_3C)

(i) It is an intermetalic compound of iron & carbon.

(ii) It has a fixed carbon contained that is 6.67% by weight.

(iii) It has a complex crystal structure having 12 iron atoms & 4 carbon atoms in a unit cell that is 3:1 ratio.

(iv) It is hard & brittle in nature & having low tensile strength.

(v) It is the hardest structure that appears in iron- carbon diagram.

Difference Reactions occurring in iron carbon carbon equilibrium diagram.

(a) Peritectic reaction(P):

б + L ---1497^0C--→ ɣ

(0.1%C) (0.5%C) (0.18%C)

– At temperature 1497^0C liquid having composition 0.5% carbon react with б-ferrite having composition of 0.1% carbon and give a single solid phase that is Austenite (ɣ) having composition 0.18% carbon.

(b) Eutectic Reaction(E) :

L ---1130^0C--→ ɣ + Fe_3C

(4.3%) (2%C) (6.67%C)

– Liquid having composition 4.3% carbon at 1130^0C transforms to 2 solid phases that is Austenite (ɣ) and cementite (Fe_3C) having composition 2% carbon & 6.67% carbon respectively.

(c) Eutectoid Reaction (E'):

ɣ --- 723^0C--→ α + Fe_3C

(0.8%) (0.025 %C) (6.67% C)

– Austenite having composition 0.8% carbon and at temp. 723^0C transforms to ferrite & cementite, simultaneously having composition 0.025%C & 6.67%C respectively.

- This eutectoid mixture is called as **pearlite. (α+Fe_3C).**

– It consists of thin lamellar structure of ferrite & cementite.

Critical temperatures:

- The temperatures at which phase change occurs during, heating and cooling are called critical temperature.

Eutectoid temp. (A_1):-

- The temperature at which austenite transfer to pearlite on cooling.
- This transformation occurs at 723 degree c. and is called eutectoid temperature.
- It does not depend on the % of carbon in the alloy. This temperature is also known as lower critical temperature.

Hypoeutectoid temp. (A_3):-

- It is the temperature at which free ferrite transforms to austenite while heating. It is the boundary between austenite and (γ+α) region.
- It is a function of carbon content.
- It increases from 910˚C. for 0% carbon and 723˚C. for 0.8% carbon .it is also known as upper critical temperature.

Hyper eutectoid temp. (A_{cm}):-

- It is the temperature at which free cementite transforms to austenite while heating. It is boundary between austenite and(γ+fe_3c) region.
- It increases from 723˚C for 0.8% carbon to 1130˚C. for 2% carbon.
- It is the function of carbon content. It is known hyper critical temperature.

CAST IRON

- Cast iron is the alloy of iron & carbon having carbon contain 2% to 6.67%.i.e more than the carbon content of austenite & less than that the carbon content of cementite.
- With the increase of carbon content the amount of cementite increase, which makes the cast iron hard & brittle. This becomes unsuitable for commercial application.
- Commercially cast iron contains 2% to 4% carbon & other alloying elements also present in slightly amount like Mn, Si, P, Cr, etc.
- Because of their poor ductility & malleability they cannot be subjected to any mechanical operation to get desire shape.
- They get lower melting point compare to steel. Hence they can be subjected to casting. Since casting is the only suitable process to get the desirable shape it is called as cast iron.

TYPES OF CAST IRON

- Cast irons are may be classified as**:-**
  - White cast iron
  - Gray cast iron
  - Malleable cast iron
  - Nodular cast iron
  - Chilled cast iron
  - Alloy cast iron

PROPERTIES

- They are cheapest compare to steel.
- They are easier to melt because of their low melting point .i.e. 1150^0C to 1300^0C.
- They are brittle & hard.
- They have excellent cast ability.
- Property can be easier adjusted by proper alloying & suitable heat treatment.
- They are highly corrosive resistance.

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

THEORY OF MACHINE

4TH SEMESTER

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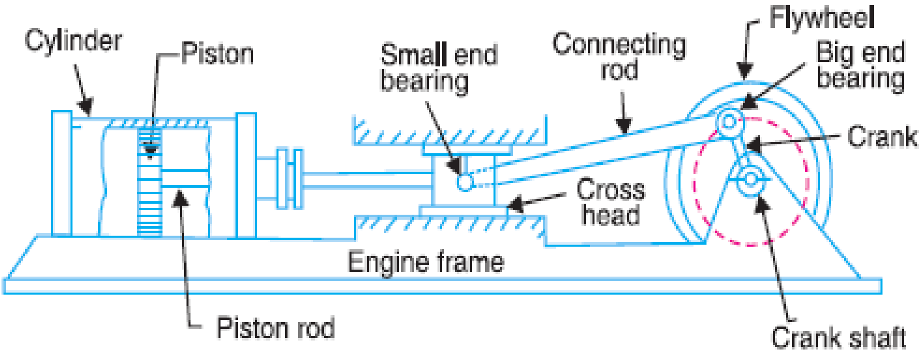
SIMPLE MECHANISM

Q.1) Explain the term kinematic link? Give the classification of kinematic links?

Ans) ***Kinematic link*:** Each part of a machine which moves relative to some other part is called a kinematic link.

Explanation:



From the above Reciprocating steam engine (Slider crank mechanism) kinematic links are:

Link (1) - Frame & guides, Link (2) - Crank, Link (3) - Connecting rod, Link (4) – Slider.

***Types of links*:**

♣ Rigid Link**:** It is one which does not undergo any deformation while transmitting motion.

Example: The deformation of a connecting rod and crank of a reciprocating steam engine is can be considered as rigid links.

♣ Flexible Link**:** It is one which is partly deformed in a manner not to affect the transmission of motion.

Example: Belts, ropes, chain drives & wires are flexible links.

♣ Fluid Link**:** It is one which is formed by having a fluid & the motion is transmitted through the fluid by pressure or compression only.

Example: Hydraulic presses, jacks and brakes.

Q.2) What is a kinematic pair? Explain different types of kinematic pairs?

Ans) ***Kinematic pair*:** The two links of a machine when in contact with each other are said to form a kinematic pair.

***Classification of kinematic pairs*:**

(a) *According to nature of relative motion*:

- Sliding Pair**:** If one link of a pair has a sliding motion relative to other, then the pair is called as sliding pair.
  Example: Rectangular rod in a rectangular hole.

- Turning Pair / Revolving Pair**:** If one link of a pair has a revolving motion relative to the other, then the pair is called as turning pair.
  Example: Circular shaft revolving in a bearing.

- Rolling Pair**:** If one link of a pair has a rolling motion relative to the other, then the pair is called as rolling pair.
  Example: Ball & roller bearings, and a rolling wheel on a flat surface.

- Screw Pair / Helical Pair**:** If two mating links of a pair have a turning as well as sliding motion between them, then the pair is called as screw pair.
  Example: Lead Screw & the Nut of a Lathe.

- Spherical Pair**:** When one link in the form of a sphere turns inside a fixed link, then the obtained pair is called as spherical pair.
  Example: Ball & Socket Joint.

(b) *According to nature of contact*:

- Lower Pair**:** A pair of links having surface or area contacts between the members is called as lower pair.

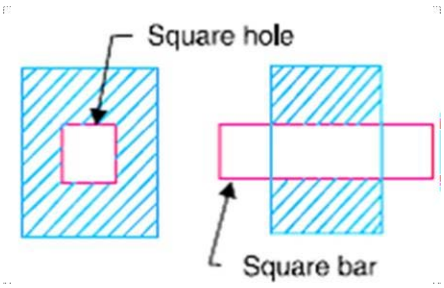
  Example: All pairs of Slider crank mechanism, nut turning on a screw, and shaft rotating in bearing.

- Higher Pair: A pair of links having a point or line contact between the members is called as higher pair.
  Example: Wheel rolling on a surface, cam & follower, and tooth gears.

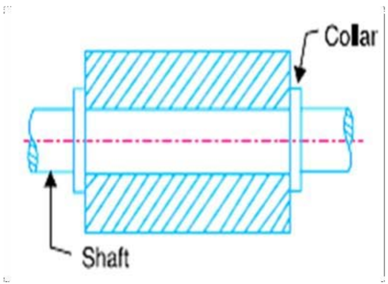
(c) *According to the nature of mechanical constraint or type of closure*:

- Closed pair / Self closed pair**:** When the elements of a pair are held together mechanically, then the pair is called as closed pair
  Example: All Lower pairs & some higher pairs.

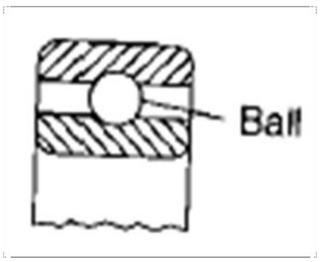
- Unclosed / forced closed pairs**:** When two links of a pair are in contact either due to force of gravity or some spring action, then the pair is called as unclosed pair.
  Example: Cam & Follower pairs.



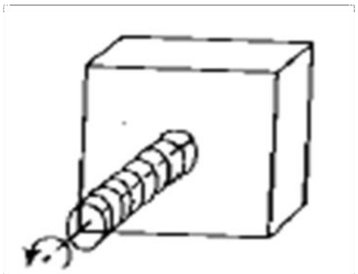
(Sliding Pair)

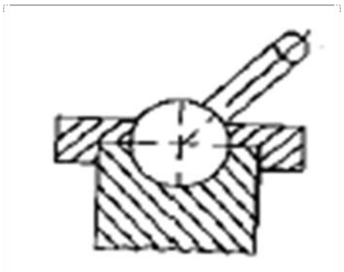


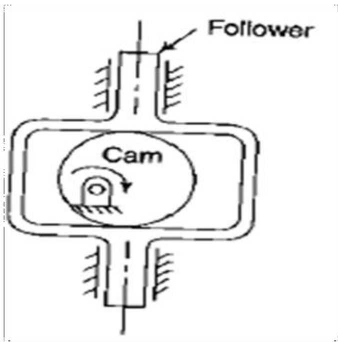
(Turning Pair)



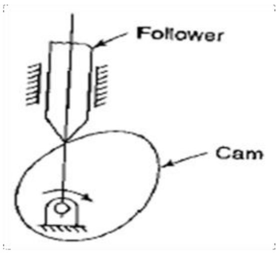
(Rolling Pair)


(Screw Pair)


(Spherical Pair)

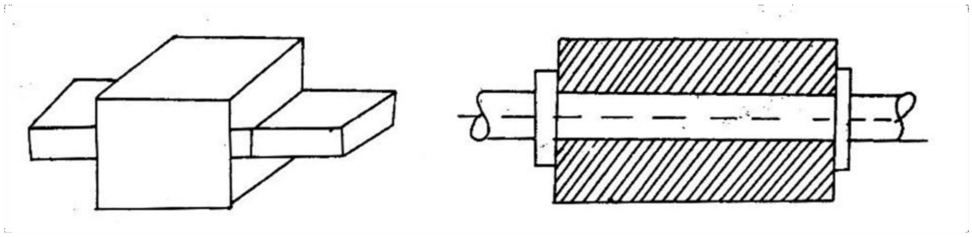


(Closed Pair)



(Unclosed Pair)

(Higher Pair)



(Lower Pair)

Q.3) Define Kinematic chain. Give the classification of joints in a chain?

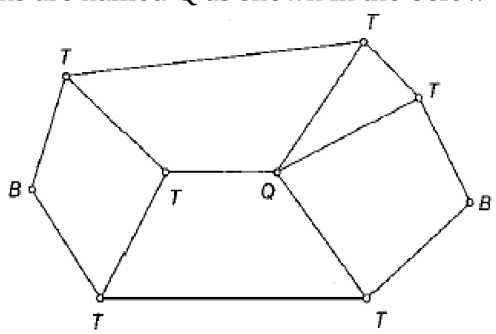
Ans) ***Kinematic Chain*****:** When the kinematic pairs are coupled in such a way that last link is joined to the first link to transmit definite motion, it is called as kinematic chain.

Number of joints in a chain: J = (3 /2) L - 2

Types of joints**:**

- Binary Joint: If two links are joined at the same connection, it is called a binary joint.

  Example: A joint with two binary joints named B as shown in the below figure.
- Ternary Joint: If three links are joined at a connection, it is known as a ternary joint. Example: Ternary links are named T as shown in the below figure.
- Quaternary Joint: If four links are joined at a connection, it is known as quaternary joint.
  Example: Quaternary links are named Q as shown in the below figure.



Q.4) Define Inversion of mechanism?

Ans) Inversion is the method of obtaining different mechanisms by fixing different links in a kinematic chain.

Q.5) What are the types of Kinematic Chains?

Ans) Types of kinematic Chains are **(i)** Four Bar Chain / Quadric Cycle Chain, **(ii)** Single Slider Crank Chain, **(iii)**Double Slider Crank Chain.

Q.6) Distinguish between 'Machine' and 'Mechanism'.

Ans) ***Machine*:**

- It is a mechanism which receives energy and transforms it into some useful work.
- A machine transmits power & performs some particular type of work.
- All machines are mechanisms.

***Mechanism*:**

- When one of the links of a kinematic chain is fixed, then it is known as mechanism. Thus mechanism is a constrained chain.
- A mechanism transmits & modifies a motion.
- All mechanisms are not machines.

Q.7) Distinguish between Structure and Machine

Ans) ***Machine*:**

- It is a mechanism or a combination of mechanisms.
- The parts of a machine move relative to one another.
- A machine transforms the available energy into some useful work.
- The links of a machine may transmit both power and motion.

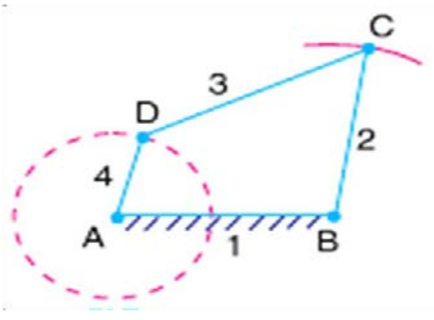
***Structure*:**

- It is an assembly of a number of resistant bodies having no relative motion between them.
- The members of a structure do not move relative to one another.
- A structure does not move relative to one another.
- The members of a structure transmit forces only.

Q.8) Describe the four bar chain mechanism and its inversions.

Ans) ***Four Bar Chain / Quadric Cycle Chain***:

- It consists of four rigid links which are connected in the form of a quadrilateral by four pin-joints.
- A link makes complete revolution is called Crank (4).
- The link which is fixed is called fixed link (1).
- The link opposite to the fixed link is called Coupler (3).
- The fourth link is called Lever or Rocker (2).
- It is impossible to have a four bar linkage, if the length of one of the links is greater than the sum of the other three.
- *Grashof's Law*: For a four bar mechanism, the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths.

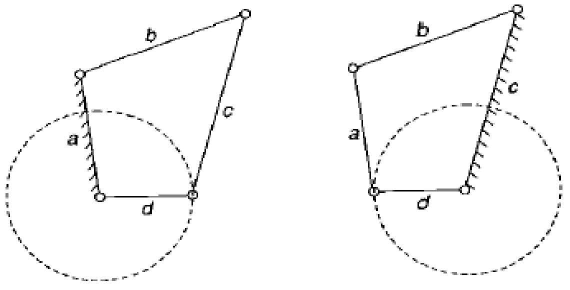


(Four bar chain)

***Inversions of Four Bar Chain*:**

(i) *First Inversion* (Crank & Lever Mechanism):

If any of the adjacent links of link ‘d’, either link ‘**a’** or ‘**c’** is fixed, then the link ‘**d’** (crank) can have full revolution and the link ‘**b’** opposite to it oscillates. Such type of mechanism is called as crank-lever mechanism.

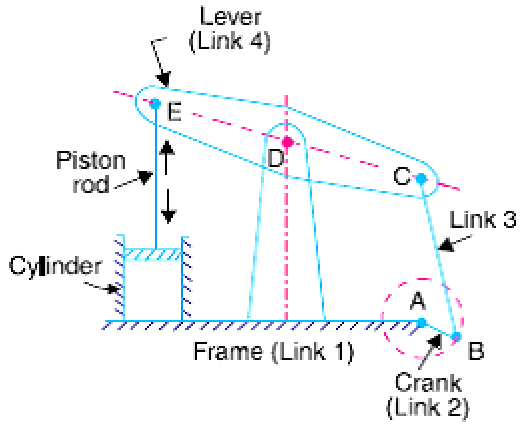


(a) (b)

Example:- Beam Engine

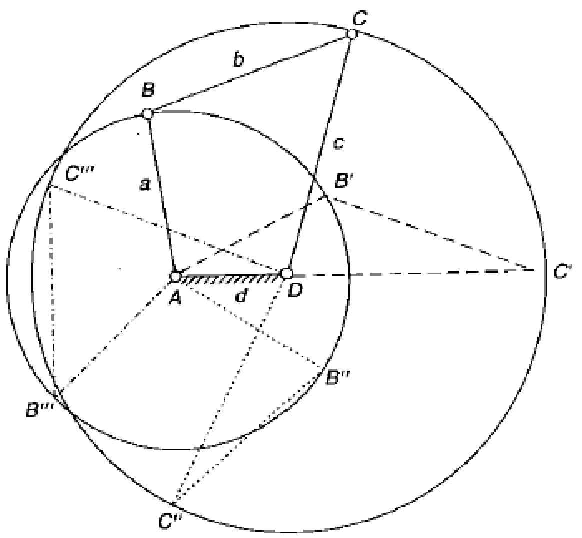
In this mechanism the crank rotates about the fixed centre A and the lever oscillates about a fixed centre D.

The purpose of this mechanism is to convert rotary motion into reciprocating motion.



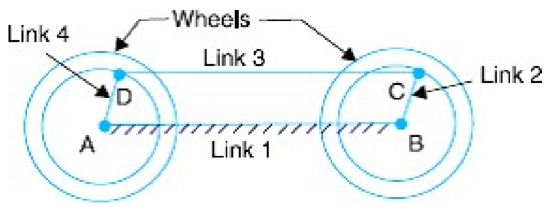
(ii) *Second Inversion* (Double Crank mechanism):

If the shortest link ‘d’ is fixed then the links ‘**a’** and ‘**c’** rotates full circle and link ‘**b’** also complete one revolution relative to fixed link ‘**d’**.



Example: Coupling Rod of a Locomotive (Double Crank Mechanism):

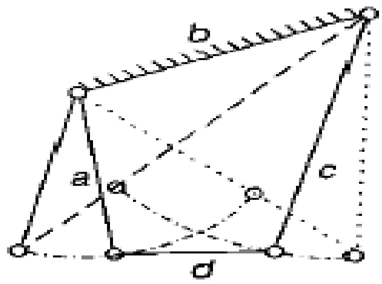
In this mechanism the two links 2 and 4 respectively are transmitting rotary motion between them. They are rotating with respect to link 1.



(iii) ***Third Inversion*** (Double Lever mechanism):

If the link opposite to the shortest link.

i.e., link '**b**' is fixed and the two links '**a**' and '**c**' would oscillate.



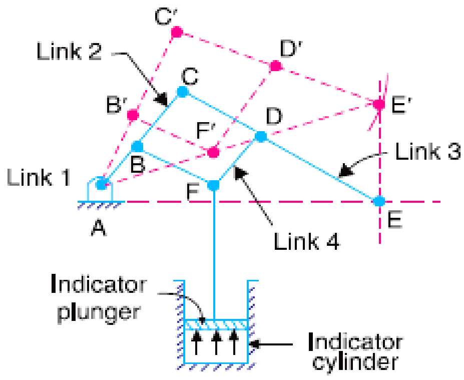
Example: Watt's indicator (Double Lever Mechanism):

It consists of four links which are:

Fixed link at A, link AC, link CE and link BFD.

The links CE and BFD act as lever.

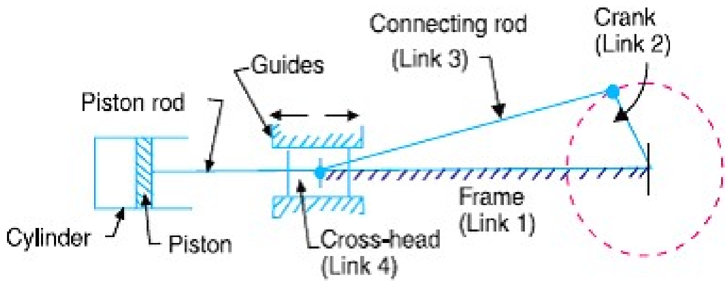
It is also called Watt's straight line mechanism and the dotted line shows the position of the mechanism.



Q.9) Sketch and describe the various inversions of a Slider Crank Chain?

Ans) ***Slider Crank Chain***:

- When one of the turning pairs of a four bar chain is replaced by a sliding pair, it becomes a single slider crank chain.
- It consists of one sliding pair and three turning pairs.
- In a single slider crank chain as shown in the above figure, the links 1&2, links 2&3, and links 3&4 form three turning pairs while the links 4&1 form a slider pair.



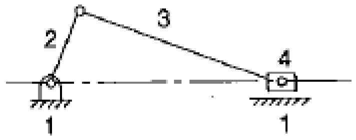
***Inversions of Single Slider Crank Chain*:**

(i) First Inversion**:**

This inversion is obtained when **link 1** is fixed and links 2 & 4 are made the crank & the slider respectively.

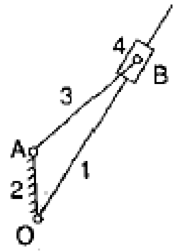
Example:

- Reciprocating Steam Engine: Link 4 (piston) is the driver.
- Reciprocating Compressor. Link 2 (crank) is the driver.



(ii) Second Inversion**:**

This inversion is obtained when link 2 is fixed; link 3 along with the slider becomes crank and link 1 rotate about O along with the slider which also reciprocates on it.

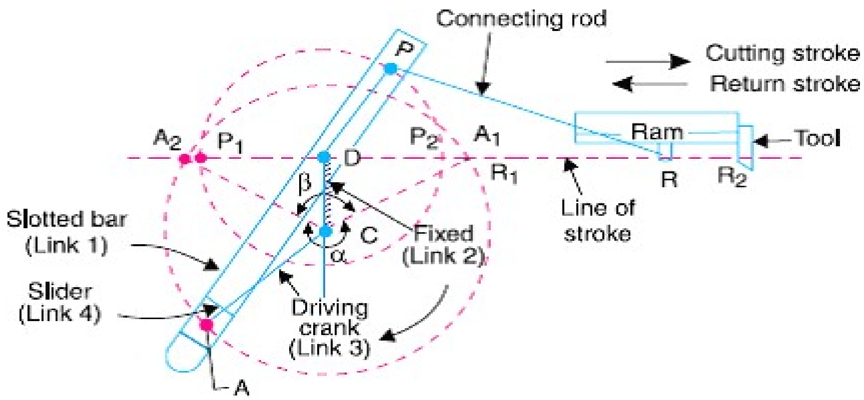


Example:

(a) *Whitworth quick-return mechanism***:**

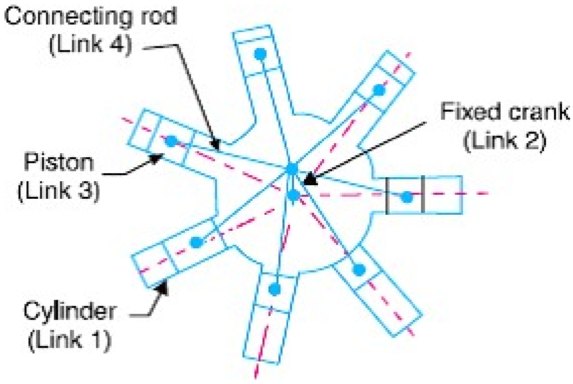
- This mechanism used in shaping and slotting machines.
- In this mechanism the link CD (link 2) forming the turning pair is fixed; the driving crank CA (link 3) rotates at a uniform angular speed and the slider (link 4) attached to the crank pin at A slides along the slotted bar PA (link 1) which oscillates at D.
- The connecting rod PR carries the ram at R to which a cutting tool is fixed and the motion of the tool is constrained along the line RD produced.
- The length of effective stroke = 2 PD. And mark $P_1R_1 = P_2R_2 = PR$.

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\alpha}{\beta} = \frac{\alpha}{360° - \alpha} \quad \text{or} \quad \frac{360° - \beta}{\beta}$$



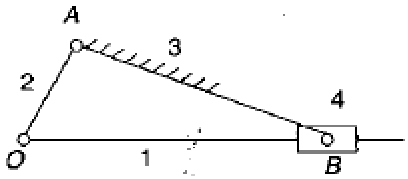
(b) ***Rotary internal combustion engine*:**

- This mechanism is used in aviation.
- It consists of seven cylinders in one plane and all revolves about fixed centre D.
- The crank 2 is fixed, connecting rod 4 rotates and the piston 3 reciprocates inside the cylinders forming link 1.



(iii) Third Inversion**:**

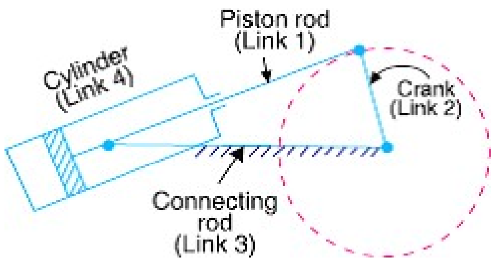
This inversion is obtained when the link 3 is fixed, the link 2 acts as a crank and link 4 oscillates.



Example:

(a) *Oscillating cylinder engine*:

- It is used to convert reciprocating motion into rotary motion.
- In this mechanism link 3 is fixed, the crank 2 rotates, piston rod 1 reciprocates and cylinder 4 oscillates about A.



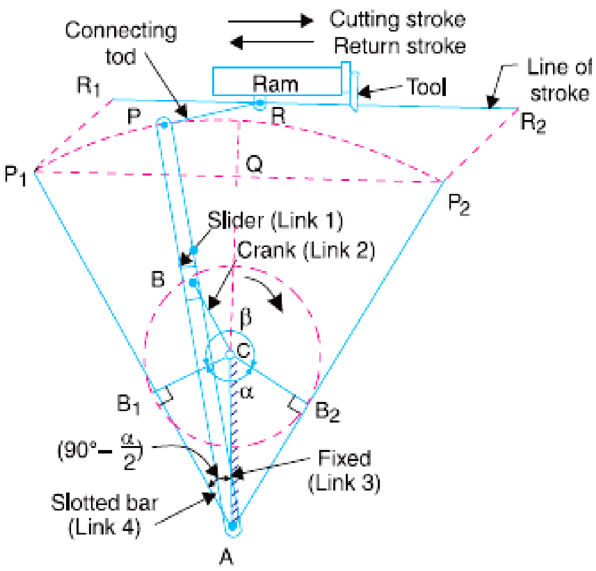
(b) *Crank & slotted lever mechanism*:

- This mechanism is used in shaping machines, slotting machines and in rotary internal combustion engine.
- In this mechanism link AC(3) corresponding to the connecting rod is fixed, the driving crank CB revolves about the fixed centre C and a sliding block attached to the crank pin at B slides along the slotted bar AP.

- AP oscillates about A and a short link PR transmits motion from AP to the arm which reciprocates along the line of stroke R_1R_2.

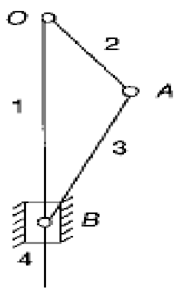
$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360^\circ - \beta} \quad \text{or} \quad \frac{360^\circ - \alpha}{\alpha}$$

$$\text{Length of stroke} = R_1R_2 = P_1P_2 = 2P_1Q = 2AP\cos\frac{\alpha}{2} = 2AP \times \frac{CB_1}{AC} = 2AP \times \frac{CB}{AC}$$



(iv) <u>Fourth Inversion</u>:

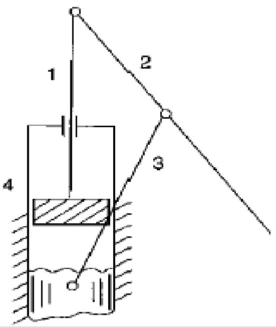
This inversion is obtained when the link 4 is fixed, the link 3 oscillates about B on the link 4 and the end A of the link 2 is oscillates about B and the end O reciprocates along the fixed link-4.



<u>Example</u>:

(a) <u>*Hand Pump*</u>:

The link 4 is made in the form of a cylinder and a plunger fixed to the link 1 reciprocates in it.



Q.10) Write a short note on Cam and Follower.

Ans) ***<u>Cam & Follower</u>***:

- A cam may be defined as a rotating, reciprocating or oscillating machine part, designed to produce reciprocating and oscillating motion of another mechanical part, called a follower.
- A follower is a reciprocating or oscillating member which follows motion of cam.
- A cam and follower have a line contact between them and as such they constitute a higher pair. The contact between them is maintained by an external force which may provide by a spring or sometimes by the sufficient weight of the follower itself.
- Cams are classified according to its Shape, Follower movement and Type of constraints.
- Followers may be classified according to the type of motion, the axis of the motion and the shape of their contacting end with the cam.
- Various types of cams are flat cams, disc cams, spiral cams, cylindrical cams and spherical cams etc.
- Various types of follower are knife-edge, roller, reciprocating, oscillating, radial follower etc.
- <u>Applications</u>:

  The cams are widely used for inlet and exhaust valve of internal combustion engine, automatic attachment of machineries, paper cutting machines, feed mechanism of automatic lathe etc.

END of Chapter

FRICTION

Q.1) ***Define the terms (i) coefficient of friction, (ii) angle of friction, (iii) angle of repose and (iv) limiting friction.***

Ans) (i) <u>*Coefficient of friction*</u>**:**

It is defined as the ratio of the limiting friction (F) to the normal reaction (R_N) betweenthe two bodies. It is denoted by ‘μ’. $\mu = F / R_N$

(ii) <u>*Limiting angle of friction*</u>**:**
It is the angle between the resultant limiting friction and the normal reaction.
It is the angle made by the resultant of force of friction and normal reaction with normal reaction. It is denoted by ‘ ∅ ’.
We may write, $\tan \emptyset = \mu = F / R_N$ OR $\emptyset = \tan^{-1}(\mu)$

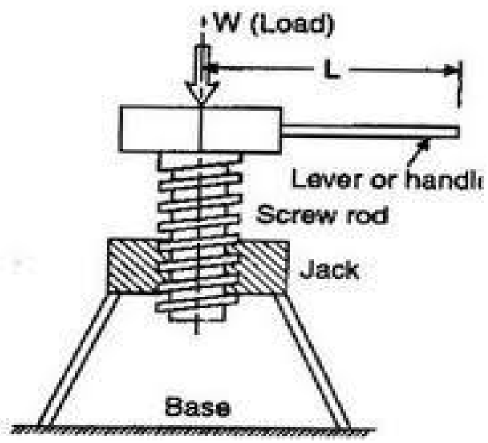
(iii) <u>*Angle of Repose*</u>**:**
It is the angle made by the inclined plane with the horizontal plane when a body starts moving without the application of force. The body tends to slide when the angle of inclination of the plane is equal to the angle of friction. i.e. $\mu = \emptyset$.

(iv) <u>*Limiting friction*</u>**:**

It is the maximum value of frictional force experienced by the body, when the body just begins to slide over the surface of another body.

Q.2) ***Draw the neat sketch of screw jack.***

Ans)



Q.3) ***Define pitch and lead. State the relation between them.***

Ans) <u>*Pitch* (p)</u>**:** It is the linear distance taken from one point of thread to corresponding point of next thread.

<u>*Lead* (L)</u>**:** It is the axial distance covered by a screw in one rotation.

<u>*Relation between lead and pitch*</u>**:**

Lead = n × pitch where, n = number of threads per pitch length

Q.4) ***Derive an expression for torque required to raise and lower the load by Screw jack. Determine its efficiency.***

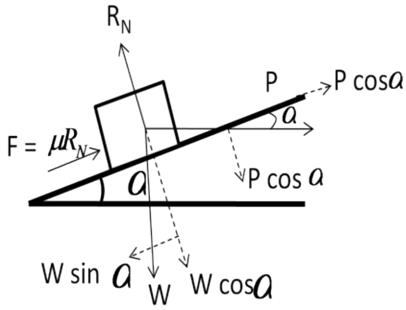
Ans) *<u>Torque required lowering the load by Screw jack</u>*:

Let, W= weight to be lifted α = helix angle R_N = normal reaction

$\emptyset$ = limiting angle of friction P = effort required to lower the load

Resolving all the forces perpendicular the plane,

R_N = W cos α + P sin α-------(i)



Resolving the forces parallel to the plane,

P cos α = W sin α - μ R_N -----(ii)

Putting the value of R_N in equation-(ii), we

getP cos α = W sin α - μ (W cos α + P sin α)

= W sin α - μW cos α - μP sin α

⇒ P cos α + μP sin α = Wsin α - μWcos

⇒ P (cos α + μ sin α) = W(sin α - μcos α)

⇒ $\boxed{P = W \times \frac{\sin\alpha - \mu\cos\alpha}{\cos\alpha + \mu\sin\alpha}}$ ________ (iii)

Replacing the value, $\mu = \frac{\sin\emptyset}{\cos\emptyset}$

$$\Rightarrow P = W \times \frac{\sin\alpha - \frac{\sin\emptyset}{\cos\emptyset}.\cos\alpha}{\cos\alpha + \frac{\sin\emptyset}{\cos\emptyset}.\sin\alpha}$$

$$\Rightarrow P = W \times \left(\frac{\sin\alpha.\cos\emptyset - \sin\emptyset.\cos\alpha}{\cos\alpha.\cos\emptyset + \sin\alpha\sin\emptyset}\right)$$

$$\Rightarrow P = \frac{W\sin(\alpha - \emptyset)}{\cos(\alpha - \emptyset)}$$

$$\Rightarrow \boxed{P = W\tan(\alpha - \emptyset)} \text{.........(iv)}$$

Torque required to lower the load (T) = $P \times \frac{d}{2}$

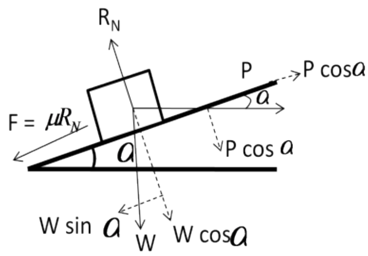
<u>Torque required rising the load by Screw jack</u>:

Let, W= weight to be lifted α = angle of inclination R_N = normal reaction

$\emptyset$ = limiting angle of friction, P = effort required to raise the load

Resolving all the forces perpendicular the plane,

R_N = W cos α + P sin α ______(i)



Resolving the forces parallel to the plane,

P cos α = W sin α + μ R_N______(ii)

Putting the value of R_N in equation-(ii), we

get:P cos α = W sin α + μ (W cos α + P sin α)

⇒ P cos α - μP sin α = Wsin α + μWcos α

⇒ P (cos α - μ sin α) = W(sin α + μcos α)

⇒ $\boxed{P = W \times \frac{\sin\alpha + \mu\cos\alpha}{\cos\alpha - \mu\sin\alpha}}$________ (iii)

Replacing the value, $\mu = \frac{\sin\emptyset}{\cos\emptyset}$ we get:

$$\Rightarrow P = W \times \frac{\sin\alpha + \frac{\sin\emptyset}{\cos\emptyset}.\cos\alpha}{\cos\alpha - \frac{\sin\emptyset}{\cos\emptyset}.\sin\alpha}$$

$$\Rightarrow P = W \times \left(\frac{\sin\alpha.\cos\emptyset + \sin\emptyset.\cos\alpha}{\cos\alpha.\cos\emptyset - \sin\alpha\sin\emptyset}\right)$$

$$\Rightarrow P = \frac{W\sin(\alpha + \emptyset)}{\cos(\alpha + \emptyset)}$$

$$\Rightarrow \boxed{P = W\tan(\alpha + \emptyset)} \text{\_\_\_\_\_\_\_\_\_(iv)}$$

Torque required to raise the load (T) = $P \times \frac{d}{2}$

Mechanical efficiency of a square threaded screw jack:

The efficiency of the screw jack may be defined as the ratio of the ideal effort to the actual effort.

We know that actual effort (P) = W tan $(\alpha + \emptyset)$
Where, α = helix angle,
$\emptyset$ = angle of friction,
μ = coefficient of friction
If there will no friction between screw and nut, then $\emptyset = 0$,

Thus ideal effort P_o = W tan α ,

$$\text{Efficiency} = \frac{\text{Ideal effort}}{\text{Actual effort}} = \frac{Po}{P} = \frac{W \tan \alpha}{W \tan(\alpha + \emptyset)} = \frac{\tan \alpha}{\tan(\alpha + \emptyset)}$$

Q.5) ***State the condition of reversibility and self-locking of a Screw jack.***

Ans) *Condition of self locking*:

If the efficiency of the screw jack is greater than 50% then the machine is known as reversible.

For self locking of the screw, $\emptyset \geq \alpha$ or $\emptyset \leq \alpha$.

Thus; Efficiency ($\boldsymbol{\eta}$) $< \frac{\tan \alpha}{\tan(\alpha + \emptyset)} < \frac{\tan \alpha}{\tan 2\emptyset} < \frac{\tan \alpha \times (1 - \tan^2 \emptyset)}{2 \tan \emptyset} < \frac{1 - \tan^2 \emptyset}{2} < ½ - \frac{\tan^2 \emptyset}{2}$

From this expression we conclude that, $\boldsymbol{\eta} < (1/2)$ or 50%.
This is the condition of self locking.

Condition of reversibility or overhauling:

If the efficiency of the screw jack is less than or equal to 50% then the machine is known as self-locking.

For overhauling or reversibility of screw**,** $\emptyset \leq \alpha$ or $\emptyset \geq \alpha$**.**

Thus; Efficiency **($\boldsymbol{\eta}$)** $\geq \frac{\tan \alpha}{\tan(\alpha + \emptyset)} < \frac{\tan \alpha}{\tan 2\emptyset} < \frac{\tan \alpha \times (1 - \tan^2 \emptyset)}{2 \tan \emptyset} < \frac{1 - \tan^2 \emptyset}{2} < ½ - \frac{\tan^2 \emptyset}{2}$

From this expression we conclude that, $\eta > (1/2)$ or 50%.
This is the condition of reversibility.

Q.6) ***State the condition for maximum efficiency of a screw jack. State the formula to determine maximum efficiency.***

Ans) The condition for maximum efficiency of the screw jack is: $\alpha = 45^0 - \emptyset/2$
Where, α = helix angle and $\emptyset$ = friction angle

Maximum efficiency is given by $\eta_{max} = \frac{1 - \sin \emptyset}{1 + \sin \emptyset}$

Q.7) ***The following data are related to a screw jack. Pitch of the screw = 8 mm, diameter of the screw = 40 mm, coefficient of friction between screw and nut = 0.1, load = 20 KN. Assuming that the load rotates with the screw, determine the torque required to raise the load and efficiency.***

Ans) Data given:

pitch (p) = 8 mm mean diameter of screw (d) = 40 mm

coefficient of friction (μ) = tan Ø = 0.01 load (W) = 20 KN

we know that, $\tan\alpha = \frac{p}{\pi d} = \frac{8}{\pi \times 40} = 0.063$

effort (P_0) = W tan (α + Ø)

$$= 20 \times \frac{\tan\alpha + \tan\emptyset}{1 - \tan\alpha \times \tan\emptyset} = 20 \times \frac{0.063 + 0.1}{1 - 0.063 \times 0.1} = 20 \times \frac{0.163}{0.9937} = 3.28 \text{ KN}$$

Torque required to raise the load (T) = $P_0 \times \frac{d}{2} = 3.28 \times 20 = 65.6$ KN-mm

efficiency (Ƞ) = $\frac{\tan\alpha}{\tan(\alpha + \emptyset)} = \frac{0.063}{0.164} = 0.3841$ or, efficiency is 38.41% (Ans)

Q.8) ***A 150 mm diameter valve against which a steam pressure of 2 MN/m² is acting. It is closed by means of a square threaded screw 50 mm in external diameter with 6 mm pitch. If the coefficient of friction is 0.12, find the torque required to turn the handle.***

Ans) Data given

diameter of valve (D) = 150 mm = 0.15 m

steam pressure (Ps) = 2 MN/m^2 = 2×10^6 N/m^2

screw diameter (d_o) = 50 mm pitch (p) = 6 mm

coefficient of friction (μ) = tan Ø = 0.12

load on valve = pressure × area = $2 \times 10^6 \times \frac{\pi}{4}(0.15)^2 = 35400$ N

mean diameter of the screw (d) = d_o – p/2 = 50 – 6/2 = 47 mm = 0.047 m

we know that, $\tan\alpha = \frac{p}{\pi d} = \frac{6}{\pi \times 47} = 0.0406$

force required to turn the handle (P) =

$$W \tan(\alpha + \emptyset) = W \times \frac{\tan\alpha + \tan\emptyset}{1 - \tan\alpha \times \tan\emptyset} = 35400 \times \frac{0.0406 + 0.12}{1 - 0.0406 \times 0.12} = 5713 \text{ N}$$

torque required to turn the handle (T) = $p \times \frac{d}{2} = 5713 \times 0.04712 = 134.2$ N-m

Q.9) ***What are the functions of bearing*?**

Ans) The function of bearing is to fix, support and guide the rotating axle or sliding component in machines.

Q.10) ***What do you mean by collar and pivot*?**

Ans) *Collars or collar bearings* are the machine elements which are used to carry axial thrust of the rotating shafts. These are provided at any position of the shaft and bear the axial thrust on a mating surface. Collar bearings are also known as *thrust bearings*.

Example: These are used in the propeller shaft of ships, shafts of steam turbine and vertical machine shafts etc.

Pivots are the machine elements which are used to carry axial thrust of the rotating shafts. These are provided at the end of the shafts. Pivots are of a flat surface or conical surface. Flat pivot bearing is known as *foot step bearing*.

Q.11) ***Classify bearings and explain them.***

Ans) Bearings are classified as sliding bearing and rolling bearing. Sliding bearing is including journal bearing and thrust bearing. Rolling bearing is including ball bearing, roller bearing and needle roller bearing.

Journal bearing:

Journal bearing is used to support the load in the direction of diameter.

Thrust bearing:

Thrust bearing is used to support the axle which carries the axial load.

Rolling bearing:

Rolling bearing can reduce the friction produced by the rotating shaft when it rotates.

Ball bearing:

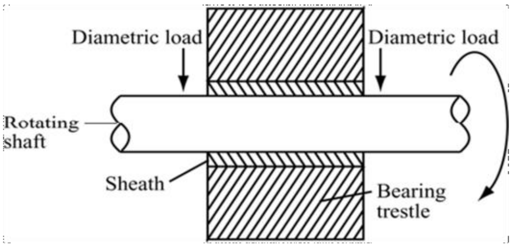
Ball bearing uses balls as a medium between the fixed components and the rotating components, such as the moving parts at the bottom of a gate and reduces the friction.

Roller bearing:

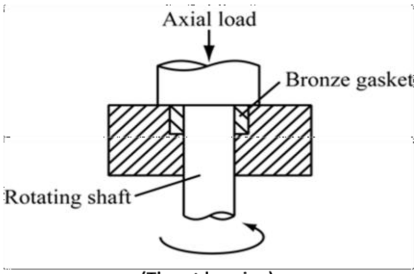
Roller bearing works similarly as ball bearing but it uses cylinders instead of balls.

Needle roller bearing:

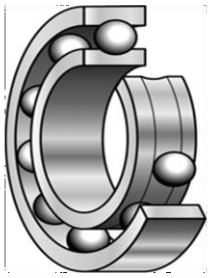
A needle roller bearing works similarly as ball bearing but it uses the typical structure consists of a needle cage which orients and contains the needle rollers. Needle bearings have a large surface area that is in contact with the bearing outer surfaces compared to ball bearings.

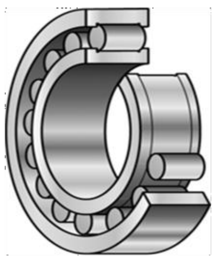


(Journal bearing)



(Thrust bearing)


(Cross-section of ball bearing)

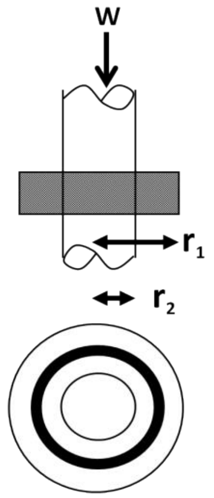

(Cross-section of roller bearing)

Q.12) ***What are the assumptions made in finding power lost in friction in bearing.***

Ans) Assumptions are: (i) uniform pressure theory, (ii) uniform wear theory.

Q.13) ***Derive an expression for total frictional torque in a flat collar bearing / thrust bearing.***

Ans) Total frictional torque in a flat collar bearing**:**



Consider a single flat collar bearing supporting a shaft as shown in figure.

Let, W = load transmitted over bearing surface.

p = intensity of pressure per unit area of bearing surface.

r_1 = external radius of collar.

r_2 = internal radius of collar.

μ = coefficient of friction.

Area of the bearing surface (A) = $\pi [r_1^2 - r_2^2]$

Consider a ring of radius 'r' and thickness 'dr'.

Area of the ring = $2\pi r \times dr$

Load transmitted on the ring (dW) = $p \times 2\pi r \times dr$

Frictional resistance on the ring (dF) = $\mu \times dW = 2\pi \times \mu \times p \times r \times dr$

Frictional torque on ring (dT) = $dF \times r = 2\pi \times \mu \times p \times r^2 \times dr$

Considering uniform pressure condition:

Intensity of pressure (p) = $\frac{W}{\pi [r_1^2 - r_2^2]}$ ------------------- (1)

We know that, Frictional torque on ring (dT) = $dF \times r = 2\pi \times \mu \times p \times r^2 \times dr$

By integrating the above equation from r_2 to r_1 we get;

Total frictional torque on bearing surface (T) = $\int_{r_2}^{r_1} (2\pi \times \mu \times p \times r^2 \times dr)$

$= 2\pi \times \mu \times p \times \int_{r_2}^{r_1} (r^2 \times dr)$

$= 2\pi \times \mu \times p \times \left[\frac{r^3}{3}\right]_{r_2}^{r_1}$

$= 2\pi \times \mu \times p \times \left(\frac{r_1^3 - r_2^3}{3}\right)$

Replacing the value of 'p' from equation-1, we get:

Total frictional torque on bearing surface (T) = $2\pi \times \mu \times \frac{W}{\pi [r_1^2 - r_2^2]} \times \left(\frac{r_1^3 - r_2^3}{3}\right)$

$= \frac{2}{3} \times \mu \times W \times \left(\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right) = \mu \times W \times R$

Where, $R = \frac{2}{3} \times \frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}$ = mean radius

Considering uniform wear condition:

The rate of wear depends upon the intensity of pressure and velocity of rubbing surface. It is proportional to (p × v), but velocity increases with distance or radius 'r'. So we can write:

$p.r = C$ or $p = \frac{C}{r}$

We know that, Load transmitted on ring = $p \times 2\pi r \times dr = \frac{C}{r} \times 2\pi r \times dr = 2\pi C \times dr$

Load transmitted to bearing (W) = $\int_{r_2}^{r_1} (2\pi \times C \times dr) = 2\pi C \times [r]_{r_2}^{r_1} = 2\pi C \times (r_1 - r_2)$

Or $C = \frac{W}{2\pi \times (r1 - r2)}$ -------------- (2)

We know that, Frictional torque on ring (dT) = $dF \times r = 2\pi \times \mu \times p \times r^2 \times dr$

replacing the 'p' value we get;

Frictional torque on ring (dT) = $dF \times r = 2\pi \times \mu \times C \times r \times dr$

By integrating the above equation from r_2 to r_1 we get;

Total frictional torque on bearing surface (T) = $\int_{r_2}^{r_1}(2\pi \times \mu \times C \times r \times dr)$

$= 2\pi \times \mu \times C \times \int_{r_2}^{r_1}(r \times dr)$

$= 2\pi \times \mu \times C \times [\frac{r^2}{2}]_{r2}^{r1}$

$= 2\pi \times \mu \times C \times (\frac{r_1^2 - r_2^2}{2})$

$= \pi \times \mu \times C \times (r_1^2 - r_2^2)$

replacing the value of 'C' from equation-2, we get

Total frictional torque on bearing surface (T) = $\pi \times \mu \times \frac{W}{2\pi \times (r1 - r2)} \times (r_1^2 - r_2^2)$

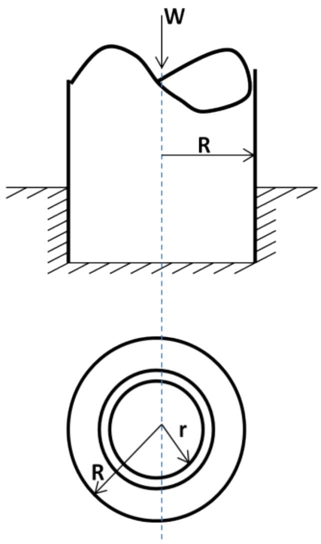
$= \frac{1}{2} \times \mu \times W \times (r_1 + r_2) = \mu \times W \times R$

where, $R = \frac{r1 + r2}{2}$ = mean radius

Q.14) Derive an expression for total frictional torque in a flat pivot bearing.

Ans) *Total frictional torque in a flat pivot bearing*:

Consider a flat pivot bearing supporting a shaft as shown in figure.



Let, W = load transmitted over bearing surface.

p = intensity of pressure per unit area of bearing surface.

R = radius of the shaft.

μ = coefficient of friction.

Area of the bearing surface (A) = πR^2

Consider a ring of radius 'r' and thickness 'dr'.

Area of the ring = $2\pi r \times dr$

Load transmitted on the ring (dW) = $p \times 2\pi r \times dr$

Frictional resistance (dF) = $\mu \times dW = 2\pi \times \mu \times p \times r \times dr$

Frictional torque on ring (dT) $= dF \times r = 2\pi \times \mu \times p \times r^2 \times dr$

Considering uniform pressure condition:

Intensity of pressure (p) = $\frac{W}{\pi R^2}$ ------------------ (1)

We know that, Frictional torque on ring (dT) = $dF \times r = 2\pi \times \mu \times p \times r^2 \times dr$

By integrating the above equation from r_2 to r_1 we get;

Total frictional torque on bearing surface (T) = $\int_0^R(2\pi \times \mu \times p \times r^2 \times dr)$

$= 2\pi \times \mu \times p \times \int_0^R(r^2 \times dr)$

$= 2\pi \times \mu \times p \times (\frac{R^3}{3})$

Replacing the value of 'p' from equation-1, we get:

Total frictional torque on bearing surface (T) = $2\pi \times \mu \times \frac{W}{\pi R^2} \times (\frac{R^3}{3})$

$= \frac{2}{3} \times \mu \times W \times R$

When the shaft rotates at w rad/s, power lost in friction (P) = T.w

$\Rightarrow$ $\mathbf{P} = \frac{2\pi N T}{60}$ where, $w = \frac{2\pi N}{60}$ and N = speed of the shaft in r.p.m.

Considering uniform wear:

The rate of wear depends upon the intensity of pressure and velocity of rubbing surface. It is proportional to (p × v), but velocity increases with distance or radius 'r'. So we can write:

p.r = C or $p = \frac{C}{r}$

We know that, Load transmitted on ring = p × 2π r × dr = $\frac{C}{r}$ × 2π r × dr = 2π C × dr

Load transmitted to bearing (W) = $\int_0^R (2\pi \times C \times dr) = 2\pi C \times [r]_0^R = \boxed{2\pi C \times R}$

Or $\boxed{C = \frac{W}{2\pi \times R}}$ -------------- (2)

We know that, Frictional torque on ring (dT) = dF × r = 2π × μ × p × r^2 × dr

replacing the 'p' value we get;

Frictional torque on ring (dT) = dF × r = 2π × μ × C × r × dr

By integrating the above equation from r_2 to r_1 we get;

Total frictional torque on bearing surface (T) = $\int_0^R (2\pi \times \mu \times C \times r \times dr)$

$$= 2\pi \times \mu \times C \times \int_0^R (r \times dr)$$

$$= 2\pi \times \mu \times C \times \left[\frac{r^2}{2}\right]_0^R$$

$$= 2\pi \times \mu \times C \times \left(\frac{R^2}{2}\right)$$

$$= \pi \times \mu \times C \times R^2$$

replacing the value of 'C' from equation-2, we get

Total frictional torque on bearing surface (T) = $\pi \times \mu \times \frac{W}{2\pi \times R} \times R^2 = \boxed{\frac{1}{2} \times \mu \times W \times R}$

Q.15) A shaft has a number of collars integral with it. External diameter of collars is 400 mm and the shaft diameter is 250 mm. If the uniform intensity of pressure is 35×10^4 N/m^2 and its coefficient of friction is 0.05, estimate (i) power absorbed in overcoming friction when the shaft runs at 105 rpm and carries a load of 15×10^4 N (ii) number of collars.

Ans) Data Given:

d_1 = external diameter of collar = 400 mm, d_2 = internal radius of collar = 250 mmuniform pressure (p) = 35×10^4 N/m^2, coefficient of friction (μ) = 0.05

N = 105 r.p.m W = 15×10^4 N

r_1 = 200 mm = 0.2 m, r_2 = 125 mm = 0.125 m

Torque transmitted (T) = $\frac{2}{3}\mu W\left(\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right) = \frac{2}{3}\times 0.05\times 15\times 10^4 \times\left(\frac{0.2^3 - 0.125^3}{0.2^2 - 0.125^2}\right)$=1240.4 N-m

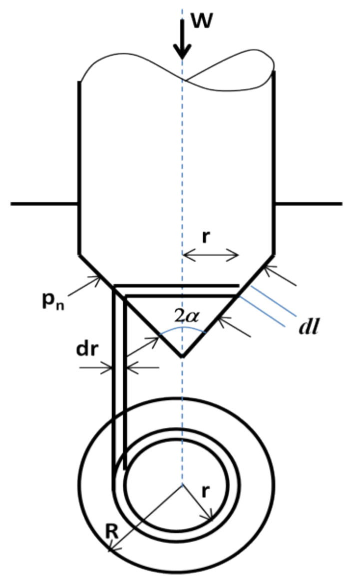
Power absorbed in overcoming friction = P = $\frac{2\pi NT}{60} = \frac{2\pi\times 105\times 1240.4}{60} = 13.6\times10^3$ Watt

Number of collars required (n) = $\frac{Total\ load}{load\ per\ collar} = \frac{W}{p\times\pi\times(r_1^2 - r_2^2)}$

$$= \frac{15\times10^4}{35\times10^4\times\pi\times(0.2^2 - 0.125^2)} = 5.6 \cong 6$$ (***Ans***)

Q.16) Derive an expression for total frictional torque in a conical pivot bearing.

Ans) <u>*Total frictional torque in a conical pivot bearing*</u>**:**



Consider a conical collar bearing as shown in figure.

Let, W = normal load transmitted over the bearing surface

P_n = intensity of pressure normal to the cone

α = semi angle of the cone

μ = coefficient of friction between shaft and bearing

r_1 = radius of the shaft

Consider a small ring of radius ‘ r ’ and thickness ‘dr’

Let, ‘d*l* ’ is the length of the ring along the cone = dr.cosec α

Area of the ring (A) = 2 π r × d*l* = 2 π r × d*r* × cosec α

<u>Considering uniform pressure condition</u>:

Normal load acting on the ring $dW_n = P_n \times$ Area of the ring $= P_n \times (2\pi r \times dr \times \text{cosec}\,\alpha)$

Vertical load acting on the ring = dW = vertical component of $dW_n = dW_n \times \sin\alpha$

$= P_n \times (2\pi r \times dr \times \text{cosec}\,\alpha) \times \sin\alpha = P_n \times 2\pi r \times dr$

Total axial load acting on the bearing (W) $= \int_{r2}^{r1} Pn \times 2\pi r \times dr$

$= 2\pi P_n \times \left[\frac{r^2}{2}\right]_0^R = 2\pi P_n \times \frac{R^2}{2} = \pi \times R^2 \times P_n$

$\therefore \qquad P_n = \frac{W}{\pi R^2}$

Frictional force acting on the ring (dF) $= \mu \times W_n = \mu \times P_n \times 2\pi r \times dr \times \text{cosec}\,\alpha$

Frictional torque on the ring $= dF \times r = 2\pi\mu P_n \times \text{cosec}\,\alpha \times r^2 \times dr$

By integrating the above equation from 0 to R we get;

Total frictional torque on bearing surface (T) $= \int_0^R (2\pi\mu Pn \times \text{cosec}\,\alpha \times r^2 \times dr)$

$= 2\pi\mu Pn \times \text{cosec}\,\alpha \times \left[\frac{r^3}{3}\right]_0^R$

$= 2\pi\mu Pn \times \text{cosec}\,\alpha \times \frac{R^3}{3}$

$= \frac{2\pi R^3}{3} \times \mu Pn \times \text{cosec}\,\alpha$

Replacing the value of P_n we get, $\quad T = \frac{2\pi R^3}{3} \times \mu \times \frac{W}{\pi R^2} \times \text{cosec}\,\alpha$

$\Rightarrow \quad T = \frac{2}{3} \times \mu \times W \times R \times \text{cosec}\,\alpha$

<u>*Considering uniform wear condition*</u>:

Total frictional torque acting ob bearing $= T = \frac{1}{2} \times \mu \times W \times R \times \text{cosec}\,\alpha$

Q.17) ***A conical pivot with angle of cone as 100^0 supports a load of 18 kN. The external radius is 2.5 times the internal radius. The shaft rotates at 150 rpm. If the intensity of pressure is to be 300 kN/m^2 and coefficient of friction as 0.05, what is the power lost in working against friction?***

Ans) <u>Data Given</u>:

Load (W) = 18 kN, semi cone angle (α) = 50^0, coefficient of friction (μ) = 0.00 rpm,
N = 150 rpm, intensity of pressure (p) = 300 kN/m^2
External radius (r_1) = 2.5 × Internal radius (r_2)

Assuming uniform pressure; $p = \dfrac{W}{\pi \times \left(r_1^2 - r_2^2\right)} = \dfrac{18\times10^3}{\pi \times \left((2.5r_2)^2 - r_2^2\right)}$

$$\Rightarrow 300\times10^3 = \frac{18\times10^3}{\pi \times \left((2.5r_2)^2 - r_2^2\right)}$$

$$\Rightarrow (2.5r_2)^2 - r_2^2 = \frac{18\times10^3}{300\times10^3\times\pi} = 0.019$$

$$\Rightarrow 5.25r_2^2 = 0.019 \qquad \Rightarrow r_2 = 0.0601m$$

$$\Rightarrow r_1 = 2.5\times0.0601 = 0.1502m$$

Torque transmitted (T) = $\dfrac{2}{3}\times\dfrac{\mu W}{\sin\alpha}\times\left[\dfrac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right] = \dfrac{2}{3}\times\dfrac{0.05\times18\times10^3}{\sin 50^0}\times\left[\dfrac{0.1502^3 - 0.0601^3}{0.1502^2 - 0.0601^2}\right]$

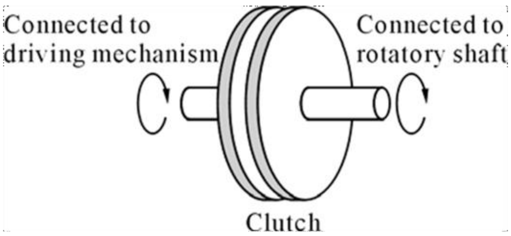
= 131.6 N-m

Power lost (P) = $\dfrac{2\pi NT}{60} = \dfrac{2\times\pi\times150\times131.6}{60}$ = 2067 *Watt*

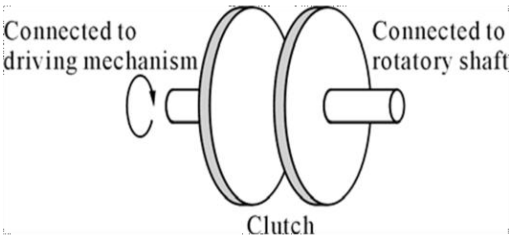
Q.18) ***What are the functions of Clutch? Explain how it works with neat sketch.***

Ans) A clutch is used to connect or disconnect the rotating shaft and driving mechanisms.

One side of the clutch is connected to the driving mechanism, and the other side is connected to the rotating shaft. When the clutch is in contact, the rotating shaft will rotate with the driving mechanism. When the clutch is separated, the driving force will not be transmitted to the rotating shaft.



(When the clutch is in contact)

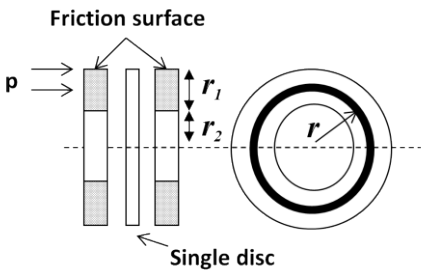


(When the clutch is separated)

Q.19) Derive the expression for torque transmission in a Single disc or plate clutch.

Ans) *Torque transmission in a Single disc or plate clutch*:

Consider two friction surfaces of a single plate or disc clutch as shown in figure.



Let, W = axial thrust acting on the friction surfaces.
p = intensity of axial pressure per unit area of contact surfaces.

r_1 = external radius of friction surface. r_2 = internal radius of friction surface. μ = coefficient of friction.

T = torque transmitted by clutch.
Area of the contact surface (A) = $\pi [r_1^2 - r_2^2]$

Consider a ring of radius 'r' and thickness 'dr'.
Area of the ring = 2 π r × dr
Axial load transmitted on the ring (dW) = p × 2π r × dr
Frictional resistance acting on the ring (dF) = μ × dW = 2π × μ × p × r × dr
Frictional torque acting on the ring (dT) = dF × r = 2π × μ × p × r^2 × dr

Considering uniform pressure condition:

Intensity of pressure (p) = $\frac{W}{\pi [r_1^2 - r_2^2]}$ ------------------ (1)

We know that, Frictional torque on ring (dT) = dF × r = 2π × μ × p × r^2 × dr

By integrating the above equation from r_2 to r_1 we get;

Total frictional torque on contact surface (T) = $\int_{r_2}^{r_1} (2\pi \times \mu \times p \times r^2 \times dr)$

$= 2\pi \times \mu \times p \times \int_{r_2}^{r_1} (r^2 \times dr)$

$= 2\pi \times \mu \times p \times \left[\frac{r^3}{3}\right]_{r_2}^{r_1}$

$= 2\pi \times \mu \times p \times \left(\frac{r_1^3 - r_2^3}{3}\right)$

Replacing the value of 'p' from equation-1, we get:

Total frictional torque on contact surface (T) = $2\pi \times \mu \times \frac{W}{\pi [r_1^2 - r_2^2]} \times \left(\frac{r_1^3 - r_2^3}{3}\right)$

$= \frac{2}{3} \times \mu \times W \times \left(\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right) = \mu \times W \times R$

Where, $R = \frac{2}{3} \times \frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}$ = mean radius

Considering uniform wear condition:

The rate of wear depends upon the intensity of pressure and velocity of rubbing surface. It is proportional to (p × v), but velocity increases with distance or radius 'r'. So we can write:

p.r = C or $p = \frac{C}{r}$

We know that, Load transmitted on ring = p × 2π r × dr = $\frac{C}{r}$ × 2π r × dr = 2π C × dr

Load transmitted to contact surface (W) = $\int_{r_2}^{r_1} (2\pi \times C \times dr) = 2\pi C \times [r]_{r_2}^{r_1} = 2\pi C \times (r_1 - r_2)$

Or $C = \frac{W}{2\pi \times (r1 - r2)}$ -------------- (2)

We know that, Frictional torque on ring (dT) = dF × r = $2\pi \times \mu \times p \times r^2 \times dr$
replacing the 'p' value we get;

Frictional torque on ring (dT) = dF × r = $2\pi \times \mu \times C \times r \times dr$

By integrating the above equation from r_2 to r_1 we get;

Total frictional torque on contact surface (T) = $\int_{r_2}^{r_1}(2\pi \times \mu \times C \times r \times dr)$

$$= 2\pi \times \mu \times C \times \int_{r_2}^{r_1}(r \times dr)$$

$$= 2\pi \times \mu \times C \times [\frac{r^2}{2}]_{r2}^{r1}$$

$$= 2\pi \times \mu \times C \times (\frac{r_1^2 - r_2^2}{2})$$

$$= \pi \times \mu \times C \times (r_1^2 - r_2^2)$$

replacing the value of 'C' from equation-2, we get

Total frictional torque on contact surface (T) = $\pi \times \mu \times \frac{W}{2\pi \times (r1 - r2)} \times (r_1^2 - r_2^2)$

$$= \frac{1}{2} \times \mu \times W \times (r_1 + r_2) = \mu \times W \times R$$

where, $R = \frac{r1 + r2}{2}$ = mean radius

Total frictional torque acting on the friction surface is, **T = n.μ.W.R**

For single disc clutch, both sides of the disc is effective, so number of pairs in contact (n) = 2

Intensity of pressure is maximum at the inner radius (r_2), ⇒ $\mathbf{p_{max} \times r_2 = C}$

Intensity of pressure is minimum at the outer radius (r_1), ⇒ $\mathbf{p_{min} \times r_1 = C}$

Q.20) A plate clutch has ten operating faces with inner and outer diameter of 15 cm and 25 cm respectively. It runs at 1200 r.p.m with a total end load of 4500 N. The coefficient of friction is 0.08. Find the maximum torque and power that can be transmitted in KW. Assume uniform wear condition.

Ans) <u>Data given</u>

number of faces (n) = 10 outer diameter (D_1) = 25 cm = 0.25
mouter radius (r_1) = 0.125 m inner diameter (D_2) = 15 cm = 0.15
m
inner radius (r_2) = 0.075 m speed (N) = 1200 rpm load (W) = 4500 N
coefficient of friction (μ) = tan Ø = 0.08

Torque transmitted (T) = $\frac{1}{2} \times \mu \times W (r_1 + r_2)$

$$= \frac{1}{2} \times 0.08 \times 4500 \times (0.125 + 0.075) = 360 \text{ N-m}$$

Power transmitted (P) = $\frac{2 \pi N T}{60} = \frac{2 \times \pi \times 1200 \times 360}{60}$ = 45238.9 Watt = 45.238 kW (*Ans*)

Q.21) A multiple disc clutch has five plates having four active pairs of frictional surface. Determine the maximum axial intensity of pressure between the disc for transmitting18 KW at 500 r.p.m, if the outer and inner radius of frictional surface is 125 mm and 75 mm respectively. Assume uniform wear theory and coefficient of friction is 0.3.

Ans) <u>Data given</u>

number of active plates (n) = 4 inner radius (r_2) = 0.75 mm = 0.075
outer radius (r_1) = 125 mm = 0.125 mmaximum power (P) = 18 KW
mspeed (N) = 500 rpm coefficient of friction (μ) = tan Ø = 0.3

we know that, Power transmitted (P) = $\frac{2\pi N T}{60}$

$\Rightarrow \quad 18 \times 10^3 = \frac{2 \times \pi \times 500 \times T}{60} \quad \Rightarrow \quad T = \frac{18 \times 10^3 \times 60}{2 \times \pi \times 500} = 343.77$ N-m

Torque transmitted (T) = $\frac{1}{2} \times \mu \times W (r_1 + r_2)$

$\Rightarrow \quad 343.77 = \frac{1}{2} \times 0.3 \times W (0.125 + 0.075)$

$\Rightarrow \quad W = \frac{2 \times 343.77}{0.3 \times 0.2} = 2864.75$ N

we know that, $W = 2\pi C \times (0.125 - 0.075)$

$\Rightarrow \quad C = \frac{2864.75}{2\pi \times 0.05} = 9118.78$ N/m

$P_{max} = \frac{9118.78}{0.075} = 121583.76 \text{ N/m}^2 = 0.12158 \text{ N/mm}^2$ (Ans)

Q.22) ***A multiple disc clutch transmits 55 KW at 1800 rpm, coefficient of friction for surfaces is 0.01 and axial intensity of pressure is not to exceed 150 KN/m². The internal radius is 80mm and is 0.7 times the external radius. Find the number of plates needed to transmit the required torque.***

Ans) Data given

power (P) = 55 KW = 55×10^3 W — coefficient of friction (μ) = tan Ø = 0.1

intensity of pressure (p) = 150 K N/m^2 — inner radius (r_2) = 80 mm = 0.08 m,

outer radius (r_1) = 0.08/7 mm = 114.28 mm = 0.114 m — speed (N) = 1800 rpm,

we know that, Power transmitted (P) = $\frac{2\pi N T}{60}$

$\Rightarrow \quad 55 \times 10^3 = \frac{2 \times \pi \times 1800 \times T}{60}$

$\Rightarrow \quad T = \frac{55 \times 10^3 \times 60}{2 \times \pi \times 1800} = 291.78$ N-m

Torque transmitted (T) = $\frac{1}{2} \times \mu \times W (r_1 + r_2)$

$\Rightarrow \quad 291.78 = \frac{1}{2} \times 0.1 \times W (0.114 + 0.08)$

$\Rightarrow \quad W = \frac{2 \times 291.78}{0.1 \times 0.194} = 30080.41$ N

we know that, C = pressure × r_2 = $150 \times 10^3 \times 0.08 = 12000$ N/m

$W = 2\pi C \times (0.114 - 0.08) \times n$

$\Rightarrow \quad 30080.41 = 2\pi \times 12000 \times (0.114 - 0.08) \times n$

$\Rightarrow \quad n = \frac{30080.41}{2\pi \times 12000 \times (0.114 - 0.08)} = 11.73 \simeq 12$

$\therefore$ number of contact surface = 12

$\therefore$ number of plates = 12+1 = 13 (***Ans***)

Q.23) ***A multiple disc clutch has five plates having four active pairs of frictional surface. If the intensity of pressure is not to exceed 0.15 N/mm², find the power transmitted at 400 r.p.m. The outer and inner radius of frictional surface is 120 mm and 60 mm respectively. Assume uniform wear theory and coefficient of friction is 0.3.***

Ans) Data given

number of active plates (n) = 4 — inner radius (r_2) = 60 mm = 0.06 m

outer radius (r_1) = 120 mm = 0.12 m — intensity of pressure (p) = 0.15 N/mm^2

speed (N) = 400 rpm — coefficient of friction (μ) = tan Ø = 0.3

we know that, C = maximum pressure × r_2 = 0.15 × 60 = 9

N/mmW = 2 π C × (120 - 60) = 2 π × 9 × (120 - 60) = 3392.92 N

Torque transmitted (T) = $\frac{1}{2} \times \mu \times W (r_1 + r_2) \times n = \frac{1}{2} \times 0.3 \times 3392.92 \times (120 + 60) \times 4$

$= \frac{732870.72}{2}$ = 366435.66 N-mm = 366.435 N-m

Power transmitted (P) = $\frac{2 \pi N T}{60} = \frac{2 \times \pi \times 400 \times 366.435}{60 \times 1000}$ = 15.349 KW (***Ans***)

Q.24) A single plate friction clutch both side effective is to transmit 12 KW at 3000 rpm. The axial pressure being limiting to 0.09 N/mm². Find the required dimension of the friction lining, assume uniform wear condition, coefficient of friction is 0.03 and external diameter is 1.4 times internal diameter.

Ans) Data given:

Power (P) = 12 KW = 12×10^3 W
axial pressure (p) = 0.09 N/mm²
speed (N) = 3000 rpm
coefficient of friction (μ) = tan ∅ = 0.03
external diameter (D_1) = 1.4 × internal diameter (D_2)
external radius (r_1) = 1.4 × internal radius (r_2)

power transmitted (P) = $\frac{2 \pi N T}{60}$ ⇒ $12 \times 10^3 = \frac{2 \times \pi \times 3000 \times T}{60}$

⇒ $T = \frac{12 \times 10^3 \times 60}{2 \times \pi \times 3000}$ = 38.12 N-m = 38.12×10^3 N-mm

Torque transmitted (T) = $\frac{1}{2} \times \mu \times W (r_1 + r_2)$

⇒ $38.12 \times 10^3 = \frac{1}{2} \times 0.03 \times W (1.4 \times r_2 + r_2)$ ---------------(1)

We know that, W = 2 π C × (r_1 - r_2)

$= 2 \times \pi \times 0.09 \times r_2 \times (1.4 \times r_2 - r_2)$

$= 2 \times \pi \times 0.09 \times r_2 \times (0.4 \times r_2) = 0.226 r_2^2$ ----------- (2)

putting the values of W in equation-1, we get

⇒ $38.12 \times 10^3 = \frac{1}{2} \times 0.03 \times 0.226 r_2^2 \times (1.4 \times r_2 + r_2)$

$= 8.136 \times 10^{-3} \times r_2^3$

⇒ $r_2^3 = \frac{38.12 \times 10^3}{8.136 \times 10^{-3}} = 4.67 \times 10^6$ mm³

⇒ $r_2 = \sqrt[3]{(4.67 \times 10^6)}$ = 167.14 mm

∴ r_1 = 1.4 × 167.14 = 234.009 mm (Ans)

Q.25) A single dry plate clutches transmits 7.5 KW at 900 rpm. If the coefficient of friction is 0.25 and external pressure is 0.07 N/mm², find i) mean radius and face width of the friction lining assuming the ratio of the mean radius to the face width as 4 and ii) outer and inner radius of the clutch plate.

Ans) Data given:

Power (P) = 7.5 KW = 7.5×10^3 W
speed (N) = 900 rpm
external pressure (p) = 0.07 N/mm²
coefficient of friction (μ) = tan ∅ = 0.25

$w = \frac{2 \pi N}{60} = \frac{2 \times \pi \times 900}{60}$ = 94.26 rad/s

Let, R = mean radius of the friction lining in mm b = face width of the friction lining in mm

Ratio of mean radius to the face width = $\frac{R}{b} = 4$ (given)

Area of the friction faces (A) = 2 π R w

Axial force acting on the friction faces (W) = A × P = 2 π R w P

Assuming uniform wear, T = n × μ × W × R = 2 × 0.25 × 2 π R w P × R

$= 2 \times 0.25 \times 2 \pi R \times \frac{R}{4} \times 0.07 \times R = 0.055 R^3$ N-mm --- (1)

(assume n = 2, for single plate clutch)

Power transmitted (P) = T. w

$\Rightarrow$ $T = \frac{7.5 \times 10^3}{94.26} = 79.56$ N-m = 79.56×10^3 N-mm ------------------- (2)

from equation 1 and 2, we get $R^3 = \frac{7.5 \times 10^3}{0.055} = 1446.5 \times 10^3$

$\Rightarrow$ R = 113 mm

or b = 113/4 = 28.25 mm

Let r_1 and r_2 are the outer and inner radius respectively.b = $r_1 - r_2$ = 28.25 mm (3)

Also for uniform wear condition mean radius of clutch plate (R) = $\frac{r1 + r2}{2}$

or $r_1 + r_2 = 2R = 2 \times 113 = 226$ mm -------------- (4)

solving 3 and 4, we get

$r_1 + r_2 = 226$

$r_1 - r_2 = 28.25$

$\Rightarrow$ $2 \times r_1 = 254.5$ $\Rightarrow$ $r_1 = 127.25$ mm

as $r_1 + r_2 = 226$ $\Rightarrow$ $r_2 = 98.75$ mm

Q.26) What is the function of dynamometer? Classify.

Ans) It is used to measure the frictional resistance. By finding the frictional resistance, we can find out the torque transmitted and power absorbed.

1) *Absorption type dynamometer* – In these dynamometers the entire energy of the engine is absorbed by the frictional resistances of the brake and is transformed into heat. It is classified as: 1) prony brake dynamometer & 2) rope brake dynamometer.
2) *Transmission dynamometers* – In these dynamometers the energy is not wasted in friction but is used to do work. The energy produced by the engine is transmitted to the other machines through the dynamometers.

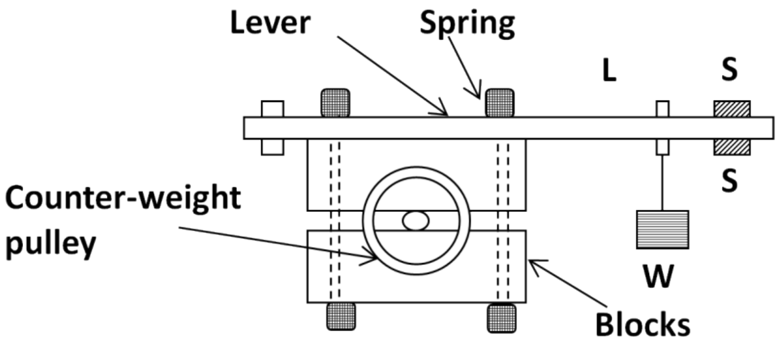
Q.27) Explain the working of absorption type dynamometer.

Ans) *Absorption type dynamometer* – In these dynamometers the entire energy of the engine is absorbed by the frictional resistances of the brake and is transformed into heat. It is classified as: 1) prony brake dynamometer & 2) rope brake dynamometer.

Prony brake dynamometer:

An absorption type prony brake dynamometer is shown in figure. It consists of two wooden blocks placed around a pulley. It is fixed with the engine shaft. The blocks are clamped by nut and bolts. A helical spring is provided between nut and upper block to control the pressure on the pulley or to control its speed. A long lever is attached to the upper block, which carries weights at its outer end. A counter weight is provided at the other end of lever to balance the brake when unloaded. Two stops ‘S’ is provided to limit the motion of the lever.

When the brake comes in action, the long end of lever is loaded with weights W and nuts are tightened until the engine shaft runs at mean speed and lever lies in horizontal position. For this case the moment due to weight W must be balance the moment of frictional resistance between the blocks and the pulley.



(Prony brake dynamometer)

Let, W = weight at the outer end of lever in N
L = horizontal distance of weight W from centre of pulley in metres
F = frictional resistance between block and pulley in N
R = radius of pulley in metres
N = speed of shaft in r.p.m

Moment of frictional resistance or torque on shaft (T) = W.L = F.R N-m

Work done in one revolution = torque × angle turned in radian
= T × 2π N-m

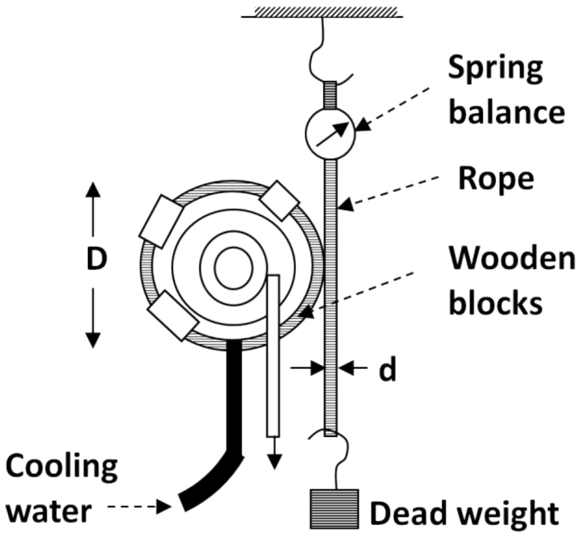
Work done per minute = T × 2π × N N-m

Brake power of the engine = B.P = $\frac{work\ \ done\ \ per\ \ minute}{60} = \frac{T \times 2\pi N}{60} = \frac{W \times L \times 2\pi N}{60}$

<u>Rope brake dynamometer</u>:

It is most common dynamometer which is used to measure the brake power of the engine. It consists of one, two or more ropes wound around the fly wheel or rim of the pulley which is fixed to the shaft of the engine. The upper end of the shaft is attached to a spring balance and the lower end of the rope is attached with a dead weight. Wooden blocks are provided in the intervals around the circumference of flywheel to prevent the slipping of rope from flywheel.

Let, W = dead load in N
S = spring balance reading in N
D = diameter of wheel in 'm'
d = diameter of rope in 'm'
N = speed of the engine in r.p.m
Net load on the brake = (W - S) in N



(Rope brake dynamometer)

Distance moved in one revolution = π (D + d) in m
Work done per revolution = (W - S) π (D + d) N in N-m

Brake power (B.P) = $\frac{work\ \ done\ \ per\ \ minute}{60} = \frac{(W - S)\ \pi\ (D + d)\ N}{60}$ in Watts
If the diameter of the rope is neglected, then B.P = $\frac{(W - S)\ \pi\ D\ N}{60}$ in Watts

The frictional torque due to rope equals to torque transmitted by the engine.

Q.28) What is the function of frictional brakes.

Ans) A brake is a device which is used to offer frictional resistance to moving machine elements to stop the motion of the element or retard its motion. It absorbs the kinetic or potential energy when applied.

ASSIGNMENT

Q.1) A thrust bearing has four collars of 600 mm diameter and 250 mm internal diameter. The total thrust from the shaft is 80 KN. If the coefficient of friction is 0.2 and engine speed is 100 r.p.m. Find the power absorbed in friction, assuming **i)** uniform wear **ii)** uniform pressure.

Q.2) A shaft has a number of collars integral with it. The external diameter of the collars is 400 mm and the shaft diameter is 250 mm. if the uniform intensity of pressure is 0.35 N/mm^2 and the coefficient of friction is 0.05, estimate: **1**) Power absorbed when shaft runs at 105 r.p.m carrying a load of 150 kN; and **2)** Number of collars required.

Q.3) A conical pivot bearing 150 mm diameter has a cone angle of 120^0. If the shaft supports an axial load of 20 KN and the coefficient of friction is 0.03, find the power lost in friction when the shaft rotates at 200 r.p.m, assuming **1)** uniform wear **2)** uniform pressure.

Q.4) A conical pivot supports a load of 20 kN, the cone angle is 120^0 and the intensity of normal pressure is not exceed 0.3 N/mm^2. The external diameter is twice the internal diameter. Find the outer and inner radii of the bearing surface. If the shaft rotates at 200 r.p.m and the coefficient of friction is 0.1, find the power absorbed in friction. Assume uniform pressure.

Q.5) A conical pivot bearing supports a vertical shaft of 200 mm diameter. It is subjected to a load of 30 kN. The angle of the cone is 1200 and the coefficient of friction is 0.025. Find the power lost in friction when the speed is 140 r.p.m, assuming **1)** Uniform pressure; and **2)** Uniform wear.

END of Chapter

POWER TRANSMISSION

Q.1) ***Define the velocity ratio of the belt drive. State its expressions.***

Ans) It is defined as the ratio between the velocities of driver and driven or follower.
Mathematically it may be expressed as - $\frac{N_2}{N_1} = \frac{d_1}{d_2}$

where, N_2 = speed of the follower, N_1 = speed of the driver,
d_1 = diameter of the driver, d_2 = diameter of the follower

If the thickness (t) of the belt is considered,
then velocity ratio is expressed as - $\frac{N_2}{N_1} = \frac{d_1+t}{d_2+t}$

If the thickness (t) and slip (s) both are considered,
then the velocity ratio is expressed as - $\frac{N_2}{N_1} = \frac{d_1+t}{d_2+t}\left(1-\frac{s}{100}\right)$

where, N_1 = speed of the pulley-1 in r.p.m, N_2 = speed of the pulley-2 in r.p.m,
d_1 = diameter of the pulley-1, d_2 = diameter of the pulley-2
s = slip between the belt and pulley, t = thickness of belt

Q.2) ***State the expression for the length of an open belt drive.***

Ans) It is given by the relation - $\mathbf{L} = \pi\,(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x}$

where, r_1= radius of larger pulley, r_2= radius of smaller pulley
x = distance between the centre of two pulleys, L = length of belt

Q.3) ***State the expression for the length of a cross belt drive.***

Ans) It is given by the relation - $\mathbf{L} = \pi\,(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$

where, r_1= radius of larger pulley, r_2= radius of smaller pulley
x = distance between the centre of two pulleys, L = length of belt

Q.4) ***State the expression for ratio of tension in belt drive.***

Ans) It is given by the relation - $\frac{T_1}{T_2} = e^{\mu\theta}$

where, T_1 = tension in tight side in N, T_2 = tension in slack side in
Nμ = coefficient of friction, Θ = angle of lap

Q.5) ***State the expression for centrifugal tension in belt drive.***

Ans) It is given by the relation - $\mathbf{T_c = mV^2}$

where, T_c = centrifugal tension in N, m = mass of the belt per unit length in Kg
V = velocity of the belt in m/s, r = radius of the pulley over which the belt runs.

Q.6) ***State the condition for maximum power transmission in belt drive.***

Ans) It is given by the relation - $\mathbf{T = 3\,T_c}$

where, T = maximum tension in N, T_c = centrifugal tension in N

Q.7) ***State the expression for power transmitted in a belt drive.***

Ans) It is given by the relation - $\mathbf{P = (T_1 - T_2) \times \boldsymbol{v}}$ *N-m/s* (1 N-m/s = 1 watt)

where, T_1 = tension in the tight side of the belt in N
T_2 = tension in the slack side of the belt in N
v = velocity of the belt in m/s

Q.8) ***Derive an expression for length of an open belt drive.***

Ans) Consider an open belt drive as shown in figure.

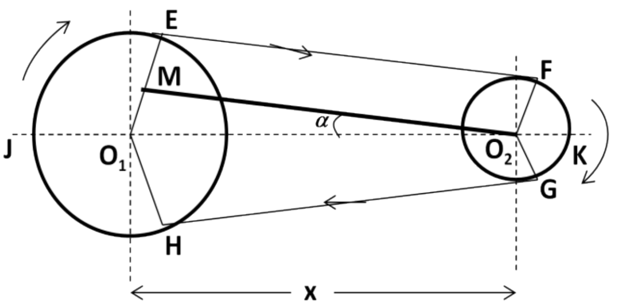
Let, r_1 and r_2 are the radii of larger and smaller pulley, x = distance between the centres of two pulleys and L = total length of the belt.

Let, O_2M parallel to EF and perpendicular to O_1E.

Angle M O_2 O_1 = α

so, $\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E - EM}{O_1O_2} = \frac{r_1 - r_2}{x}$

since α is very small so $\sin\alpha = \alpha = \frac{r_1 - r_2}{x}$



(Open belt drive)

In figure total length of belt (L) = (2 × arc JE) + EF + (2 × arc FK) + GH

⇒ L = (2 × arc JE) + EF + (2 × arc FK) + GH

⇒ L = (2 × arc JE) + (2 × EF) + (2 × arc FK)

⇒ L = 2 [arc JE + EF + arc FK]

We know that, arc JE = $r_1 \times (\frac{\pi}{2} + \alpha)$ arc FK = $r_2 \times (\frac{\pi}{2} - \alpha)$

$$EF = MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2}$$

$$= \sqrt{x^2 - (r_1 - r_2)^2} = x\sqrt{1 - \frac{(r_1 - r_2)^2}{x^2}}$$

Expanding this equation by binomial theorem, we get

$$EF = x \times [1 - \frac{1}{2}\frac{(r_1 - r_2)^2}{x^2} + \ldots\ldots] = x - \frac{(r_1 - r_2)^2}{2x}$$

Putting the all the obtained values in the below equation, we get

$$\Rightarrow L = 2\,[r_1 \times (\frac{\pi}{2} + \alpha) + x - \frac{(r_1 - r_2)^2}{2x} + r_2 \times (\frac{\pi}{2} - \alpha)]$$

$$= 2\,[r_1 \times \frac{\pi}{2} + r_1 \times \alpha) + x - \frac{(r_1 - r_2)^2}{2x} + r_2 \times \frac{\pi}{2} - r_2 \times \alpha)]$$

$$= 2\,[\frac{\pi}{2}(r_1 + r_2) + \alpha\,(r_1 - r_2) + x - \frac{(r_1 - r_2)^2}{2x}]$$

$$= \pi\,(r_1 + r_2) + 2\,\alpha\,(r_1 - r_2) + 2\,x - \frac{(r_1 - r_2)^2}{x}$$

$$= \pi\,(r_1 + r_2) + 2 \times \frac{r_1 - r_2}{x}\,(r_1 - r_2) + 2\,x - \frac{(r_1 - r_2)^2}{x}$$ (The value of α is replaced)

$$= \pi\,(r_1 + r_2) + 2 \times \frac{(r_1 - r_2)^2}{x} + 2\,x - \frac{(r_1 - r_2)^2}{x}$$

$$\Rightarrow \mathbf{L = \pi\,(r_1 + r_2) + 2\,x + \frac{(r_1 - r_2)^2}{x}}$$ ---------------- (in terms of pulley radii)

$$\Rightarrow \mathbf{L = \frac{\pi}{2}\,(d_1 + d_2) + 2\,x + \frac{(d_1 - d_2)^2}{4x}}$$ ---------------- (in terms of pulley diameter)

Q.9) ***Derive an expression for length of a crossed belt drive.***

Consider a crossed belt drive as shown in figure.

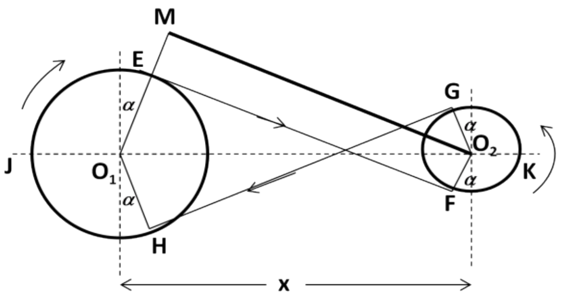
Let, r_1 and r_2 are the radii of larger and smaller pulley, x = distance between the centres of two pulleys and L = total length of the belt.

Let, O_2M parallel to EF and perpendicular to O_1E.

Angle $M O_2 O_1 = \alpha$

so, $\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E + EM}{O_1O_2} = \frac{r_1 + r_2}{x}$

since α is very small so $\sin\alpha = \alpha = \frac{r_1 + r_2}{x}$



(Crossed belt drive)

In figure total length of belt (L) = (2 × arc JE) + EF + (2 × arc FK) + GH

$\Rightarrow$ L = (2 × arc JE) + EF + (2 × arc FK) + GH

$\Rightarrow$ L = (2 × arc JE) + (2 × EF) + (2 × arc FK)

$\Rightarrow$ L = 2 [arc JE + EF + arc FK]

We know that, arc JE = $r_1 \times (\frac{\pi}{2} + \alpha)$ arc FK = $r_2 \times (\frac{\pi}{2} + \alpha)$

$$EF = MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2} = \sqrt{x^2 - (r_1 - r_2)^2}$$

$$= x\sqrt{1 - \frac{(r_1 - r_2)^2}{x^2}}$$

Expanding this equation by binomial theorem, we get

$$EF = x \times [1 - \frac{1}{2}\frac{(r1 - r2)^2}{x^2} + \ldots\ldots] = x - \frac{(r1 - r2)^2}{2x}$$

Putting the all the obtained values in the below equation, we get

$$\Rightarrow L = 2\,[r_1 \times (\frac{\pi}{2} + \alpha) + x - \frac{(r1 + r2)^2}{2x} + r_2 \times (\frac{\pi}{2} + \alpha)]$$

$$= 2\,[r_1 \times \frac{\pi}{2} + r_1 \times \alpha) + x - \frac{(r1 + r2)^2}{2x} + r_2 \times \frac{\pi}{2} + r_2 \times \alpha)]$$

$$= 2\,[\frac{\pi}{2}(r_1 + r_2) + \alpha\,(r_1 + r_2) + x - \frac{(r1 + r2)^2}{2x}]$$

$$= \pi\,(r_1 + r_2) + 2\,\alpha\,(r_1 + r_2) + 2\,x - \frac{(r1 + r2)^2}{x}$$

$$= \pi\,(r_1 + r_2) + 2 \times \frac{r1 + r2}{x}(r_1 - r_2) + 2\,x - \frac{(r1 + r2)^2}{x}$$ **(The value of α is replaced)**

$$= \pi\,(r_1 + r_2) + 2 \times \frac{(r1 + r2)^2}{x} + 2\,x - \frac{(r_1 + r_2)^2}{x}$$

$\Rightarrow$ $\mathbf{L = \pi\,(r_1 + r_2) + 2\,x + \frac{(r_1 + r_2)^2}{x}}$ ---------------- (in terms of pulley radii)

$\Rightarrow$ $\mathbf{L = \frac{\pi}{2}(d_1 + d_2) + 2\,x + \frac{(d_1 + d_2)^2}{4x}}$ ---------------- (in terms of pulley diameter)

Q.10) *Derive an expression for ratio of driving tension for a belt drive.*

Ans) Consider a driven pulley rotating in clockwise direction as shown in figure.

Let, T_1 = tension in tight side, T_2 = tension in slack-side, θ = angle of contact in radian

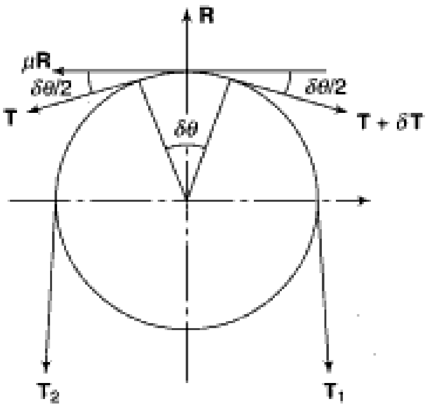
Now consider a small portion of the belt PQ, which subtends with an angle $\delta\theta$ at the centre of the pulley. The belt PQ remains in equilibrium under the action following forces.

Tension T in the belt

Tension (T + δT)

Normal reaction R_N

Frictional force F = μ R_N



Resolving the forces horizontally, $\Rightarrow$ $R_N = (T + \delta T) \sin\frac{\delta\theta}{2} + T \sin\frac{\delta\theta}{2}$ ---------- (1)

since the angle $\delta\theta$ is very small, considering $\sin\frac{\delta\theta}{2} = \frac{\delta\theta}{2}$ in equation-1, we get

$R_N = (T + \delta T) \times \frac{\delta\theta}{2} + T \times \frac{\delta\theta}{2} = T \times \delta\theta$ --------- (2), (neglecting the smaller terms)

Resolving the forces vertically, $\Rightarrow$ $\mu R_N = (T + \delta T) \cos\frac{\delta\theta}{2} - T \cos\frac{\delta\theta}{2}$ ---------- (3)

since the angle $\delta\theta$ is very small, considering $\cos\frac{\delta\theta}{2} = 1$, in equation-3, we get

$\mu R_N = T + \delta T - T = \delta T$-------------- (4)

From equation 2 and 4, we get, $\mu \times T \times \delta\theta = \delta T$

$\Rightarrow$ $T \times \delta\theta = \frac{\delta T}{\mu}$ $\Rightarrow$ $\frac{\delta T}{T} = \mu \times \delta\theta$

Integrating both sides between the limits T_2 and T_1 and from 0 to θ, we get

$$\int_{T_2}^{T_1} \frac{\delta T}{T} = \mu \times \int_0^{\theta} \delta\theta$$

$$\Rightarrow \quad \mathbf{\log_e\left(\frac{T1}{T_2}\right) = \mu\, \theta} \text{-----------------------------------}\mathbf{(5)}$$

$$\Rightarrow \quad \mathbf{\frac{T1}{T_2} = e^{\mu\,\theta}} \text{---}\ \mathbf{(6)}$$

$$\Rightarrow \quad \mathbf{2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\, \theta} \text{ ------------------------------ } \mathbf{(7)}$$

Q.11) *State the expression for angle of contact or lap (θ).*

Ans) For an open belt drive, $\theta = (180^0 - 2\,\alpha) \times \frac{\pi}{180}$ radian

For a crossed belt drive, $\theta = (180^0 + 2\,\alpha) \times \frac{\pi}{180}$ radian

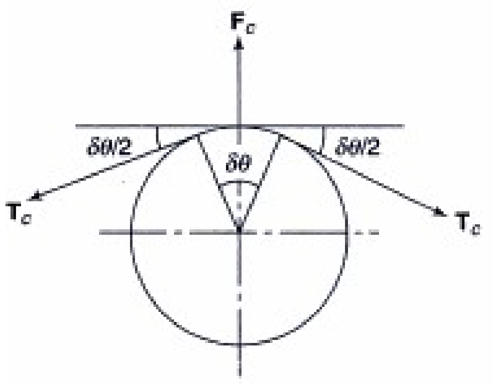
Q.12) *What do you mean by slip and creep in belt.*

Ans) **SLIP -** There is a firm frictional grip between the belt and pulley, but in some time due to insufficient frictional grip, some forward motion of the driver without carrying the belt or some forward motion of the belt without carrying the driven pulley occurs. This is called slip of the belt.

CREEP – When a belt passes over pulleys it expands or contracts due to which a relative motion takes place between the belt and pulley. This relative motion reduces slightly the speed of driven pulley which is known as creep in belt.

Q.13) ***Derive an expression for centrifugal tension in belt drive.***

Ans) The tension caused by centrifugal force is called centrifugal tension.



Let, m = mass of the belt per unit length in Kg

v = velocity of the belt in m/s

r = radius of the pulley in m

T_c = centrifugal tension in N

Length of the belt PQ = r. dθ

Mass of the belt PQ = m. r. dθ

Centrifugal force acting on the belt PQ,

$$F_c = (m.\ r.\ d\theta)\ \frac{v^2}{r} = m.\ d\theta\ .\ v^2$$

Resolving the forces horizontally, we get

$$T_c \sin\frac{d\theta}{2} + T_c \sin\frac{d\theta}{2} = m.\ d\theta\ .\ v^2$$

Since $\frac{d\theta}{2}$ is very small, considering $\sin\frac{d\theta}{2} = \frac{d\theta}{2}$, we get

$$T_c \times \frac{d\theta}{2} + T_c \times \frac{d\theta}{2} = m.\ d\theta\ .\ v^2$$

$\Rightarrow \quad 2 \times T_c \times \frac{d\theta}{2} = m.\ d\theta\ .\ v^2$

$\Rightarrow \quad \mathbf{T_c = m.\ v^2}$

Q.14) ***What do you mean by initial tension in belt? State its expression.***

Ans) *Initial tension*:

Initial tension in the belt without considering centrifugal tension is: $\mathbf{T_0 = \frac{T1 + T2}{2}}$

Initial tension in the belt considering centrifugal tension is: $\mathbf{T_0 = \frac{T1 + T2 + TC}{2}}$

Q.15) ***What is the expression for velocity of the belt for maximum power transmission?***

Ans) The velocity of the belt for maximum power transmission is: $\boldsymbol{v = \sqrt{\frac{T}{3m}}}$

Q.16) **Find the width of the belt to transmit 7.5 KW to a pulley 300 mm diameter, if the pulley makes 1600 rpm, coefficient of friction is 0.22. Assume angle of friction is 210^0 and maximum tension is not to exceed 8 N/mm widths.**

Ans) Data given

Power (P) = 7.5 KW = 7500 Watt

pulley diameter (D) = 300 mm = 0.3 m

speed (N) = 1600 rpm

coefficient of friction (μ) = 0.22

angle of contact (θ) = $210^0 = 210 \times \frac{\pi}{180}$ = 3.665 rad

maximum tension (T) = 8 N/mm widths

we know that, $v = \frac{\pi\ DN}{60} = \frac{\pi \times 0.3 \times 1600}{60} = 25.132$ m/s

$\Rightarrow \quad \frac{T1}{T2} = e^{\mu\ \theta} = e^{(0.22 \times 3.665)} = 2.239 \qquad \Rightarrow \quad T_1 = 2.239 \times T_2$------------------(1)

Power transmitted (P) = $(T_1 - T_2) \times v$ N-m/s

$\Rightarrow \quad 7500 = (2.239 \times T_2 - T_2) \times 25.132 \qquad \Rightarrow \quad 7500 = 1.239\ T_2 \times 25.132$

$\Rightarrow \quad T_2 = \frac{7500}{1.239 \times 25.132} = 240.85$ N $\qquad \Rightarrow \quad T_1 = 2.239 \times 240.85 = 539.28$ N

$\therefore$ width of the belt (b) = $\frac{539.28}{8}$ = 67.41 mm (Ans)

Q.17) ***A leather belt is required to transmit 7.5 KW from a pulley 1.2 m in diameter running at 250 rpm. The angle embraced is 165^0 and coefficient of friction is 0.3. If the safe working stress for the leather belt is 1.5 MPa and the thickness of belt is 10 mm, determine the width of the belt required.***

Ans) Data given

Power (P) = 7.5 KW = 7500 Watt pulley diameter (D) = 1.2 m

speed (N) = 250 rpm coefficient of friction (μ) = 0.3

angle of contact (θ) = 165^0 = $165 \times \frac{\pi}{180}$ = 2.879 rad

safe working stress (σ) = 1.5 MPa = 1.5×10^6 N/m^2 thickness of the belt (t) = 10 mm

we know that, $v = \frac{\pi DN}{60} = \frac{\pi \times 1.2 \times 250}{60}$ = 15.70 m/s

$\Rightarrow$ $\frac{T1}{T_2} = e^{\mu\theta} = e^{(0.3\times2.879)}$ = 2.372 $\Rightarrow$ $T_1 = 2.372\times T_2$------------------(1)

Power transmitted (P) = $(T_1 - T_2) \times v$ N-m/s

$\Rightarrow$ 7500 = $(2.372 \times T_2 - T_2) \times 15.70$ $\Rightarrow$ 7500 = $1.372\, T_2 \times 15.70$

$\Rightarrow$ $T_2 = \frac{7500}{1.372 \times 15.70}$ = 348.182 N $\Rightarrow$ $T_1 = 2.372 \times 348.182$ = 825.88 N

We know that $T_1 = \sigma\, b\, t$

$\Rightarrow$ $825.88 = 1.5 \times 10^6 \times b \times 0.01$ $\Rightarrow$ $b = \frac{825.88}{1.5 \times 10^6 \times 0.01}$ = 0.05505 m

$\therefore$ width of the belt (b) = 0.05505 × 1000 = 55.05 m (Ans)

Q.18) ***A pulley is driven by a flat belt running at a speed of 600 m/min. The coefficient of friction is 0.3 and the angle of lap is 160^0. The maximum tension in the belt is 700 N. Find the power transmitted in the belt.***

Ans) Data given

speed (v) = 600 m/min = (600/60) m/s = 10 m/s coefficient of friction (μ) = 0.3

angle of lap (θ) = 160^0 = $160 \times \frac{\pi}{180}$ = 2.792 rad maximum tension (T) = 700 N

Let P = power transmitted in the belt.

We know that, $\frac{T1}{T_2} = e^{\mu\theta} = e^{(0.3\times2.792)}$ = 2.3108

$\Rightarrow$ $T_1 = 2.3108\times T_2$ ----------- (1) $\Rightarrow$ $T_2 = \frac{700}{2.3108}$ = 302.925 N

Power transmitted (P) = $(T_1 - T_2) \times v$ N-m/s

$\Rightarrow$ P = (700 - 302.925) × 10 = 3970.75 W = 3.97 KW (Ans)

Q.19) ***A leather belt 125 mm wide and 6 mm thick transmits power from a pulley 750 mm diameter which runs at 500 rpm. The angle of lap is 150^0 and coefficient of friction is 0.3. If the density of leather is 1 Mg/m^3 and the stress in the belt is not to exceed 2.75 MPa, find the maximum power that can be transmitted.***

Ans) Data given

width (b) = 125 KW = 0.125 m thickness (t) = 6 mm = 0.006 m

diameter (D) = 500 mm speed (N) = 500 rpm

coefficient of friction (μ) = 0.3 angle of lap (θ) = 150^0 = $150 \times \frac{\pi}{180}$ = 2.617 rad

density (ρ) = 1 Mg/m^3 = 10^6 g/m^3 = 1000 Kg/m^3 stress (σ) = 2.75 Mpa = 2.75×10^6 N/m^2

we know that, $v = \frac{\pi DN}{60} = \frac{\pi \times 0.75 \times 500}{60}$ = 19.635 m/s

maximum tension in the belt (T) = $\sigma\, b\, t = 2.75 \times 10^6 \times 0.125 \times 0.006$ = 2062.5 N

mass of belt per meter length (m) = $\rho \times (b \times t \times l) = 1000 \times 0.125 \times 0.006 \times 1$ = 0.75 Kg/m

we know that for maximum power transmission, $\boldsymbol{v} = \sqrt{\frac{T}{3m}} = \sqrt{\frac{2062.5}{3\times0.75}}$ = 30.276 m/s condition of maximum power transmission, $\Rightarrow$ $T_c = \frac{2062.5}{3} = 687.5$ N

$T_1 = T - T_c = 2062.5 - 687.5 = 1375$ N

We know that, $\frac{T1}{T_2} = e^{\mu\,\theta}$

$\Rightarrow \quad \frac{1375}{T_2} = e^{\mu\,\theta} = e^{(0.3\times 2.617)} = 2.1926 \quad \Rightarrow \quad T_2 = \frac{1375}{2.1926} = 627.109$ N

We know that, $P = (1375 - 626.109) \times 30.276$

$\Rightarrow \quad P = 22643.42$ Watt (Ans)

Q.20) ***The power transmitted between two shafts 3.5 m apart by a cross belt drive round the two pulleys 600 mm and 300 mm in diameter is 6 KW. The speed of the larger pulley is 220 rpm. The permissible load on the belt is 25 N/mm width of the belt which is 5 mm thick. The coefficient of friction is 0.35. Determine (i) necessary length of the belt (ii) width of the belt (iii) initial belt tension.***

Ans) Data given

distance between the shafts (x) = 3.5 m
diameter (D_1) = 600 mm = 0.6
mdiameter (D_2) = 300 mm = 0.3 m
power (P) = 6 KW = 6000 Watt
speed (N_1) = 220 rpm
coefficient of friction (μ) = 0.3
permissible load (T) = 10 N/mm Width
thickness (t) = 5 mm = 0.005 m

length of the belt (L) $= \pi\,(r_1 + r_2) + 2x + \frac{(r_1+r_2)^2}{x}$

$= \pi\,(0.3 + 0.15) + 2 \times 3.5 + \frac{(0.3+0.15)^2}{3.5}$

$= 1.4137 + 7 + 0.0578$

$= 8.4715$ m (Ans)

$\sin\alpha = \frac{r1 + r2}{x} = \frac{0.3 + 0.15}{3.5} = 0.1285$

$\Rightarrow \quad \alpha = \sin^{-1} 0.1285 = 7.38^0$

$\Rightarrow \quad 2\alpha = 14.76^0$

In case of cross belt drive angle of lap (θ) = $180^0 + 2\alpha = 180 + 14.76^0 = 194.76^0$

$\Rightarrow \quad \theta = 194.76^0 \times \frac{\pi}{180} = 3.39$ rad

We know that, $\frac{T1}{T_2} = e^{\mu\,\theta} = e^{(0.35\times 3.35)} = 3.285$

$\Rightarrow \quad T_1 = 3.285\times T_2$ ----------------------(1)

we know that, $v = \frac{\pi\,DN}{60} = \frac{\pi\times 0.6\times 220}{60} = 6.9$ m/s

Power transmitted (P) = $(T_1 - T_2) \times v$ N-m/s

$\Rightarrow \quad 6000 = (3.285\times T_2 - T_2) \times 6.9 \quad \Rightarrow \quad 6000 = 2.285T_2 \times 6.9$

$\Rightarrow \quad T_2 = \frac{6000}{2.285\,T_2 \times 6.9} = 380.55$ N $\quad \Rightarrow \quad T_1 = 3.285\times 380.55 = 1250.11$ N

If b = width of belt

Then $b = \frac{T1}{25} = \frac{1250.11}{25} = 50.004$ mm

Initial tension in belt (T_0) = $\frac{T1 + T2}{2} = \frac{1250.11 + 380.55}{2} = 815.33$ N (Ans)

Q.21) ***Write a short note on V-belt and V-belt pulley.***

Ans) These are used where large amount of power transmission is required. V – Belts are made endless, so there is no problem of joints. The distance between the pulleys is small. The rim of the pulley is grooved in which the belt runs. This groove increases the frictional grip of the V-belt on the pulley and reduces the chance of slipping. For a good grip the V-belt is in contact with the side faces of the groove of pulley.

Q.22) ***What do you mean by crowning of pulley*?**

Ans) In general the rim of the pulley is not a circular surface, but it is a conical or convex surface to avoid the slipping of the belt from the pulley. This is known as crowning of pulleys. The amount of crowning is 1/96 of the pulley face width.

Q.23) Define circular pitch, diametral pitch and module of a gear.

Ans) **Circular pitch:**

It is the distance measured on the circumference of the pitch circle from a point of one tooth to the corresponding point on the next tooth. It is denoted by (p_c).

Mathematically, *Circular pitch* (p_c) = $\frac{\pi D}{T}$, where D = pitch circle diameter,

T = number of teeth on wheel

Diametral pitch:

It is the ratio of number of teeth to the pitch circle diameter in millimetres.

It is denoted by (p_c). Mathematically, *Diametral pitch* (p_d) = $\frac{T}{D} = \frac{\pi}{p_c}$,

where D = pitch circle diameter, T = number of teeth

Module:

It is the ratio of the pitch circle diameter in millimeters to the number of teeth. It is denoted by (m). Mathematically, *Module (m)* = $\frac{D}{T}$

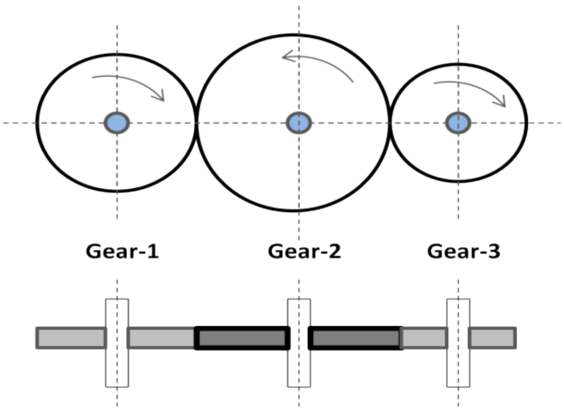
Q.24) ***Explain the working of Simple gear train*.**

Ans) In simple gear train each shaft supports one gear. In figure, gear 1 is called driver, gear 2 is called intermediate gear and gear 3 is called driven gear.

When the gear-1 rotates clockwise, it revolves gear-2 in anticlockwise direction and gear-2 revolves gear-3 in clockwise direction. If number of gears are odd then driver and driven gears are revolve in same direction and if number of gears are even then driver and driven gears are revolve in opposite direction.

***<u>Velocity ratio</u>*:**

Let N_1= speed of gear 1, N_2= speed of gear 2, N_3 = speed of gear 3, T_1 = number of teethof gear 1, T_2 = number of teeth of gear 2, and T_3 = number of teeth of gear 3.



(Simple Gear Train)

Velocity ratio of gear 1 and 2 = $\frac{N_1}{N_2} = \frac{T2}{T_1}$

Velocity ratio of gear 2 and 3 = $\frac{N_2}{N_3} = \frac{T3}{T_2}$

Multi plying the above two relation we get,

$\frac{N_1}{N_2} \times \frac{N_2}{N_3} = \frac{T_2}{T_1} \times \frac{T_3}{T_2}$ or $\frac{N_1}{N_3} = \frac{T_3}{T_1}$

Velocity ratio = $\frac{\text{speed of driver}}{\text{speed of driven}} = \frac{\text{No .of teeth on driven}}{\text{No .of teeth on driver}}$

Q.25) ***Explain the working of Compound gear train.***

Ans) In a compound gear train, each shaft supports more than one gear except the first and the last shaft.

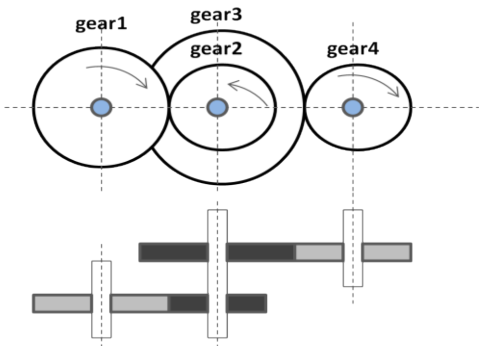
In figure, gear-1 is the first driver which revolves gear-2. Gear-2 and gear-3 are mounted on same shaft, so their speed is same ($N_2=N_3$) and direction of rotation is also same. Gear-3 is the driver of gear-4, the last driven.

***Velocity ratio*:**

Let N_1= speed of gear 1(driver), T_1 = number of teeth on gear 1N_2, N_3, N_4 = respective speed of gears
T_2, T_3, T_4 = number of teeth on respective gears.

Considering gear1 and 2, $\frac{N_2}{N_1} = \frac{d1}{d_2} = \frac{T1}{T_2}$ ------ (1)

Considering gear3 and 4, $\frac{N_4}{N_3} = \frac{d3}{d_4} = \frac{T3}{T_4}$ ------ (2)



(Compound Gear Train)

Multiplying 1 and 2, we get

$$\frac{N_2}{N_1} \times \frac{N_4}{N_3} = \frac{d_1}{d_2} \times \frac{d_3}{d_4} = \frac{T_1}{T_2} \times \frac{T_3}{T_4}$$

i.e. **Velocity ratio =** $\frac{\text{speed of the first driver}}{\text{speed of the last driven}}$

$= \frac{\text{Product of the number of teeth on drivens}}{\text{Product of the number of teeth on drivers}}$

Q.26) ***Explain the working of Reverted gear train.***

Ans) In a reverted gear train the driving and the driven gears are coaxial or coincident.

In figure, gear-1 is meshed with gear-2 and gear-3 meshed with gear-4. Gear-1 and gear-4 are mounted on same shaft. Gear-2 and gear-3 are mounted on same shaft. Gear-1 revolves gear-2 and gear-3 revolves gear-4.

***Velocity ratio*:**

Let , N_1= speed of gear 1(driver),

T_1 = number of teeth on gear

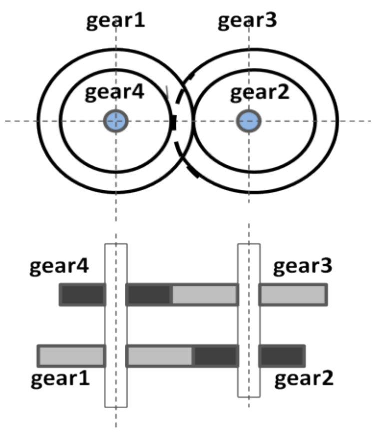
1,r_1 = pitch circle radius of gear

1

N_2, N_3, N_4 = speed of respective gears

T_2, T_3, T_4 = number of teeth on respective gears and

r_2, r_3 and r_4 = pitch circle radii of respective gears



(Reverted Gear Train)

Considering gear 1 and 2, we get $\frac{N_2}{N_1} = \frac{d1}{d_2} = \frac{T1}{T_2}$ --------- (1)

Considering gear 3 and 4, we get $\frac{N_4}{N_3} = \frac{d3}{d_4} = \frac{T3}{T_4}$ ---------(2)

Multiplying equation 1 and 2 we get, $\frac{N_2}{N_1} \times \frac{N_4}{N_3} = \frac{d_1}{d_2} \times \frac{d_3}{d_4} = \frac{T_1}{T_2} \times \frac{T_3}{T_4}$

$$\Rightarrow \quad \frac{N_4}{N_1} = \frac{d_1}{d_2} \times \frac{d_3}{d_4} = \frac{T_1}{T_2} \times \frac{T_3}{T_4} = \frac{\text{Product of the number of teeth on drivens}}{\text{Product of the number of teeth on drivers}}$$

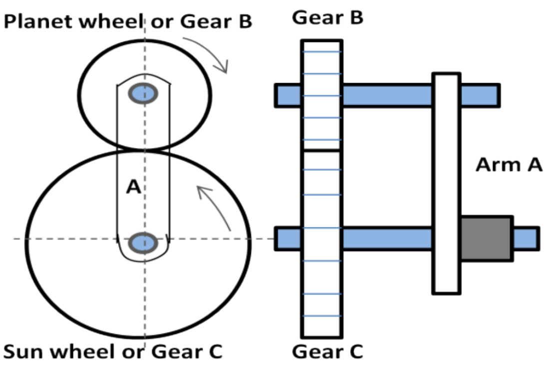
Q.27) ***Explain the working of Epicyclic gear train.***

Ans) In epicycle gear train the axes of some of wheels are not fixed but rotate around the axes of other wheels. Epicyclic means one gear revolving upon and around another. This design can produce large gear ratios in a small space and are used on a wide range of applications from marine gearboxes to electric screwdrivers.

In figure, Gear B meshes with gear C and revolves around it when the arm is rotated. B is called the planet gear and C the sun.

If planet gear rotates around sun gear, then Gear B revolves once on its own axis.

If sun gear rotates around planet gear, then Gear C revolves once on its own axis.



(Epicyclic Gear Train)

Q.28) ***Define speed ratio, train value and gear ratio.***

Ans) **Speed ratio:** It is the ratio of the speed of the driver to the speed of the driven.
Mathematically, speed ratio or velocity ratio = $\frac{N_1}{N_2} = \frac{T_2}{T_1}$

Train value: It is the ratio of speed of the driven to the speed of the driver.
Mathematically, Train value = $\frac{N_2}{N_1} = \frac{T_1}{T_2}$

Gear ratio: It is the ratio of number of teeth on the gear to the number of teeth on the pinion.
Mathematically, G = $\frac{T}{t}$ where, T = number of teeth on gear and t = number of teeth on pinion

Q.29) **State the advantages of V-belt drive over flat belt drive. State its disadvantages.**

Ans) The following are the advantages of V-belt drive.

- ♣ Positive drive can be obtained due to no slip and creep.
- ♣ They are suitable for short distance.
- ♣ They are flexible and have no joint problems.
- ♣ Less repairing and maintenance is required.
- ♣ Smoother in operation and less noise.
- ♣ More power can be transmitted due to no slip, creep and higher velocity ratio.
- ♣ High efficiency.

The following are the disadvantages.

- ♣ Construction of V-belt is complicated.
- ♣ They are not suitable for long distances.
- ♣ The v-belts are expensive.
- ♣ Velocity fluctuation is higher.
- ♣ Friction between belt and groove is higher and it leads to wear.

ASSIGNMENT

Group - A: 2 Mark Questions

1. State the expression for velocity ratio in belt drive considering both thickness and slip.
2. Define velocity ratio in belt drive.
3. State the expression for ratio of tension in belt drive.
4. In which type of drive the angle of contact or lap is same for both the pulleys.
5. State the expression for centrifugal tension in belt drive.
6. State the condition for maximum power transmission in belt drive.
7. State the expression for length of belt of an open belt drive.
8. State the expression for length of belt in a crossed belt drive.
9. Define creep and slip in belt.
10. What do you mean by initial tension in belt?
11. Define Simple and Compound gear train.
12. Define Reverted and Epicyclic gear train.
13. Define circular pitch. Diametral pitch and module.
14. Express the relation between circular pitch. Diametral pitch and module.

Group - B: 5 Mark questions

1. Derive the expression for length of belt in a open belt drive.
2. Derive the expression for length of belt in a crossed belt drive.
3. Derive expression for centrifugal tension in belt drive.
4. Derive the expression $\frac{T_1}{T_2} = e^{\mu \theta}$ in a belt drive.
5. Explain the working of reverted and epicyclic gear train.
6. Explain and determine the velocity ratio of Simple gear train.
7. Explain and determine the velocity ratio of Compound gear train.

Group - C: 7 Mark questions

1. Find the power transmitted by a belt running over a pulley of 600 mm diameter at 200 rpm. The coefficient of friction between the belt and the pulley is 0.25, angle of lap 150^0 and maximum tension in the belt is 2400 N.
2. A leather belt having thickness of 9 mm is required to transmit 12 KW from a motor at 900 rpm. The diameter of driving pulley is 300 rpm. The driven pulley runs at 400 rpm and the centre distance is 3.2 m. Find the width of the belt required for the following data:
   i) density of leather = 1000 Kg/m^3 ii) maximum allowable stress = 2.5 MPa
   iii) coefficient of friction = 0.3
3. An open belt drive connects two pulleys 120 cm and 50 cm diameters, on parallel shafts 4 m apart. The maximum tension in the belt is 1855.3 N. The coefficient of friction is 0.3. The driver pulley of diameter 120 cm runs at 200 r.p.m calculates:
   (i) The power transmitted, and
   (ii) Torque on each of the two shafts.

END of Chapter

GOVERNOR

Q.1) ***State the function of governor.***

Ans) A governor is used to maintain the mean equilibrium speed of an engine, when there is fluctuation of speed of an engine due to variation of load upon the engine.

Q.2) **Classify the Governors.**

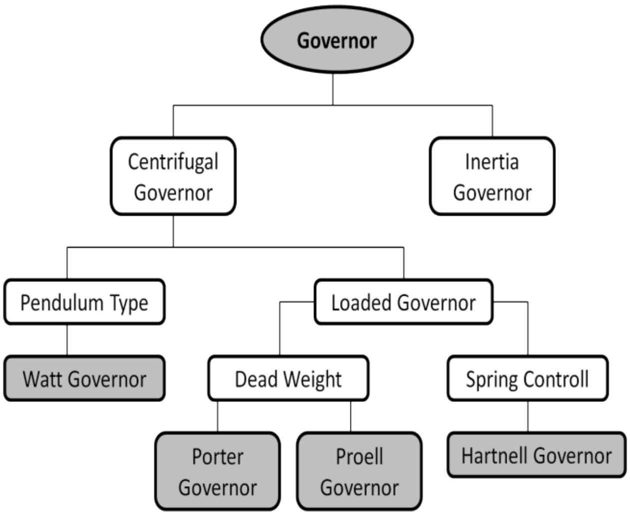
Ans)

<u>Centrifugal governor</u>**:**

In this type of governor pair of masses known as fly balls rotates with the spindle to produce centrifugal effect for the required action of governor. Examples of these types of governors are: Watt Governor, Porter Governor, Proell governor, Hartnell governor

<u>Inertia governor</u>**:**

In this type of governor the angular acceleration or deceleration of the spindle along with centrifugal forces acting on the balls is considered. The balls are operated by the rate of change of engine speed.

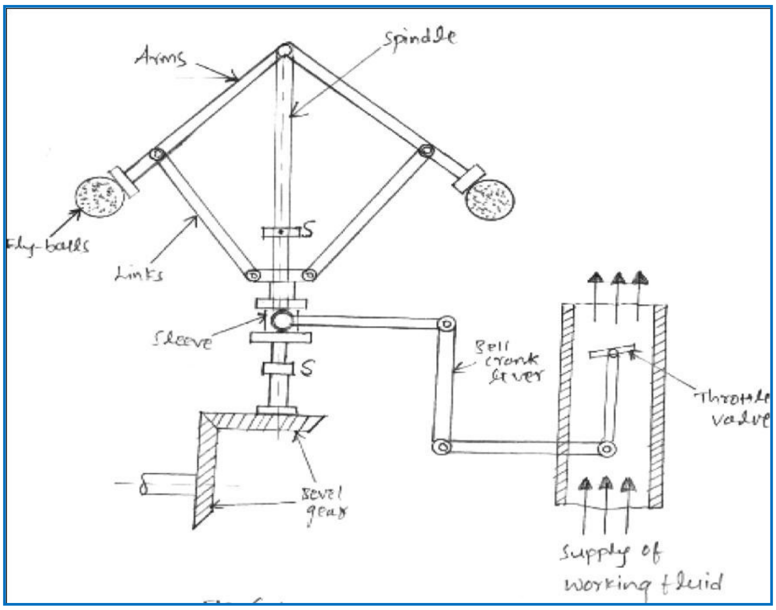


Q.3) ***Explain the working of Watt governor.***

Ans) *<u>Working of Watt governor</u>***:**

It is a simple centrifugal governor. It consists of: (i) pair of balls (fly balls) (ii) spindle (iii) links (iv) sleeve and bell crank lever

The spindle is driven by an engine through bevel gears. A sleeve is attached on to the spindle which slides over it. Fly balls are arranged by a linkage which rotates with the spindle to produce centrifugal action.

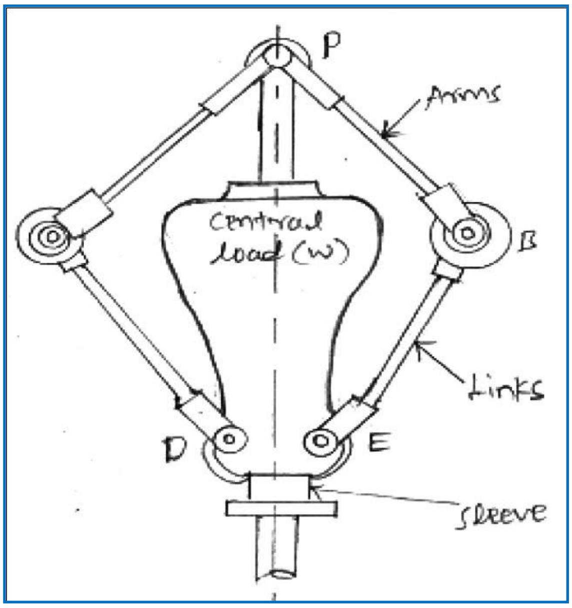


When the load on the engine shaft increases its speed decreases and the spindle of the governor rotates with this speed. The fly balls rotate so close to the axis due to decrease in centrifugal force on the balls. In this way the sleeve moves and this movement operates a linkage to operate the throttle valve for the increase of fuel supply. When the engine shaft rotates with its mean speed the governor comes back to its original position.

When the load on the engine shaft increases its speed decreases and the spindle of the governor rotates with this speed. The fly balls rotate so close to the axis due to decrease in centrifugal force on the balls. In this way the sleeve moves and this movement operates a linkage to operate the throttle valve for the increase of fuel supply. When the engine shaft rotates with its mean speed the governor comes back to its original position.

When the load on the engine shaft decreases its speed increases and the spindle of the governor rotates with this speed. The fly balls rotate away from the axis due to increase in centrifugal force on the balls. In this way the sleeve moves and this movement operates a linkage to operate the throttle valve for the decrease of fuel supply. When the engine shaft rotates with its mean speed the governor comes back to its original position.

Q.4) ***Explain the working of Porter governor*.Ans)** *Working of Porter governor*:



The Porter governor is a modification of a Watt's governor, with central load attached to the sleeve as shown in Figure.
There are two sets of arms. The top arms connect balls to the hinge. The hinge may be on the spindle or slightly away. The lower arms support dead weight and connect balls also. All of them rotate with the spindle.

When the loaded sleeve moves up and down the spindle; the frictional force acts on it in a direction opposite to that of the motion of sleeve. It works in the same principles of Watt governor.

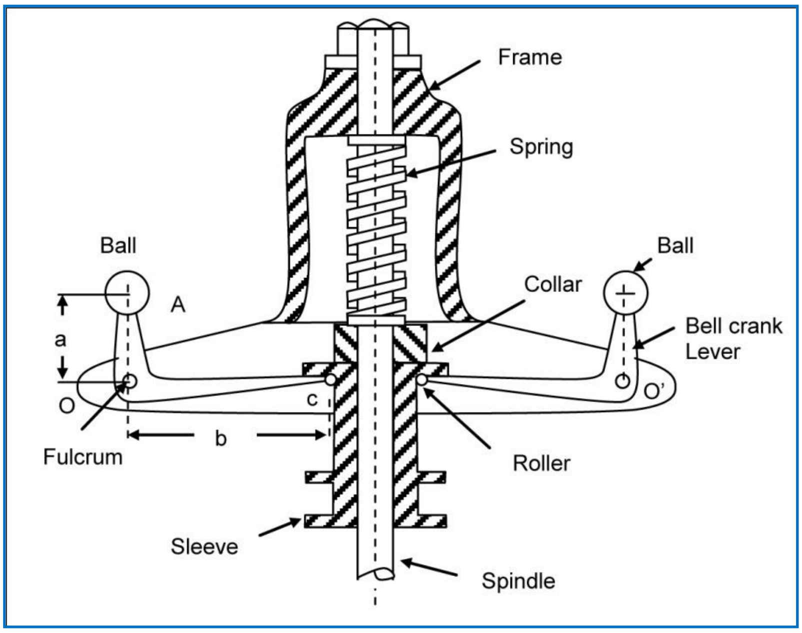
Q.5) ***Explain the working of Hartnell governor.***

Ans) *Working of Hartnell governor*:

It is a centrifugal type governor where the balls are controlled by spring force. It consists of: (i) Pair of balls, (ii) pair of bell crank levers, (iii) roller, (iv) pair of arms, (v) spindle, (vi) sleeve , (vii) spring and screw cap.

At initial position the spring is in compression and put force on the sleeve. The two bell crank levers are carrying balls at their one end and roller at the other end and are attached with the pair of arms. The arms are attached to the spindle and rotate. The rollers are fitted into the groove of a sleeve and transmit the motion.

When the speed of the engine increases, governor spindle rotates with this speed and causes the balls to move away from the axis of the spindle. The bell crank lever move on to the pivot and lift the sleeve against the spring force. In this way the throttle is operated by the linkage attached with sleeve to decrease the supply of working fuel. When the engine shaft rotates with its mean speed the governor comes back to its original position and the spring also put the force on the governor.



When the speed of the engine decreases, governor spindle rotates with this speed and causes the balls to move nearer to the axis of the spindle. The bell crank lever move and push the sleeve moves downward. In this way the throttle is operated by the linkage attached with sleeve to increase the supply of working fuel. When the engine shaft rotates with its mean speed the governor comes back to its original position and the spring also put the force on the governor.

Q.6) ***Define sensitivity, stability and isochronism of a governor.***

Ans) *Sensitiveness of a governor*:

It is the ratio of difference between the maximum and the minimum speed to the mean equilibrium speed.

Mathematically, Sensitiveness = $\frac{\text{Range of speed}}{\text{Mean speed}} = \frac{N2-N1}{\mathbf{N}} = \frac{2(N2-N1)}{\mathbf{N}}$

where, N = mean speed,

N_1= maximum speed in full load condition and N_2= minimum speed in no load condition

Stability of a governor:

If the radius of rotation of the balls of a governor doesn't decreases or increases with increase or decrease of speed, then the governor is known as stable. For stability of a governor if the equilibrium speed of engine increases, the radius of governor balls must be increase.

Isochronous governor:

If the equilibrium speed of a governor is constant or range of speed is zero, friction is not considered the governor is known as isochronous governor.

FLYWHEEL

Q.1) ***State the function of flywheel.***

Ans) A flywheel stores the excess energy in an engine and supplies it when there is a requirement of energy. It also controls the fluctuation of speed but does not control the speed variations caused by the varying loads.

Q.2) ***Distinguish among the governor and flywheel.***

Ans)

Flywheel	***Governor***
1. Flywheel controls the variation of speed of engine during each revolution of engine shaft.	1. Governor controls the variation of speed of the engine over a number of revolutions.
2. Variation of speed controlled by flywheel is caused due to fluctuation in turning moment during cycle.	2. Variation of mean speed controlled by governor is caused due to fluctuation in load on engine over a period of time.
3. It controls the variation of speed by providing stored energy during the cycle.	3. It controls the mean speed of the engine by regulating the fuel supply.
4. A flywheel has no control over the quantity of charge.	4. A governor takes care of the quantity of working fluid.
5. It is not an essential element for prime mover.	5. It is an essential element for prime mover.

Q.3) ***Define the following terms. (i) Maximum fluctuation of energy, (ii) Maximum fluctuation of speed, (iii) Coefficient of fluctuation of speed and (iv) Coefficient of Steadiness.***

Ans) *Maximum fluctuation of energy*: It is the difference between the maximum energy to the minimum energy of the engine.

Mathematically, Maximum fluctuation of energy (ΔE) = Max. Energy – Min. Energy

Maximum fluctuation of speed: It is the difference between the maximum and minimum speed of an engine.

Coefficient of fluctuation of speed: It is the ratio of maximum fluctuation of speed to the mean speed of an engine.

Mathematically, Coefficient of fluctuation of speed (Cs) = $\frac{N1-N2}{N}$

Where, N_1 = maximum speed in r.p.m N_2 = minimum speed in r.p.m$N = \frac{N1+N2}{2}$ = mean speed

Coefficient of Steadiness:

It is the reciprocal of coefficient of fluctuation of speed. It is denoted by ‘m’.

Mathematically, m = 1/Cs

END of Chapter

BALANCING OF MACHINES

Q.1) ***Define balancing.***

Ans) Balancing is the technique of correcting or eliminating unwanted inertia forces or moments in rotating or reciprocating masses and is achieved by changing the location of the mass centers.

Q.2) ***What do you mean by static and dynamic balancing? Explain.***

Ans) Static Balancing:

i) Static balancing is a balance of forces due to action of gravity.

ii) A body is said to be in static balance when its centre of gravity is in the axis of rotation.

Dynamic balancing:

i) Dynamic balance is a balance due to the action of inertia forces.

ii) A body is said to be in dynamic balance when the resultant moments or couples, which involved in the acceleration of different moving parts is equal to zero.

iii) The conditions of dynamic balance are met, the conditions of static balance are also met.

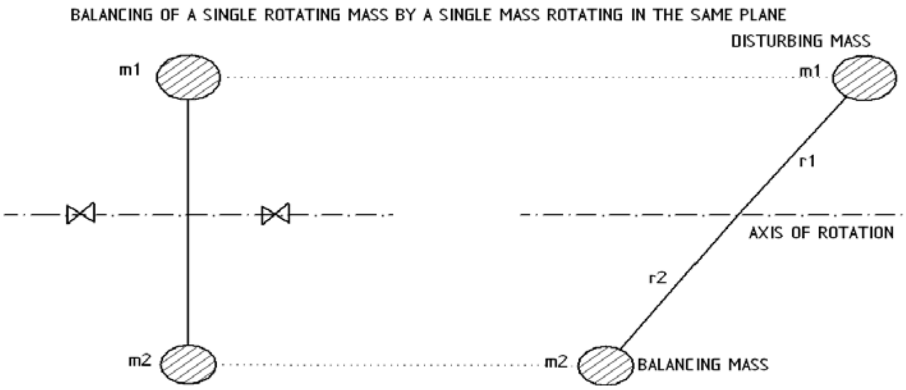
Q.3) ***What do you mean by balancing of rotating mass?***

Ans) When a mass moves along a circular path, centrifugal force acts on the mass in radially outward direction. This is a disturbing force whose direction changes with the rotation of mass. The method of balancing this disturbing forces and setting the masses in correct location to avoid unbalance is known as balancing of rotating masses.

This type of unbalance is common in steam turbine rotors, engine crankshafts, rotors of compressors, centrifugal pumps etc.

Q.4) Explain the concept of Balancing of a single rotating mass by a single mass rotating in the same plane.

Ans)



Consider a disturbing mass m_1 which is attached to a shaft rotating at ω rad/s and a balancing mass m_2 which is also attached to the same shaft rotating at ω rad/s.

Let, r_1 = radius of rotation of mass m_1 r_2 = radius of rotation of mass m_2

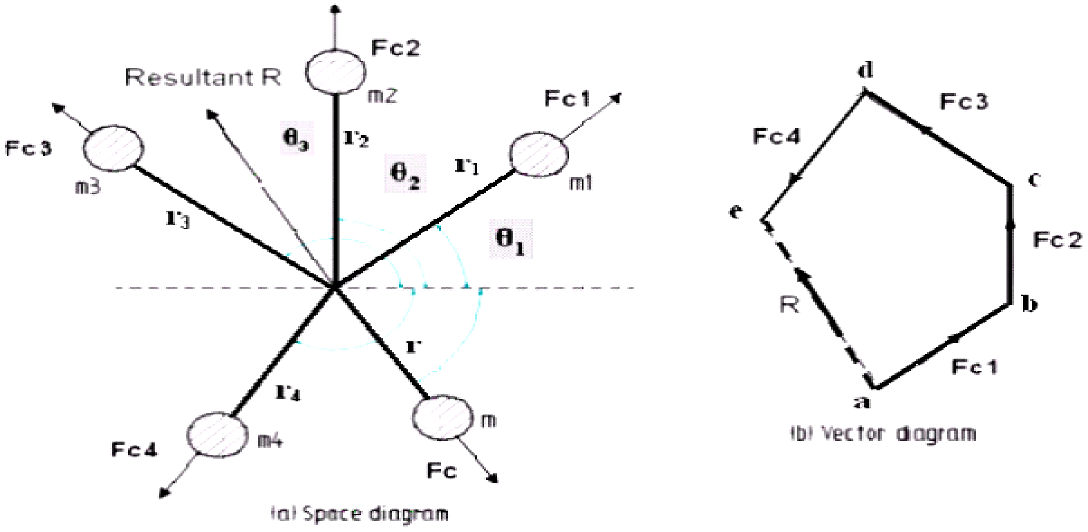
Centrifugal force exerted by mass m_1 on the shaft = $F_{c1} = m_1 \omega r_1^2$ _________(i)

Centrifugal force exerted by mass m_2 on the shaft = $F_{c2} = m_2 \omega r_2^2$ _________(ii)

The force F_{c1} of disturbing mass m_1 acts radially outwards and produces bending moment on the shaft. In order to balance its effect, an equal and opposite force F_{c2} is given by using the mass m_2.

Q.5) ***Explain the concept of balancing of several masses rotating in the same plane.***

Ans)



BALANCING OF SEVERAL MASSES ROTATING IN THE SAME PLANE

Consider four masses m_1, m_2, m_3 and m_4 revolving at radii r_1, r_2, r_3 and r_4 respectively in the same plane. These mass exerts centrifugal forces F_{c1}, F_{c2}, F_{c3} and F_{c4} respectively.

Let F = sum of forces F_{c1}, F_{c2}, F_{c3} and F_{c4}. $= F_{c1} + F_{c2} + F_{c3} + F_{c4}$

$$= m_1 r_1 \omega^2 + m_2 r_2 \omega^2 + m_3 r_3 \omega^2 + m_4 r_4 \omega^2 \quad \text{——(i)}$$

F is the resultant force of these four centrifugal forces.

Consider another mass *m* revolving at radius *r* on the same shaft which can balance these four masses. Centrifugal mass exerted by mass *m* = $F_c = m.r.\omega^2$ ________(ii)

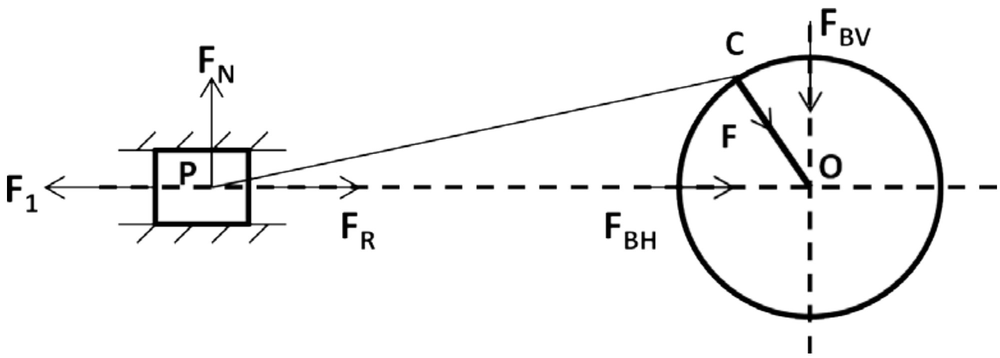
For balancing, the forces F and F_c must be equal and opposite.

Thus $m_1 r_1 \omega^2 + m_2 r_2 \omega^2 + m_3 r_3 \omega^2 + m_4 r_4 \omega^2 = m.r.\omega^2$

$$\Rightarrow \quad m_1 r_1 + m_2 r_2 + m_3 r_3 + m_4 r_4 = m.r$$

Q.6) ***Explain the concept of balancing of reciprocating masses.***

Ans) Consider the following figure to study the balancing of reciprocating masses.



F_R = Force required to accelerate the reciprocating mass

F_1 = Inertia force due to reciprocating mass

F_N = Force on the sides of the cylinder walls

F_B = Force acting on the crank shaft bearing or main bearing

Angle COP = Θ

- ♣ F_R and F_1 are equal in magnitude and opposite in direction, so they will cancel to each other.
- ♣ The horizontal component F_{BH} is equal to F_1 and opposite in direction. This force is unbalanced force which required proper balancing.
- ♣ The force on the sides of the cylinder wall and vertical component F_{BV} are equal and opposite but forms a shaking couple.
- ♣ The shaking couple or shaking force varies in magnitude and direction, so they cause vibration.
- ♣ In the reciprocating masses by adding balancing masses, it is not practically to eliminate them completely. In other words the reciprocating masses are partially balanced.

Q.7) ***What are the causes and effects of unbalance*?**

Ans) <u>*Causes of unbalance*</u>:

- ♣ Slight variation in the density of the material
- ♣ Inaccuracies in the casting
- ♣ Inaccuracies in machining of the parts
- ♣ Misalignment of parts

<u>*Effects of unbalance*</u>:

- ♣ Unbalance of machine parts causes vibration.
- ♣ Unbalance masses produce disturbing forces which causes non equilibrium of forces.
- ♣ Unbalance forces may cause bending of parts and failure of machine parts.

END of Chapter

VIBRATION

Q.1) ***Define the following terms: (i) time period (ii) amplitude (iii) cycle (iv) frequency.***

Ans) *Time Period*: It is the time taken to complete one cycle. It is the time period after which the motion of a vibratory body repeats itself. It is denoted by **T**. Its unit is second.

Amplitude: It is the maximum displacement of oscillating body from its mean equilibrium position.

Cycle: It is the motion completed during one time period.

Frequency: It is the number of cycles per unit time. It is given by Hertz (Hz)

Q.2) ***State the relation between time period and frequency.***

Ans) Frequency is the reciprocal of time period. i.e $\text{Frequency} = \frac{1}{\text{Time period}}$

Q.3) **Define the following terms: (i) free vibration (ii) forced vibration (iii) damped vibration.**

Ans) *Free/Natural vibration*: When no external force act on the body after giving an initial displacement to the body, then the body is said to be in free or natural vibration.

Forced vibration: When the body vibrates under the action of an external force, then the body is said to be in forced vibration.

Damped vibration: When there is reduction in amplitude over every cycle of vibration, it is called damped vibration.

Q.4) **Define the following terms: (i) longitudinal vibration (ii) transverse vibration (iii) torsional vibration.**

Ans) *Longitudinal vibration*: When the particles of the shaft or disc moves parallel to the axis of the shaft or disc, then the vibration produced is called longitudinal vibration.

Transverse vibration: When the particles of the shaft or disc moves approximately perpendicular the axis of the shaft or disc, then the vibration produced is called transverse vibration.

Torsional vibration: When the particles of the shaft or disc moves in a cycle about the axis of the shaft or disc, then the vibration produced is called Torsional vibration.

Q.5) **State the causes and remedies of vibration.**

Ans)

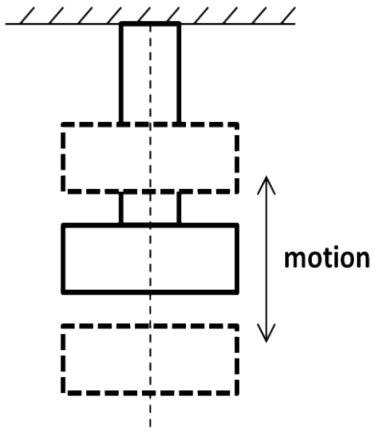
	Causes	***Remedies***
Lack of balance	In a machine there may be a number of rotating and reciprocating parts having the motion in different planes, causes dynamic forces. If all the dynamic forces are not balanced, as a result vibration produced in machine.	*The machine parts must be kept under static and dynamic balancing.*
Loose fitting	If the machine parts are not properly fitted such as the nuts, screws, bolts are not perfectly tightened; as a result vibration develops in machine.	*The machine parts must be tight fitted properly.*
Incorrect alignment	In a machine there may be one or more places where power transmission takes place. If the driver and driven parts are not properly aligned, as a result vibration produced in machine.	*The alignment test must be performed to check the alignment of the machine parts.*

Vibration wave	If the heavy machines are operated nearer to each other, then the sound produced by the working machines causes vibration.	*The heavy machines must be installing at distance places to minimize the effect of vibration sound waves.*
Lack of isolation	If the isolation is not provided between the machine and the foundation, then the vibration are transmitted to another machines.	*The isolation of machine in foundation must be done carefully to make a rigid installation for minimizing effect of vibration.*
Lack of compact soil	If the soil of the machine foundation is wet, loose or not compact then the settlement of the machine remains incorrect. It causes vibration.	*The condition of soil must be checked and corrected before installation of machine parts.*

Q.6) ***Write a short note on (i) longitudinal vibration (ii) transverse vibration (iii) torsional vibration.***

Ans) Longitudinal vibration –

When the particles of the shaft or disc moves parallel to the axis of the shaft or disc, then the vibration produced is called longitudinal vibration. In this case the shaft elongates and shortens alternately. In figure three position of disc is shown.



(Longitudinal vibration)

Time period (T) = $\frac{2\pi}{w} = 2\pi \times \sqrt{m/s}$

The frequency in the longitudinal vibration is given by the relation, $f_n = \frac{1}{2\pi} \times \sqrt{s/m}$

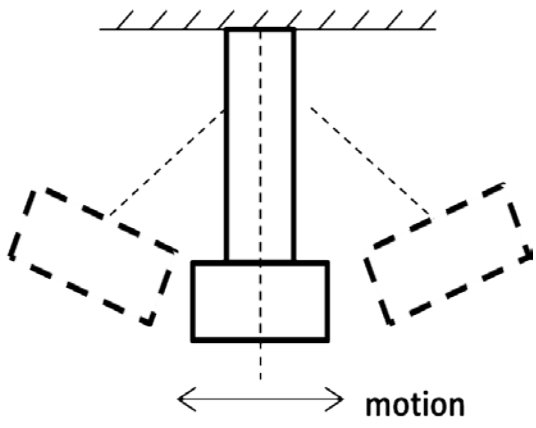
where, f_n = Natural frequency,

s = Stiffness of the spring,

m = Mass of the spring.

Transverse vibration:

When the particles of the shaft or disc moves approximately perpendicular the axis of the shaft or disc, then the vibration produced is called transverse vibration. In this case the shaft bends or straights alternatively. Bending stresses are induced in the shafts.



(Transverse vibration)

Time period (T) = $\frac{2\pi}{w} = 2\pi \times \sqrt{m/s}$

The frequency in the longitudinal vibration is given by the relation,

$f_n = \frac{1}{2\pi} \times \sqrt{s/m}$

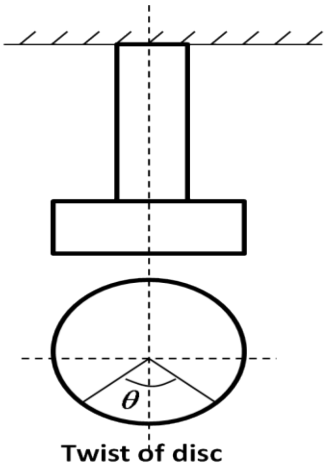
where, f_n = Natural frequency

s = Stiffness of the spring

m = Mass of the spring.

Torsional vibration:

When the particles of the shaft or disc moves in a cycle about the axis of the shaft or disc, then the vibration produced is called Torsional vibration. In this case the shaft twisted or untwisted alternatively. Torsional shear stresses are induced in the shafts.



(Torsional vibration)

The frequency in the longitudinal vibration is given by the relation, $\mathbf{f_n = \frac{1}{2\,\pi} \times \sqrt{q/I}}$

where, f_n = Natural frequency

q = Torsional stiffness of the spring

I = Mass moment of inertia of the disc.

END of Chapter

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

DESIGN OF MACHINE ELEMENT

5TH SEMESTER

PREPARED BY

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Chapter-1

1.0 INTRODUCTION

1.1 Introduction to Machine Design & Classifications of Machine Design:

Introduction to Machine Design

The subject Machine Design is the creation of new and better machines and improving the existing ones. A newor better machine is one which is more economical in the overall cost of production and operation. The process of design is a long and time consuming one. From the study of existing ideas, a new idea has to be conceived.

The idea is then studied keeping in mind its commercial success and given shape and form in the form of drawings. In the preparation of these drawings, care must be taken of the availability of resources in money, in men and in materials required for the successful completion of the new idea into an actual reality. In designing a machine component, it is necessary to have a good knowledge of many subjects such as Mathematics, Engineering Mechanics, Strength of Materials, Theory of Machines, Workshop Processes and Engineering Drawing.

Classifications of Machine Design:

The machine design may be classified as follows:

1. Adaptive design: In most cases, the designer's work is concerned with adaptation of existing designs. This type of design needs no special knowledge or skill and can be attempted by designers of ordinary technical training. The designer only makes minor alternation or modification in the existing designs of the product.

2. Development design: This type of design needs considerable scientific training and design ability in order to modify the existing designs into a new idea by adopting a new material or different method of manufacture. Inthis case, though the designer starts from the existing design, but the final product may differ quite markedly from the original product.

3. New design: This type of design needs lot of research, technical ability and creative thinking. Only thosedesigners who have personal qualities of a sufficiently high order can take up the work of a new design.

The designs, depending upon the methods used, may be classified as follows:

(a) Rational design: This type of design depends upon mathematical formulae of principle of mechanics.

(b)Empirical design: This type of design depends upon empirical formulae based on the practice and past experience.

(c)Industrial design: This type of design depends upon the production aspects to manufacture any machinecomponent in the industry.

(d) Optimum design: It is the best design for the given objective function under the specified constraints. It maybe achieved by minimising the undesirable effects.

(e)System design: It is the design of any complex mechanical system like a motor car.

(f)Element design: It is the design of any element of the mechanical system like piston, crankshaft, connectingrod, etc.

(g) Computer aided design. This type of design depends upon the use of computer systems to assist in the creation, modification, analysis and optimization of a design.

1.2 Different mechanical engineering materials used in design with their uses and their mechanical and physical properties

Engineering Materials:

The engineering materials are mainly classified as:

1.Metals and their alloys, such as iron, steel, copper, aluminium, etc.

1. Non-metals, such as glass, rubber, plastic, etc. The metals may be further classified as:

1. Ferrous metals.

The Ferrous metals are those which have the iron as their main constituent, such as cast iron, wrought iron and steel.

2. Non-ferrous metals.

The Non-ferrous metals are those which have a metal other than iron as their main constituent, such as copper, aluminum, brass, tin, zinc, etc.

The selection of a proper material, for engineering purposes, is one of the most difficult problems for the designer. The best material is one which serves the desired objective at the minimum cost.

The following factors should be considered while selecting the material:

- Availability of the materials.
- Suitability of the materials for the working conditions in service.
- The cost of the materials.

Physical Properties of Metals

The physical properties of the metals include luster, colour, size and shape, density, electric and thermal conductivity, and melting point. The following table shows the important physical properties of some pure metals.

Mechanical Properties of Metals:

The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and load. These mechanical properties of the metal include;

Strength, stiffness, elasticity, plasticity, ductility, brittleness, malleability, toughness, resilience, creep and hardness.

1. Strength: It is the ability of a material to resist the externally applied forces without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.
2. Stiffness: It is the ability of a material to resist deformation under stress. The modulus of elasticity is the measure of stiffness.
3. Elasticity: It is the property of a material to regain its original shape after deformation when the external forces are removed.
4. Plasticity: It is property of a material which retains the deformation produced under load permanently.
5. Ductility: It is the property of a material enabling it to be drawn into wire with the application of a tensile force. A ductile material must be both strong and plastic. The ductility is usually measured by the terms, percentage elongation and percentage reduction in area. The ductile material commonly used in engineering practice are mild steel, copper, aluminum, nickel, zinc, tin and lead.
6. Brittleness: It is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. Cast iron is a brittle material.
7. Malleability: It is a special case of ductility which permits materials to be rolled or hammered into thin sheets. The malleable materials commonly used in engineering practice are lead, soft steel, wrought iron, copper and aluminum.
8. Toughness: It is the property of a material to resist fracture due to high impact loads like hammer blows. The toughness of the material decreases when it is heated.
9. Resilience: It is the property of a material to absorb energy and to resist shock and impact loads. This property is essential for spring materials.
10. Creep: When a part is subjected to a constant stress at high temperature for a long period of time, it will undergo a slow and permanent deformation called creep. This property is considered in designing internal combustion engines, boilers and turbines.
11. Fatigue: When a material is subjected to repeated stresses, it fails at stresses below the yield point stresses. Such type of failure of a material is known as fatigue. This property is considered in designing shafts, connecting rods, springs, gears, etc.
12. Hardness: It is the property of the metals; it adopts many different properties such as resistance to wear, scratching, deformation and machinability etc. The hardness of a metal may be determined by the following tests:
    a) Brinell hardness test.

b) Rockwell hardness test.
c) Vickers hardness test.

1.3 Define working stress, yield stress, ultimate stress & factor of safety and stress –strain curve for M.S & C.I.

Working Stress:

When designing machine parts, it is desirable to keep the stress lower than the maximum or ultimate stress at which failure of the material takes place. This stress is known as the working stress.

yield Stress

The yield strength or yield stress is a material property and is the stress corresponding to the yield point at which the material begins to deform plastically.

Ultimate Stress

Ultimate tensile strength (UTS) is the maximum stress that a material can withstand before failure while being stretched or pulled.

Factor of Safety:

It is defined, in general, as the ratio of the maximum stress to the working stress.

Mathematically**, Factor of safety = Maximum stress / Working or design stress**

- In case of ductile materials; e.g. mild steel, where the yield point is clearly defined, the factor of safety is based upon the yield point stress.

In such cases;

Factor of safety = Yield point stress / Working or design stress

- In case of brittle materials e.g. cast iron, the yield point is not well defined as for ductile materials. Therefore, the factor of safety for brittle materials is based on ultimate stress.

In such cases:

Factor of safety = Ultimate stress / Working or design stress

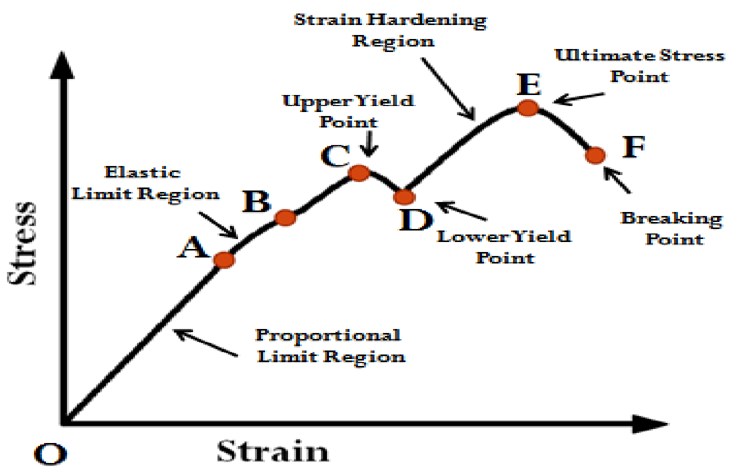
Stress Strain Curve for Mild Steel:

When a ductile material like mild steel is subjected to tensile force, it undergoes different stages before failure. Stress strain curve is the graphical representation of this stages. Different material may have different curve. Usually ductile materials follow similar pattern. so is for brittle materials. Here is the explanation

of stress strain curve for mild steel which is ductile material.

Here is the list of different stages when ductile material subjected to force till its failure.

- Proportional limit (point A)
- Elastic limit (point B)
- Yield point (upper yield point C and lower yield point D)
- Ultimate stress point (point E)
- Breaking point (point F)



Proportional limit:

As shown in stress strain curve for mild steel, up to the point A, stress and strain follow a relationship. This is known as Hook's law. Up to the limit of proportionality, stress directly followed the strain. This means ratio ofstress and strain remains constant

Elasticlimit:

Up to this limit (point B), is material will regain its original shape and size when unloaded. Point B is known as elastic point.

Yieldlimit:

When material is loaded beyond its elastic limit, it will not regain its original shape. There will be always some deformation.

Ultimatestress:

This is the maximum stress a material can bear. Value of stress corresponds to peak point on stress strain curvefor mild steel is the ultimate stress. It is denoted by point E in diagram.

Breakingstress:
Point on the stress strain curve where material fails, is known as breaking point. Stress correspond to this pointis known as breaking stress.

Stress Strain Curve for cast iron:

Materials which show very small elongation before they fracture are called brittle materials. The shape of curve for a Cast iron is shown in Fig.(b) and is typical of many brittle materials such as Carbon steel, concrete and high strength light alloys. For most brittle materials the permanent elongation (i.e., increase in length) is less than 5%.

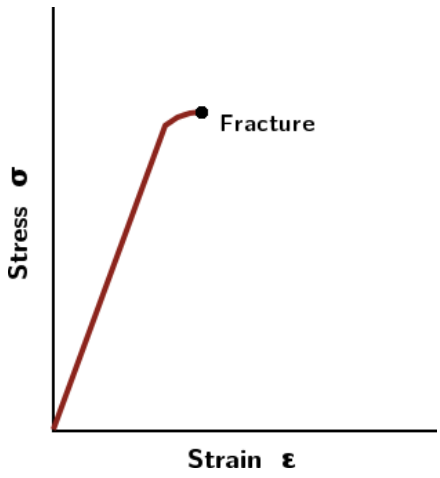


Fig.b stress-strain curve for cast iron.

The ultimate strength is coincident with the fracture point. In this case, no necking occurs.

1.4 Modes of Failure (By elastic deflection, general yielding & fracture)

Modes of failure:

A mechanical component may fail i.e. it may be unable to perform its function satisfactorily, as a result of anyone of the following three modes of failure:

1. Failure by elastic deflection.
2. Failure by Yielding
3. failure by Fracture

1. Failure by elastic deflection

In applications like transmission shaft supporting the gears, the maximum force acting on the shaft, without effecting it performance is limited by the permissible elastic deflection. Sometimes the elastic deflection results in unstable conditions, such as buckling of columns or vibrations. The design of mechanical component, in all these cases, is based on the permissible lateral or torsional deflection. The stresses induced in the component are not significant and properties of the material are not of primary importance. The moduli of elasticity and rigidity are the important properties and dimension of component are determined by the load deflection equation.

In short, in a components like : columns, beams, shafts etc.,the torsional deflection in an elastic region is termed as failure of the component

2. Failure by Yielding

For ductile material deformation occurs after the yield point, resulting in permanent deformation of the machine element which ultimately breaks at breaking point. Hence for ductile materials, failure is usually considered to have occurred when yielding i.e. plastic deformation reach a limit, when engineering usefulness of the part is destroyed, even through there is no rupture or fracture of machine part. Thus, the yield point is criterion of failure of ductile materials subjected to static loading.

In short, when a mechanical component, made of ductile material, undergoes yielding or plastic deformation, its functional utility comes to an end and it is termed as failure of the component. Such failure is known as **Plastic failure.**

3. Failure by fracture

In case of brittle materials the yield point and ultimate strain is very nearly equal to unity. So brittle materials are considered to have failed by fracture with little or no permanent deformation.

Sudden separation or a breakage of a material along the cross-section normal to the direction of stress is known as fracture. Fracture is a sudden failure without plastic deformation. The failure of components made of brittle material is due to fracture.

1.5 Factors governing the design of machine elements:

1. Type of load and stresses caused by the load.

The load, on a machine component, may act in several ways due to which the internal stresses are set up.

2. Motion of the parts or kinematics of the machine.

The successful operation of any ma-chine depends largely upon the simplest arrangement of the parts which will give the motion required.

The motion of the parts may be :

(a) Rectilinear motion which includes unidirectional and reciprocating motions.

(b) Curvilinear motion which includes rotary, oscillatory and simple harmonic.

(c) Constant velocity.

(d) Constant or variable acceleration.

3. Selection of materials.

It is essential that a designer should have a thorough knowledge of the properties of the materials and their behaviour under working conditions. Some of the important characteristics of materials are : strength, durability, flexibility, weight, resistance to heat and corrosion, ability to cast, welded or hardened, machinability, electrical conductivity, etc.

4.Form and size of the parts.

The form and size are based on judgement. The smallest practicable cross-section may be used, but it may be checked that the stresses induced in the designed cross-section are reasonably safe. In order to design any machine part for form and size, it is necessary to know the forces which the part must sustain. It is also important to anticipate any suddenly applied or impact load which may cause failure.

5. Frictional resistance and lubrication

There is always a loss of power due to frictional resistance and it should be noted that the friction of starting is higher than that of running friction. It is, therefore, essential that a careful attention must be given to the matter of lubrication of all surfaces which move in contact with others, whether in rotating, sliding, or rolling bearings.

6. Convenient and economical features.

In designing, the operating features of the machine should be carefully studied. The starting, controlling and stopping levers should be located on the basis of convenient handling .The economical operation of a machine which is to be used for production, or for the processing of material should be studied, in order to learn whether it has the maximum capacity consistent with the production of good work.

7. Use of standard parts.

The use of standard parts is closely related to cost, because the cost of standard or stock parts is only a fraction of the cost of similar parts made to order. The standard or stock parts should be used whenever possible; parts for which patterns are already in existence such as gears, pulleys and bearings and parts which may be selected from regular shop stock such as screws, nuts and pins. Bolts and studs should be as few as possible to avoid the delay caused by changing drills, reamers and taps and also to decrease the number of wrenches required.

8.Safety of operation.

Some machines are dangerous to operate, especially those which are speeded up to insure production at a maximum rate. Therefore, any moving part of a machine which is within the zone of a worker is considered an accident hazard and may be the cause of an injury. It is, therefore, necessary that a designer should always provide safety devices for the safety of the operator. The safety appliances should in no way interfere with operation of the machine.

9. Workshop facilities.

A design engineer should be familiar with the limitations of his employer’s workshop, in order to avoid the necessity of having work done in some other workshop. It is sometimes necessary to plan and supervise the workshop operations and to draft methods forcasting, handling and machining special parts.

10. Number of machines to be manufactured.

The number of articles or machines to be manufactured affects the design in a number of ways. The engineering and shop costs which are called fixed charges or overhead expenses are distributed over the number of articles to be manufactured. If only a few articles are to be made, extra expenses are not justified unless the machine is large or of some special design. An order calling for small number of the product will not permit any undue Design considerations play important role in the successful production of machines. Expense in the workshop processes, so that the designer should restrict his specification to standard parts as much as possible.

11. Cost of construction.

The cost of construction of an article is the most important consideration involved in design. In some cases, it is quite possible that the high cost of an article may immediately bar it from further considerations. If an article has been invented and tests of handmade samples have shown that it has commercial value, it is then possible to justify the expenditure of a considerable sum of money in the design and development of automatic machines to produce the article, especially if it can be sold in large numbers. The aim of design engineer under all conditions should be to reduce the manufacturing cost to the minimum.

12. Assembling.

Every machine or structure must be assembled as a unit before it can function. Large units must often be assembled in the shop, tested and then taken to be transported to their place of service. The final location of any machine is important and the design engineer must anticipate the exact location and the local facilities for erection.

1.6 General Procedure in Machine Design:

In designing a machine component, there is no rigid rule. The problem may be attempted in several ways.However, the general procedure to solve a design problem is as follows:

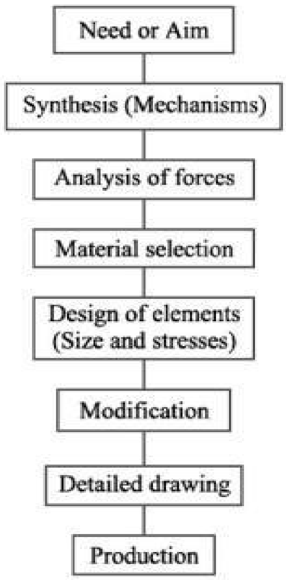


Fig. General Machine Design Procedure

1. Recognition of need: First of all, make a complete statement of the problem, indicating the need, aim orpurpose for which the machine is to be designed.

2. Synthesis (Mechanisms): Select the will give the desired motion.

3. Analysis of forces: Find the forces acting on each member of the machine and the energy transmitted byeach member.

4. Material selection: Select the material best suited for each member of the machine.

5. Design of elements (Size and Stresses): considering the force acting on the member and the permissible stresses for the material used. It should be kept in mind that each member should not deflect or deform thanthe permissible limit.

6. Modification: Modify the size of the member to agree with the past experience and judgment to facilitate manufacture. The modification may also be necessary by consideration of manufacturing to reduce overall cost.

7. Detailed drawing: Draw the detailed drawing of each component and the assembly of the machine with complete specification for the manufacturing processes suggested.

8. Production. The component, as per the drawing, is manufactured in the workshop. The flow chart for thegeneral procedure in machine design is shown in Fig.

Chapter-2

DESIGN OF FASTENING ELEMENTS

2.1 Joints and their classification.

Fasteners: It is a Mechanical Joints which is used to become a fixed / attaches to something or holds something in place.
The Fastenings may be classified into the following two groups:

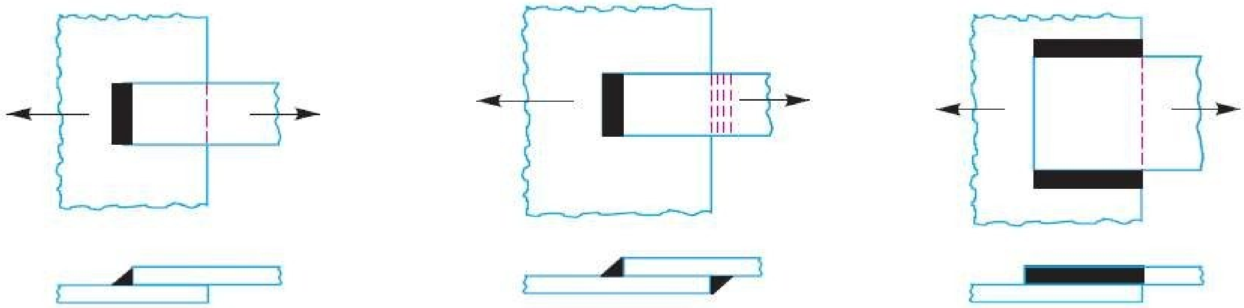
1. The Permanent Fastenings are those fastenings which cannot be disassembled withoutdestroying the connecting components. Examples: Welded joint, Rivet joint.
2. The Temporary or Detachable Fastenings are those fastenings which can be disassembledwithout destroying the connecting components.
   Examples: 1.Thread Joints
   a. Bolted Joints
   b. Screws Joints
   2. Keys
   3. Coupling
   4. Pins Joints
   a. Cotters Joints
   b. Knuckle Joints
   5. Pipe Joints

2.2 Types of welded joints .

Welded joint:
Welding can be defined as a process of joining metallic parts by heating to a suitable temperature with orwithout the application of pressure.
Welding is an economical and efficient method for obtaining a permanent joint of metallic parts. Two distinct application of welding

1. Can be used as a substitute for a riveted joint
2. Welded structure as an alternative method for casting or forging.

Types of welded joints
Following two types of welded joints
1. Lap joint or fillet joint,
2. Butt joint.
Lap Joint
The lap joint or the fillet joint is obtained by overlapping the plates and then welding the edges of the plates. The cross-section of the fillet is approximately triangular.
The fillet joints may be
1. Single transverse fillet, 2. Double transverse fillet and 3. Parallel fillet joints.
A single transverse fillet joint has the disadvantage that the edge of the plate which is not welded can buckle or warp out of shape.

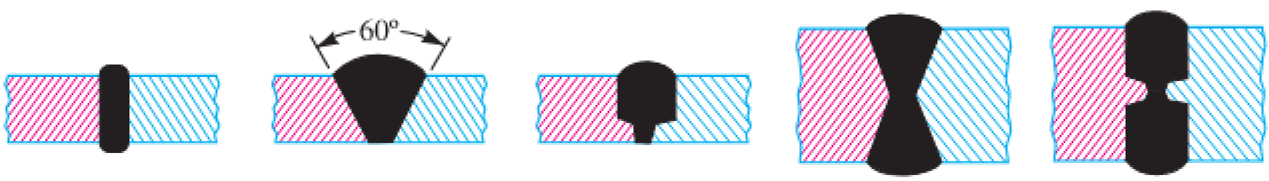


(a) Single transverse. (b) Double transverse. (c) Parallel fillet.

Butt Joint

The butt joint is obtained by placing the plates edge to edge as shown in Fig. below. In butt welds, the plate edges do not require bevelling if the thickness of plate is less than 5 mm. On the other hand, if the plate thickness is 5 mm to 12.5 mm, the edges should be bevelled to V or U-groove on both sides.

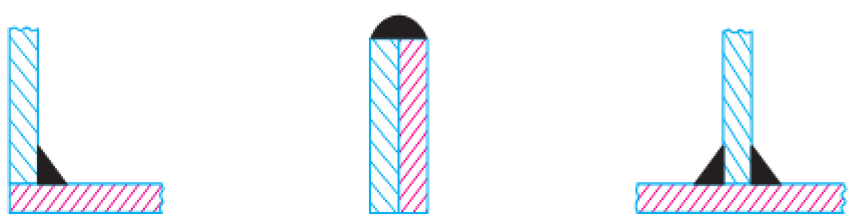
The butt joints may be
1. Square butt joint
2. Single V-butt joint
3. Single U-butt joint,
4. Double V-butt joint,
5. Double U-butt joint.



(a) Square butt joint. (b) Single V-butt joint. (c) Single U-butt joint. (d) Double V-butt joint. (e) Double U-butt joint.

<u>Other Joints</u>

The other type of welded joints are corner joint, edge joint and T-joint as shown in Fig below



(a) Corner joint. (b) Edge joint. (c) T-joint.

The main considerations involved in the selection of weld type are:
1. The shape of the welded component required,
2. The thickness of the plates to be welded, and
3. The direction of the forces applied.

<u>2.3 Welding advantages over riveting:</u>

Following are the advantages and disadvantages of welded joints over riveted joints.
Advantages

1. The welded structures are usually lighter than riveted structures. This is due to the reason, that in welding, gussets or other connecting components are not used.

2. The welded joints provide maximum efficiency (may be 100%) which is not possible in case of riveted joints.

3. Alterations and additions can be easily made in the existing structures.

4. As the welded structure is smooth in appearance, therefore it looks pleasing.

5. In welded connections, the tension members are not weakened as in the case of riveted joints.

6. A welded joint has a great strength. Often a welded joint has the strength of the parent metal itself.

7. Sometimes, the members are of such a shape (i.e. circular steel pipes) that they afford difficulty for riveting. But they can be easily welded.

8. The welding provides very rigid joints. This is in line with the modern trend of providing rigid frames.

9. It is possible to weld any part of a structure at any point. But riveting requires enough clearance.

10. The process of welding takes less time than the riveting.

Disadvantages

1. Since there is an uneven heating and cooling during fabrication, therefore the members may get distorted or additional stresses may develop.

2. It requires a highly skilled labour and supervision.

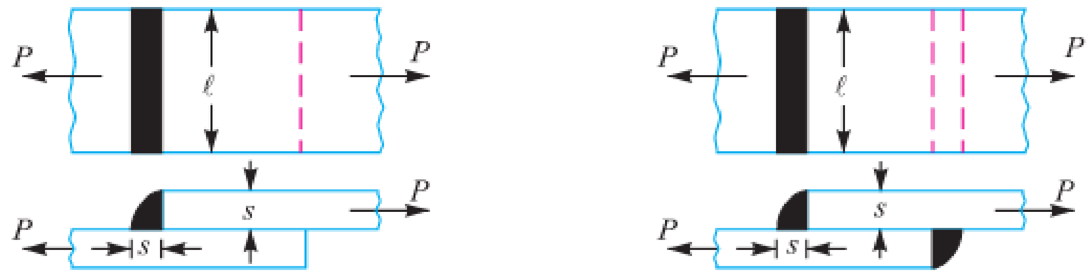
3. Since no provision is kept for expansion and contraction in the frame, therefore there is a possibility of cracks developing in it.

4. The inspection of welding work is more difficult than riveting work.

2.4 Design of welded joints

Strength of Transverse Fillet Welded Joints

We have already discussed that the fillet or lap joint is obtained by overlapping the plates and then welding the edges of the plates. The transverse fillet welds are designed for tensile strength. Let us consider a single and double transverse fillet welds as shown in Fig. (a) and (b) respectively



(*a*) Single transverse fillet weld. (*b*) Double transverse fillet weld.

Transverse fillet welds.

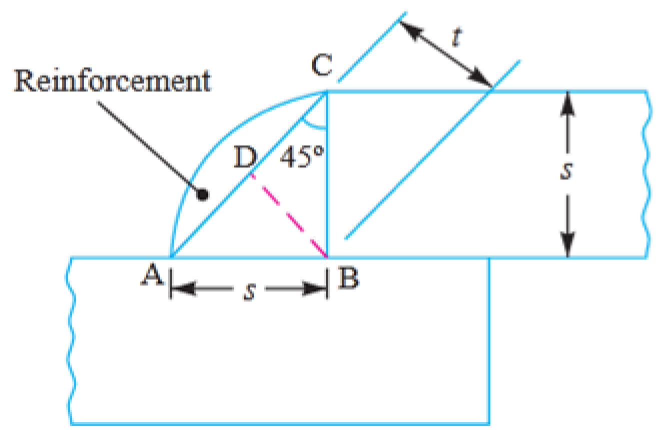
In order to determine the strength of the fillet joint, it is assumed that the section of fillet is a right angled triangle ABC with hypotenuse AC making equal angles with other two sides AB and BC. The enlarged view of the fillet is shown in Fig. The length of each side is known as leg or size of the weld and the perpendicular distance of the hypotenuse from the intersection of legs (i.e. BD) is known as throat thickness. The minimum area of the weld is obtained at the throat BD, which is given by the product of the throat thickness and length of weld.

Let t = Throat thickness (BD),

s = Leg or size of weld,

= Thickness of plate, and

l = Length of weld,



Enlarged view of a fillet weld.

From Fig. we find that the throat thickness,

$$t = s \times \sin 45° = 0.707\, s$$

∴ *Minimum area of the weld or throat area,

$$A = \text{Throat thickness} \times \text{Length of weld}$$

$$= t \times l = 0.707\, s \times l$$

If σ_t is the allowable tensile stress for the weld metal, then the tensile strength of the joint for single fillet weld,

$$P = \text{Throat area} \times \text{Allowable tensile stress} = 0.707\, s \times l \times \sigma_t$$

and tensile strength of the joint for double fillet weld,

$$P = 2 \times 0.707\, s \times l \times \sigma_t = 1.414\, s \times l \times \sigma_t$$

Strength of Parallel Fillet Welded Joints

The parallel fillet welded joints are designed for shear strength. Consider a double parallel fillet welded joint as shown in Fig.(a). We have already discussed in the previous article, that the minimum area of weld or the throat area

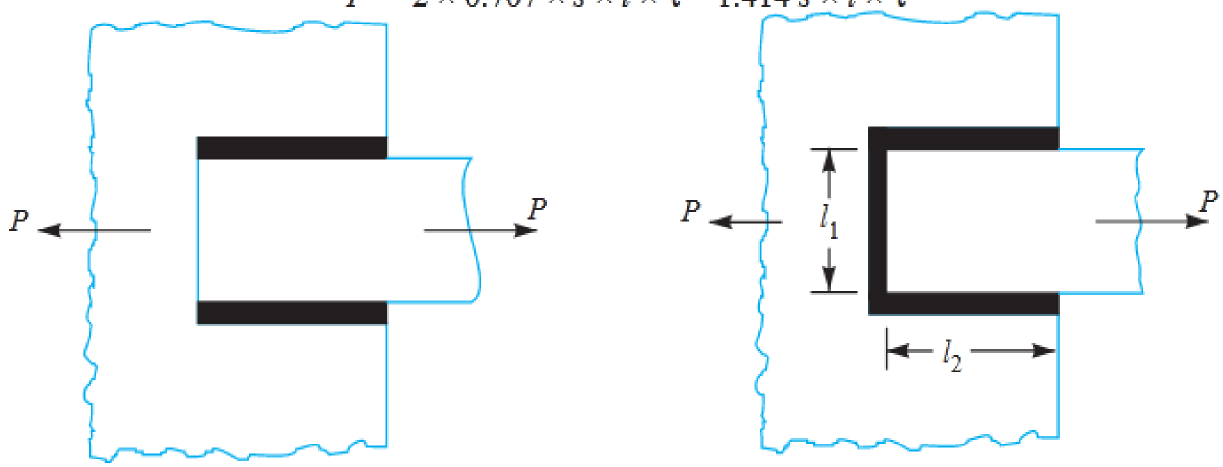
$$A = 0.707\ s \times l$$

If τ is the allowable shear stress for the weld metal, then the shear strength of the joint for single parallel fillet weld,

$$P = \text{Throat area} \times \text{Allowable shear stress} = 0.707\ s \times l \times \tau$$

and shear strength of the joint for double parallel fillet weld,

$$P = 2 \times 0.707 \times s \times l \times \tau = 1.414\ s \times l \times \tau$$



(*a*) Double parallel fillet weld.

(*b*) Combination of transverse and parallel fillet weld.

Notes: 1. If there is a combination of single transverse and double parallel fillet welds as shown in Fig. (*b*), then the strength of the joint is given by the sum of strengths of single transverse and double parallel fillet welds. Mathematically,

$$P = 0.707 s \times l_1 \times \sigma_t + 1.414\ s \times l_2 \times \tau$$

where l_1 is normally the width of the plate.

2. In order to allow for starting and stopping of the bead, 12.5 mm should be added to the length of each weld obtained by the above expression.

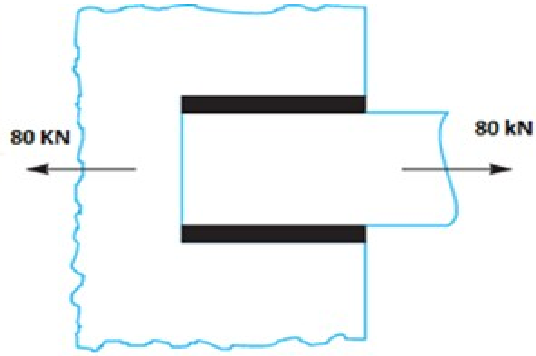
3. For reinforced fillet welds, the throat dimension may be taken as 0.85 *t*.

Example 1 *A plate 100 mm wide and 10 mm thick is to be welded to another plate by means of double parallel fillets. The plates are subjected to a static load of 80 kN. Find the length of weld if the permissible shear stress in the weld does not exceed 55 MPa.*

Solution. Given: *Width = 100 mm ; Thickness = 10 mm ; P = 80 kN = 80×10^3 N ; τ = 55 MPa = 55 N/mm²

Let l = Length of weld, and

s = Size of weld = Plate thickness = 10 mm ... (Given)



(*a*) Double parallel fillet weld.

We know that maximum load which the plates can carry for double parallel fillet weld (P),

$$80 \times 10^3 = 1.414 \times s \times l \times \tau = 1.414 \times 10 \times l \times 55 = 778\, l$$

$$\therefore \quad l = 80 \times 10^3 / 778 = 103 \text{ mm}$$

Adding 12.5 mm for starting and stopping of weld run, we have

$$l = 103 + 12.5 = 115.5 \text{ mm} \quad \textbf{Ans.}$$

Example 2

A plate 100 mm wide and 12.5 mm thick is to be welded to another plate by means of parallel fillet welds. The plates are subjected to a load of 50 kN. Find the length of the weld so that the maximum stress does not exceed 56 MPa. Consider the joint first under static loading and then under fatigue loading.

Solution. Given: *Width = 100 mm ; Thickness = 12.5 mm ; P = 50 kN = 50×10^3N ; τ = 56 MPa = 56 N/mm²

Length of weld for static loading

Let l = Length of weld, and

s = Size of weld = Plate thickness

= 12.5 mm ... (Given)

We know that the maximum load which the plates can carry for double parallel fillet welds (P),

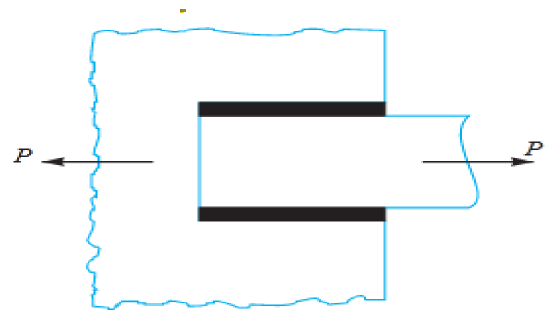
$$50 \times 10^3 = 1.414\, s \times l \times \tau$$

$$= 1.414 \times 12.5 \times l \times 56 = 990\, l$$

$$\therefore \quad l = 50 \times 10^3 / 990 = 50.5 \text{ mm}$$

Adding 12.5 mm for starting and stopping of weld run, we have

$$l = 50.5 + 12.5 = 63 \text{ mm} \quad \textbf{Ans.}$$



Length of weld for fatigue loading

From Table 10.6, we find that the stress concentration factor for parallel fillet welding is 2.7.

∴ Permissible shear stress,

$$\tau = 56 / 2.7 = 20.74 \text{ N/mm}^2$$

We know that the maximum load which the plate can carry for double parallel fillet welds (P),

$$50 \times 10^3 = 1.414\, s \times l \times \tau = 1.414 \times 12.5 \times l \times 20.74 = 367\, l$$

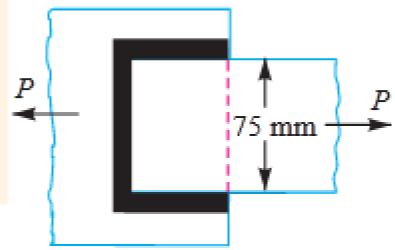
$$\therefore \quad l = 50 \times 10^3 / 367 = 136.2 \text{ mm}$$

Adding 12.5 for starting and stopping of weld run, we have

$$l = 136.2 + 12.5 = 148.7 \text{ mm} \quad \textbf{Ans.}$$

Example 3 *A plate 75 mm wide and 12.5 mm thick is joined with another plate by a single transverse weld and a double parallel fillet weld as shown in Fig. 10.15. The maximum tensile and shear stresses are 70 MPa and 56 MPa respectively.*

Find the length of each parallel fillet weld, if the joint is subjected to both static and fatigue loading.



Solution. Given : Width = 75 mm ; Thickness = 12.5 mm ; $\sigma_\tau = 70$ MPa = 70 N/mm^2 ; $\tau = 56$ MPa = 56 N/mm^2.

The effective length of weld (l_1) for the transverse weld may be obtained by subtracting 12.5 mm from the width of the plate.

$$\therefore \quad l_1 = 75 - 12.5 = 62.5 \text{ mm}$$

Length of each parallel fillet for static loading

Let $\quad l_2$ = Length of each parallel fillet.

We know that the maximum load which the plate can carry is

$$P = \text{Area} \times \text{Stress} = 75 \times 12.5 \times 70 = 65\,625 \text{ N}$$

Load carried by single transverse weld,

$$P_1 = 0.707\, s \times l_1 \times \sigma_t = 0.707 \times 12.5 \times 62.5 \times 70 = 38\,664 \text{ N}$$

and the load carried by double parallel fillet weld,

$$P_2 = 1.414\, s \times l_2 \times \tau = 1.414 \times 12.5 \times l_2 \times 56 = 990\, l_2 \text{ N}$$

$\therefore$ Load carried by the joint (P),

$$65\,625 = P_1 + P_2 = 38\,664 + 990\, l_2 \quad \text{or} \quad l_2 = 27.2 \text{ mm}$$

Adding 12.5 mm for starting and stopping of weld run, we have

$$l_2 = 27.2 + 12.5 = 39.7 \text{ say } 40 \text{ mm}$$ **Ans.**

Length of each parallel fillet for fatigue loading

From Table 10.6, we find that the stress concentration factor for transverse welds is 1.5 and for parallel fillet welds is 2.7.

$\therefore$ Permissible tensile stress,

$$\sigma_t = 70 / 1.5 = 46.7 \text{ N/mm}^2$$

and permissible shear stress,

$$\tau = 56 / 2.7 = 20.74 \text{ N/mm}^2$$

Load carried by single transverse weld,

$$P_1 = 0.707\, s \times l_1 \times \sigma_t = 0.707 \times 12.5 \times 62.5 \times 46.7 = 25\,795 \text{ N}$$

and load carried by double parallel fillet weld,

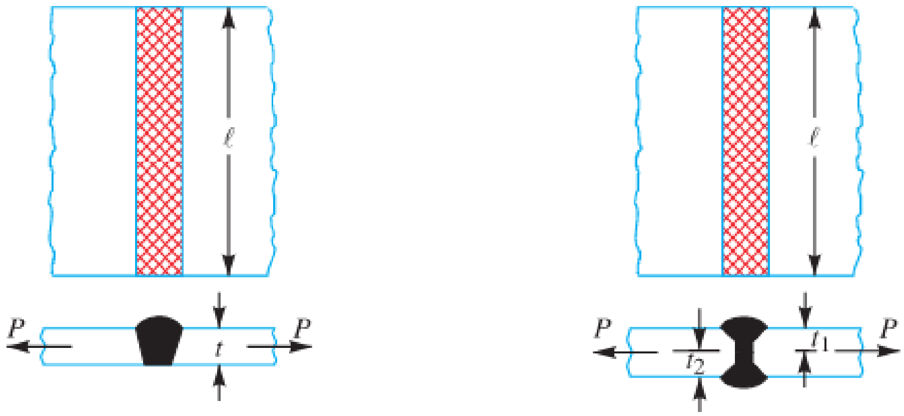
$$P_2 = 1.414\, s \times l_2 \times \tau = 1.414 \times 12.5\, l_2 \times 20.74 = 366\, l_2 \text{ N}$$

$\therefore$ Load carried by the joint (P),

$$65\,625 = P_1 + P_2 = 25\,795 + 366\, l_2 \quad \text{or} \quad l_2 = 108.8 \text{ mm}$$

Strength of Butt Joints

The butt joints are designed for tension or compression. Consider a single V-butt joint as shown in Fig. (*a*).



(*a*) Single *V*-butt joint. (*b*) Double *V*-butt joint.

In case of butt joint, the length of leg or size of weld is equal to the throat thickness which is equal to thickness of plates.

∴ Tensile strength of the butt joint (single-*V* or square butt joint),

$$P = t \times l \times \sigma_t$$

where l = Length of weld. It is generally equal to the width of plate.

and tensile strength for double-*V* butt joint as shown in Fig. (*b*) is given by

$$P = (t_1 + t_2)\, l \times \sigma_t$$

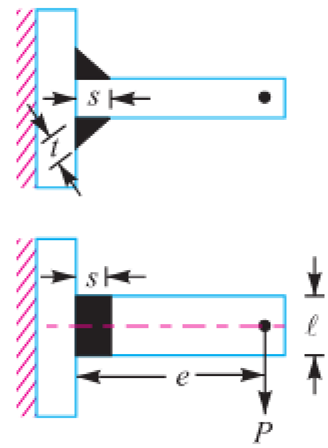
where t_1 = Throat thickness at the top, and

t_2 = Throat thickness at the bottom.

It may be noted that size of the weld should be greater than the thickness of the plate, but it may be less. The following table shows recommended minimum size of the welds.

Eccentrically Loaded Welded Joints

An eccentric load may be imposed on welded joints in many ways. The stresses induced on the joint may be of different nature or of the same nature. The induced stresses are combined depending upon the nature of stresses. When the shear and bending stresses are simultaneously present in a joint (see case 1), then maximum stresses are as follows:



Maximum normal stress,

$$\sigma_{t(max)} = \frac{\sigma_b}{2} + \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,\tau^2}$$

and maximum shear stress,

$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,\tau^2}$$

where σ_b = Bending stress, and

τ = Shear stress.

When the stresses are of the same nature, these may be combined vectorially (see case 2).

We shall now discuss the two cases of eccentric loading as follows:

Case 1

Consider a *T*-joint fixed at one end and subjected to an eccentric load *P* at a distance *e* as shown in Fig. 10.22.

Let s = Size of weld,

l = Length of weld, and

t = Throat thickness.

The joint will be subjected to the following two types of stresses:

1. Direct shear stress due to the shear force *P* acting at the welds, and
2. Bending stress due to the bending moment $P \times e$.

We know that area at the throat,

$$A = \text{Throat thickness} \times \text{Length of weld}$$

$$= t \times l \times 2 = 2\,t \times l \quad \text{... (For double fillet weld)}$$

$$= 2 \times 0.707\,s \times l = 1.414\,s \times l \quad \text{... } (\because\ t = s\cos 45° = 0.707\,s)$$

∴ Shear stress in the weld (assuming uniformly distributed),

$$\tau = \frac{P}{A} = \frac{P}{1.414\, s \times l}$$

Section modulus of the weld metal through the throat,

$$Z = \frac{t \times l^2}{6} \times 2 \qquad \text{...(For both sides weld)}$$

$$= \frac{0.707\, s \times l^2}{6} \times 2 = \frac{s \times l^2}{4.242}$$

Bending moment, $M = P \times e$

$$\therefore \text{ Bending stress, } \sigma_b = \frac{M}{Z} = \frac{P \times e \times 4.242}{s \times l^2} = \frac{4.242\, P \times e}{s \times l^2}$$

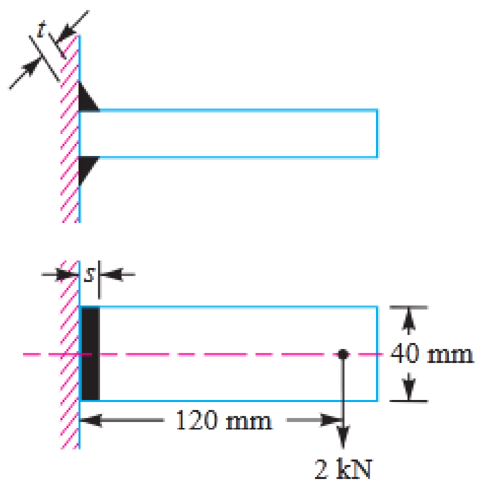
We know that the maximum normal stress,

$$\sigma_{t(max)} = \frac{1}{2}\sigma_b + \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,\tau^2}$$

and maximum shear stress,

$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,\tau^2}$$

Example 4 *A welded joint as shown in Fig. 10.24, is subjected to an eccentric load of 2 kN. Find the size of weld, if the maximum shear stress in the weld is 25 MPa.*



Solution. Given: P = 2kN = 2000 N ; e = 120 mm ; l = 40 mm ; τ_{max} = 25 MPa = 25 N/mm²

Let s = Size of weld in mm, and

t = Throat thickness.

The joint, as shown in Fig. 10.24, will be subjected to direct shear stress due to the shear force, P = 2000 N and bending stress due to the bending moment of $P \times e$.

We know that area at the throat,

$$A = 2t \times l = 2 \times 0.707\, s \times l$$

$$= 1.414\, s \times l$$

$$= 1.414\, s \times 40 = 56.56 \times s \text{ mm}^2$$

$$\therefore \text{ Shear stress,} \quad \tau = \frac{P}{A} = \frac{2000}{56.56 \times s} = \frac{35.4}{s} \text{ N/mm}^2$$

Bending moment, $M = P \times e = 2000 \times 120 = 240 \times 10^3$ N-mm

Section modulus of the weld through the throat,

$$Z = \frac{s \times l^2}{4.242} = \frac{s\,(40)^2}{4.242} = 377 \times s \text{ mm}^3$$

$$\therefore \text{ Bending stress, } \sigma_b = \frac{M}{Z} = \frac{240 \times 10^3}{377 \times s} = \frac{636.6}{s} \text{ N/mm}^2$$

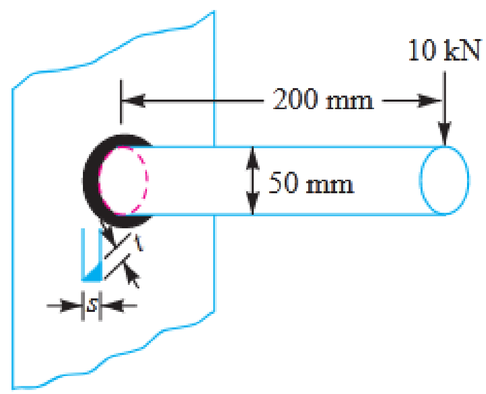
We know that maximum shear stress (τ_{max}),

$$25 = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,\tau^2} = \frac{1}{2}\sqrt{\left(\frac{636.6}{s}\right)^2 + 4\left(\frac{35.4}{s}\right)^2} = \frac{320.3}{s}$$

$\therefore$ $s = 320.3 / 25 = 12.8$ mm **Ans.**

Example 5 *A 50 mm diameter solid shaft is welded to a flat plate as shown in Fig. If the size of the weld is 15 mm, find the maximum normal and shear stress in the weld.*

Solution. Given : $D = 50$ mm ; $s = 15$ mm ; $P = 10$ kN $= 10\,000$ N ; $e = 200$ mm



Let t = Throat thickness.

The joint, as shown in Fig. 10.25, is subjected to direct shear stress and the bending stress. We know that the throat area for a circular fillet weld,

$$A = t \times \pi D = 0.707\, s \times \pi D$$
$$= 0.707 \times 15 \times \pi \times 50$$
$$= 1666 \text{ mm}^2$$

$\therefore$ Direct shear stress,

$$\tau = \frac{P}{A} = \frac{10\,000}{1666} = 6 \text{ N/mm}^2 = 6 \text{ MPa}$$

We know that bending moment,

$$M = P \times e = 10\,000 \times 200 = 2 \times 10^6 \text{ N-mm}$$

From Table 10.7, we find that for a circular section, section modulus,

$$Z = \frac{\pi\, t\, D^2}{4} = \frac{\pi \times 0.707\, s \times D^2}{4} = \frac{\pi \times 0.707 \times 15\,(50)^2}{4} = 20\,825 \text{ mm}^3$$

$\therefore$ Bending stress,

$$\sigma_b = \frac{M}{Z} = \frac{2 \times 10^6}{20\,825} = 96 \text{ N/mm}^2 = 96 \text{ MPa}$$

Maximum shear stress

We know that the maximum shear stress,

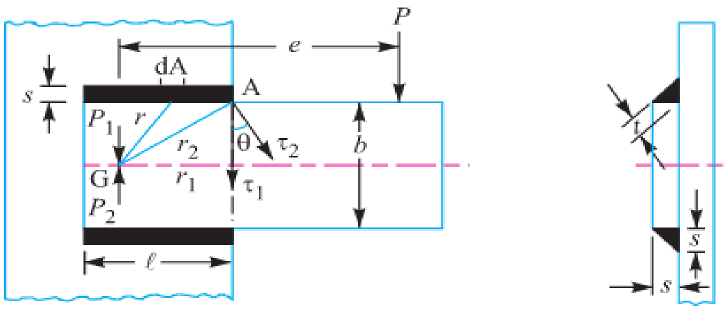
$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,\tau^2} = \frac{1}{2}\sqrt{(96)^2 + 4 \times 6^2} = 48.4 \text{ MPa} \quad \textbf{Ans.}$$

Case 2

When a welded joint is loaded eccentrically as shown in Fig. the following two types of the stresses are induced:

1. Direct or primary shear stress, and

2. Shear stress due to turning moment.



Eccentrically loaded welded joint.

Let P = Eccentric load,

e = Eccentricity *i.e.* perpendicular distance between the line of action of load and centre of gravity (G) of the throat section or fillets,

l = Length of single weld,

s = Size or leg of weld, and

t = Throat thickness.

Let two loads P_1 and P_2 (each equal to P) are introduced at the centre of gravity 'G' of the weld system. The effect of load $P_1 = P$ is to produce direct shear stress which is assumed to be uniform over the entire weld length. The effect of load $P_2 = P$ is to produce a turning moment of magnitude $P \times e$ which tends of rotate the joint about the centre of gravity 'G' of the weld system. Due to the turning moment, secondary shear stress is induced.

We know that the direct or primary shear stress,

$$\tau_1 = \frac{\text{Load}}{\text{Throat area}} = \frac{P}{A} = \frac{P}{2\,t \times l}$$

$$= \frac{P}{2 \times 0.707\, s \times l} = \frac{P}{1.414\, s \times l}$$

... ($\because$ Throat area for single fillet weld $= t \times l = 0.707\, s \times 1$)

Since the shear stress produced due to the turning moment ($T = P \times e$) at any section is proportional to its radial distance from G, therefore stress due to $P \times e$ at the point A is proportional to AG (r_2) and is in a direction at right angles to AG. In other words,

$$\frac{\tau_2}{r_2} = \frac{\tau}{r} = \text{Constant}$$

or

$$\tau = \frac{\tau_2}{r_2} \times r \qquad ...(i)$$

where τ_2 is the shear stress at the maximum distance (r_2) and τ is the shear stress at any distance r.

Consider a small section of the weld having area dA at a distance r from G.

$\therefore$ Shear force on this small section

$$= \tau \times dA$$

and turning moment of this shear force about G,

$$dT = \tau \times dA \times r = \frac{\tau_2}{r_2} \times dA \times r^2 \quad \text{... [From equation } (i)]$$

$\therefore$ Total turning moment over the whole weld area,

$$T = P \times e = \int \frac{\tau_2}{r_2} \times dA \times r^2 = \frac{\tau_2}{r_2} \int dA \times r^2$$

$$= \frac{\tau_2}{r_2} \times J \qquad \left(\because J = \int dA \times r^2\right)$$

where J = Polar moment of inertia of the throat area about G.

$\therefore$ Shear stress due to the turning moment *i.e.* secondary shear stress,

$$\tau_2 = \frac{T \times r_2}{J} = \frac{P \times e \times r_2}{J}$$

In order to find the resultant stress, the primary and secondary shear stresses are combined vectorially.

$\therefore$ Resultant shear stress at A,

$$\tau_A = \sqrt{(\tau_1)^2 + (\tau_2)^2 + 2\tau_1 \times \tau_2 \times \cos\theta}$$

where θ = Angle between τ_1 and τ_2, and

$$\cos\theta = r_1 / r_2$$

Note: The polar moment of inertia of the throat area (A) about the centre of gravity (G) is obtained by the parallel axis theorem, *i.e.*

$$J = 2\,[I_{xx} + A \times x^2] \qquad \text{... (}\because\text{ of double fillet weld)}$$

$$= 2\left[\frac{A \times l^2}{12} + A \times x^2\right] = 2A\left(\frac{l_2}{12} + x^2\right)$$

where A = Throat area $= t \times l = 0.707\, s \times l$,

l = Length of weld, and

x = Perpendicular distance between the two parallel axes.

Example 6 . *A bracket carrying a load of 15 kN is to be welded as shown in Fig. . Find the size of weld required if the allowable shear stress is not to exceed 80 MPa.*

Solution. Given : $P = 15$ kN $= 15 \times 10^3$ N ; $\tau = 80$ MPa $= 80$ N/mm^2; $b = 80$ mm ; $l = 50$ mm; $e = 125$ mm

Let s = Size of weld in mm, and

t = Throat thickness.

We know that the throat area,

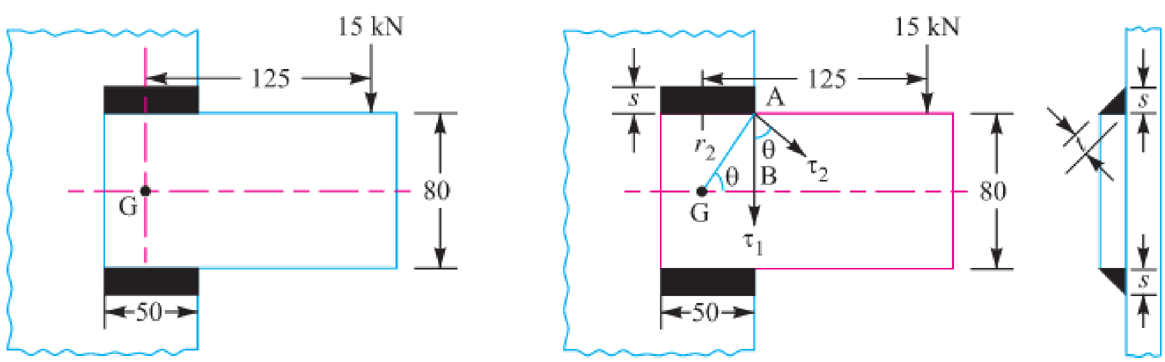
$$A = 2 \times t \times l = 2 \times 0.707\, s \times l$$
$$= 1.414\, s \times l = 1.414 \times s \times 50 = 70.7\, s \text{ mm}^2$$

∴ Direct or primary shear stress,

$$\tau_1 = \frac{P}{A} = \frac{15 \times 10^3}{70.7\, s} = \frac{212}{s} \text{ N/mm}^2$$

From Table 10.7, we find that for such a section, the polar moment of inertia of the throat area of the weld about G is

$$J = \frac{t\,l\,(3b^2 + l^2)}{6} = \frac{0.707\, s \times 50\, [3\,(80)^2 + (50)^2]}{6} \text{ mm}^4$$
$$= 127\,850\, s \text{ mm}^4 \qquad \text{... } (\because\ t = 0.707\, s)$$



All dimensions in mm.

From Fig. . we find that $AB = 40$ mm and $BG = r_1 = 25$ mm.

∴ Maximum radius of the weld,

$$r_2 = \sqrt{(AB)^2 + (BG)^2} = \sqrt{(40)^2 + (25)^2} = 47 \text{ mm}$$

Shear stress due to the turning moment *i.e.* secondary shear stress,

$$\tau_2 = \frac{P \times e \times r_2}{J} = \frac{15 \times 10^3 \times 125 \times 47}{127\ 850\ s} = \frac{689.3}{s} \text{ N/mm}^2$$

and $$\cos\theta = \frac{r_1}{r_2} = \frac{25}{47} = 0.532$$

We know that resultant shear stress,

$$\tau = \sqrt{(\tau_1)^2 + (\tau_2)^2 + 2\,\tau_1 \times \tau_2 \cos\theta}$$

$$80 = \sqrt{\left(\frac{212}{s}\right)^2 + \left(\frac{689.3}{s}\right)^2 + 2 \times \frac{212}{s} \times \frac{689.3}{s} \times 0.532} = \frac{822}{s}$$

$\therefore$ $$s = 822 / 80 = 10.3 \text{ mm} \quad \textbf{Ans.}$$

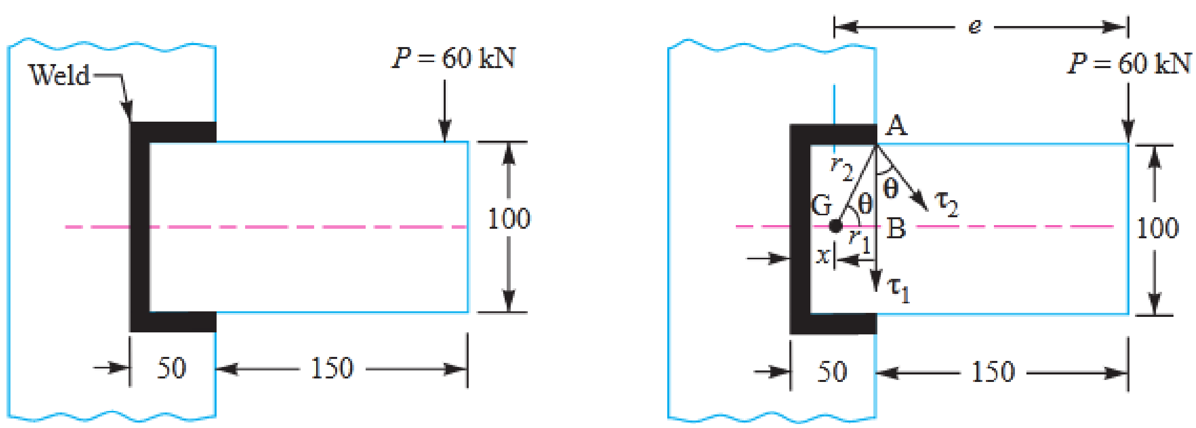
Example 7 . *A rectangular steel plate is welded as a cantilever to a vertical column and supports a single concentrated load P, as shown in Fig. 10.30.*

Determine the weld size if shear stress in the same is not to exceed 140 MPa.

Solution. Given : $P = 60$ kN $= 60 \times 10^3$ N ; $b = 100$ mm ; $l = 50$ mm ; $\tau = 140$ MPa $= 140$ N/mm^2

Let s = Weld size, and

t = Throat thickness.



All dimensions in mm.

First of all, let us find the centre of gravity (G) of the weld system, as shown in Fig.

Let x be the distance of centre of gravity (G) from the left hand edge of the weld system. From Table 10.7, we find that for a section as shown in Fig. 10.31,

$$x = \frac{l^2}{2l+b} = \frac{(50)^2}{2 \times 50 + 100} = 12.5 \text{ mm}$$

and polar moment of inertia of the throat area of the weld system about G,

$$J = t\left[\frac{(b+2l)^3}{12} - \frac{l^2\,(b+l)^2}{b+2l}\right]$$

$$= 0.707\,s\left[\frac{(100+2\times 50)^3}{12} - \frac{(50)^2\,(100+50)^2}{100+2\times 50}\right] \quad \ldots (\because\ t = 0.707\,s)$$

$$= 0.707s\,[670 \times 10^3 - 281 \times 10^3] = 275 \times 10^3\, s \text{ mm}^4$$

Distance of load from the centre of gravity (G) *i.e.* eccentricity,

$$e = 150 + 50 - 12.5 = 187.5 \text{ mm}$$

$$r_1 = BG = 50 - x = 50 - 12.5 = 37.5 \text{ mm}$$

$$AB = 100 / 2 = 50 \text{ mm}$$

We know that maximum radius of the weld,

$$r_2 = \sqrt{(AB)^2 + (BG)^2} = \sqrt{(50)^2 + (37.5)^2} = 62.5 \text{ mm}$$

$$\therefore \qquad \cos\theta = \frac{r_1}{r_2} = \frac{37.5}{62.5} = 0.6$$

We know that throat area of the weld system,

$$A = 2 \times 0.707s \times l + 0.707s \times b = 0.707\,s\,(2l + b)$$

$$= 0.707s\,(2 \times 50 + 100) = 141.4\,s \text{ mm}^2$$

$\therefore$ Direct or primary shear stress,

$$\tau_1 = \frac{P}{A} = \frac{60 \times 10^3}{141.4\,s} = \frac{424}{s} \text{ N/mm}^2$$

and shear stress due to the turning moment or secondary shear stress,

$$\tau_2 = \frac{P \times e \times r_2}{J} = \frac{60 \times 10^3 \times 187.5 \times 62.5}{275 \times 10^3\ s} = \frac{2557}{s} \text{ N/mm}^2$$

We know that the resultant shear stress,

$$\tau = \sqrt{(\tau_1)^2 + (\tau_2)^2 + 2\,\tau_1 \times \tau_2 \times \cos\theta}$$

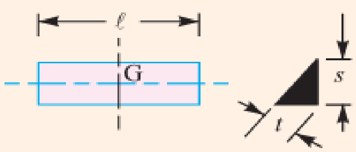
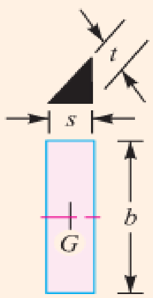
$$140 = \sqrt{\left(\frac{424}{s}\right)^2 + \left(\frac{2557}{s}\right)^2 + 2 \times \frac{424}{s} \times \frac{2557}{s} \times 0.6} = \frac{2832}{s}$$

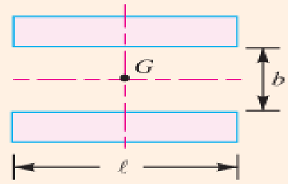
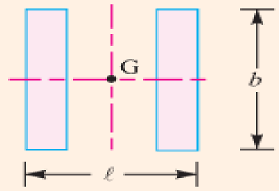
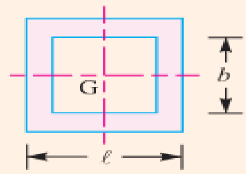
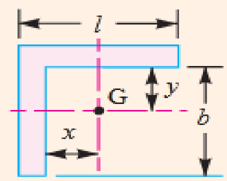
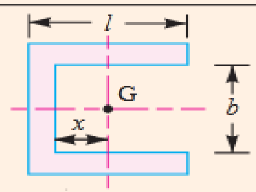
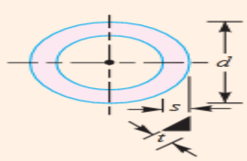
$\therefore \quad s = 2832 / 140 = 20.23$ mm **Ans.**

Polar Moment of Inertia and Section Modulus of Welds

The following table shows the values of polar moment of inertia of the throat area about the centre of gravity *'G'* and section modulus for some important types of welds which may be used for eccentric loading.

Table Polar moment of inertia and section modulus of welds.

S.No	*Type of weld*	*Polar moment of inertia (J)*	*Section modulus (Z)*
1.		$\frac{t.l^3}{12}$	—
2.		$\frac{t.b^3}{12}$	$\frac{t.b^2}{6}$

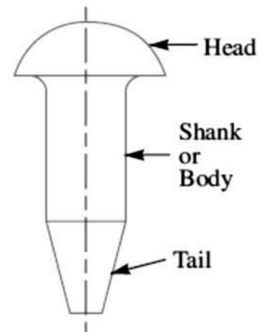
S.No	Type of weld	Polar moment of inertia (J)	Section modulus (Z)
3.		$\frac{t.l\,(3b^2 + l^2)}{6}$	$t.b.l$
4.		$\frac{t.b\,(b^2 + 3l^2)}{6}$	$\frac{t.b^2}{3}$
5.		$\frac{t\,(b + l)^3}{6}$	$t\left(b.l + \frac{b^2}{3}\right)$
6.	 $x = \frac{l^2}{2\,(l + b)},\ y = \frac{b^2}{2\,(l + b)}$	$t\left[\frac{(b + l)^4 - 6b^2l^2}{12\,(l + b)}\right]$	$t\left(\frac{4l.b + b^2}{6}\right)$ (Top) $t\left[\frac{b^2\,(4lb + b)}{6\,(2l + b)}\right]$ (Bottom)
7.	 $x = \frac{l^2}{2l + b}$	$t\left[\frac{(b + 2l)^3}{12} - \frac{l^2\,(b + l)^2}{b + 2l}\right]$	$t\left(l.b + \frac{b^2}{6}\right)$
8.		$\frac{\pi t d^3}{4}$	$\frac{\pi t d^2}{4}$

2.5 State types of riveted joints and types of rivets.

Riveted joint:

The rivets are used to make permanent fastening between the two or more plates such as in structural work, ship building, bridges, tanks and boiler shells. The riveted joints are widely used for joining light metals.

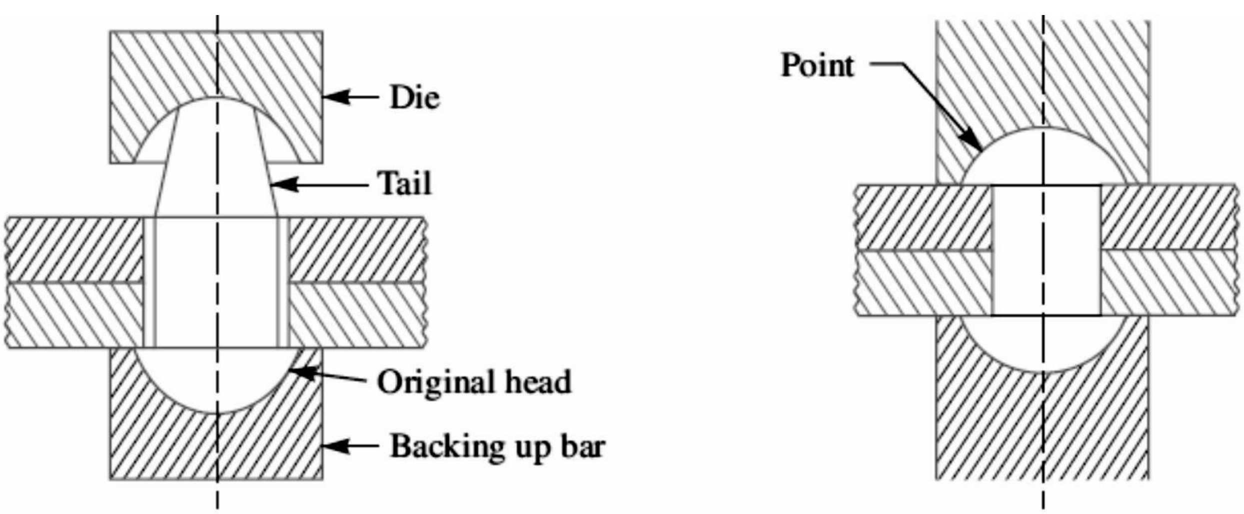
A rivet is a short cylindrical bar with a head integral to it. The cylindrical portion of the rivet is called shank or body and lower portion of shank is known as tail.



Methods of Riveting

The function of rivets in a joint is to make a connection that has strength and tightness. The strength is necessary to prevent failure of the joint. The tightness is necessary in order to contribute to strength and to prevent leakage as in a boiler or in a ship hull (The frame or body of ship).

When two plates are to be fastened together by a rivet as shows below, the holes in the plates are punched and reamed or drilled. Punching is the cheapest method and is used for relatively thin plates and in structural work. Since punching injures the material around the hole, therefore drilling is used in most pressure-vessel work.



(*a*) Initial position. (*b*) Final position.

In structural and pressure vessel riveting, the diameter of the rivet hole is usually 1.5 mm larger than the nominal diameter of the rivet.
A cold rivet or a red hot rivet is introduced into the plates and the point (i.e. second head) is then formed.
When a cold rivet is used, the process is known as cold riveting and when a hot rivet is used, the process is

known as hot riveting.

The cold riveting process is used for structural joints while hot riveting is used to make leak proof joints.

Notes: 1. For steel rivets upto 12 mm diameter, the cold riveting process may be used while for larger diameter Rivets, hot riveting process are used.

2. In case of long rivets, only the tail is heated and not the whole shank

Material of Rivets:

The material of the rivets must be tough and ductile. They are usually made of steel (low carbon steel or nickel steel), brass, aluminum or copper, but when strength and a fluid tight joint is the main consideration, then the steel rivets are used.

Types of Rivets:

1. Button Head
2. Counter sunk Head
3. Oval counter Head
4. Pan Head
5. Conical Head

Types of Riveted Joints

1. According to purpose
2. According to position of plates connected
3. According to arrangement of rivets

1. **According to purpose**:

   a) Strong Joints: In these Joints strength is the only criterion. Eg: Beams, Trusses and Machine Joints.

   b) Tight joints: These joints provide strength as well as are leak proofagainst low pressure. Eg: Reservoir, Containers and tanks.

   c) Strong-Tight Joints: These are the joints applied in boilers and pressure Vessels and ensure both strength and leak proofness.

2. **According to position of plates:**

   - **Lap Joint:** A lap joint is that in which one plate overlaps the other and the two plates are then riveted together.

   - **Butt Joint:** A butt joint is that in which the main plates are touching each other and a cover plate (i.e. Strap) is placed either on one side or on both sides of the main plates. The cover plate is then riveted together with the main plates. Butt joints are of the following two types:

     a. In a single strap butt joint, the edges of the main plates butt against each other and only one cover plate is placed on one side of the main plates and then riveted together.

     b. In a double strap butt joint, the edges of the main plates butt against each other and two cover plates are placed on both sides of the main plates and then riveted together.

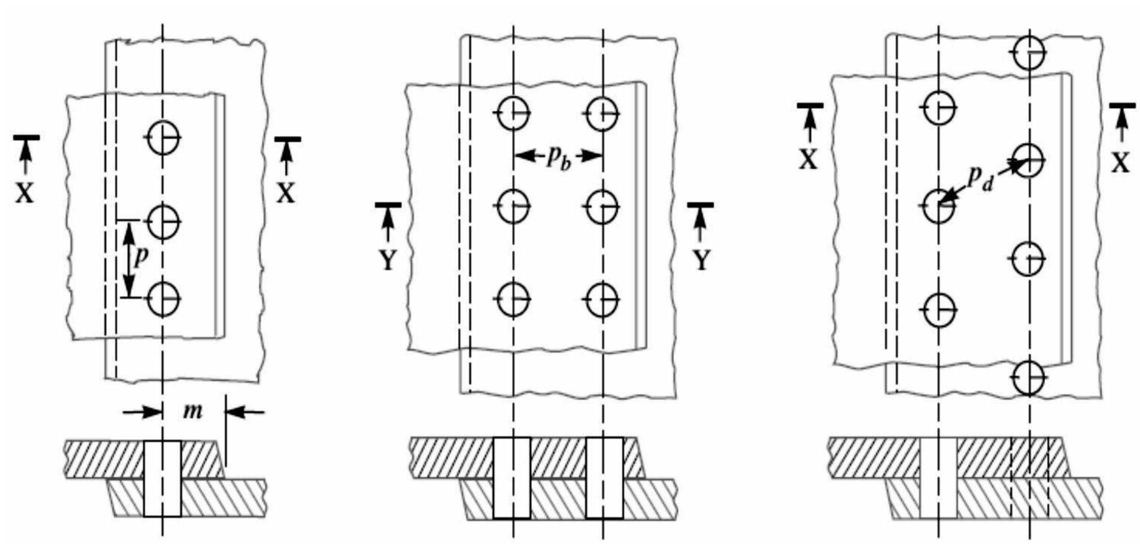
3. **<u>According to arrangement of rivets</u>:**

   a. A **single riveted joint** is that in which there is a single row of rivets in a lap joint as shown in Fig. and there is a single row of rivets on each side in a butt joint.

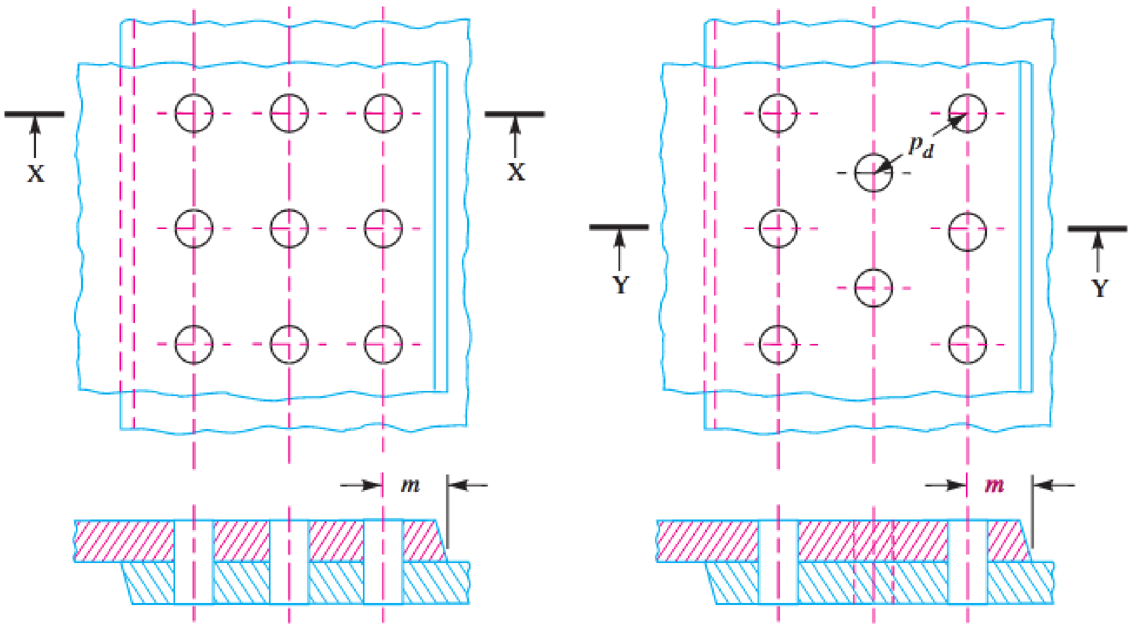
   b. A **double riveted joint** is that in which there are two rows of rivets in a lap joint as shown in Fig. and there are two rows of rivets on each side in a butt joint.

   Notes : 1. When the rivets in the various rows are opposite to each other, as shown in Fig, then the joint is said to be chain riveted.

   if the rivets in the adjacent rows are staggered in such a way that every rivet is in the middle of the two rivets of the opposite row as shown then the joint is said to be zig-zag riveted.

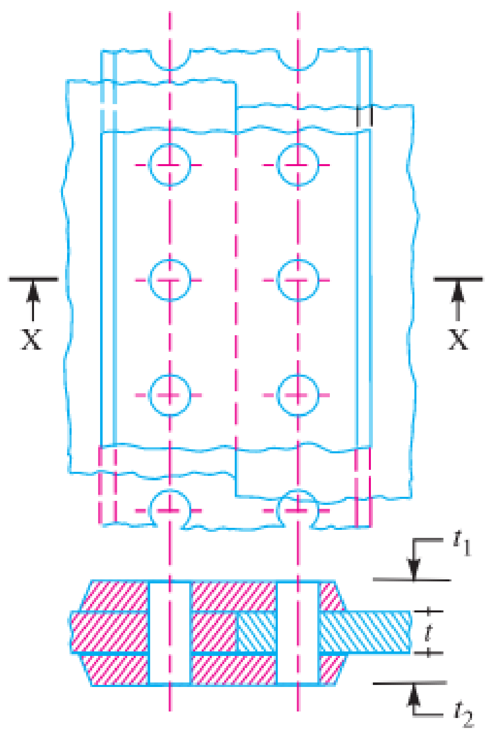


(*a*) Single riveted lap joint.
(*b*) Double riveted lap joint (Chain riveting).
(*c*) Double riveted lap joint (Zig-zag riveting).

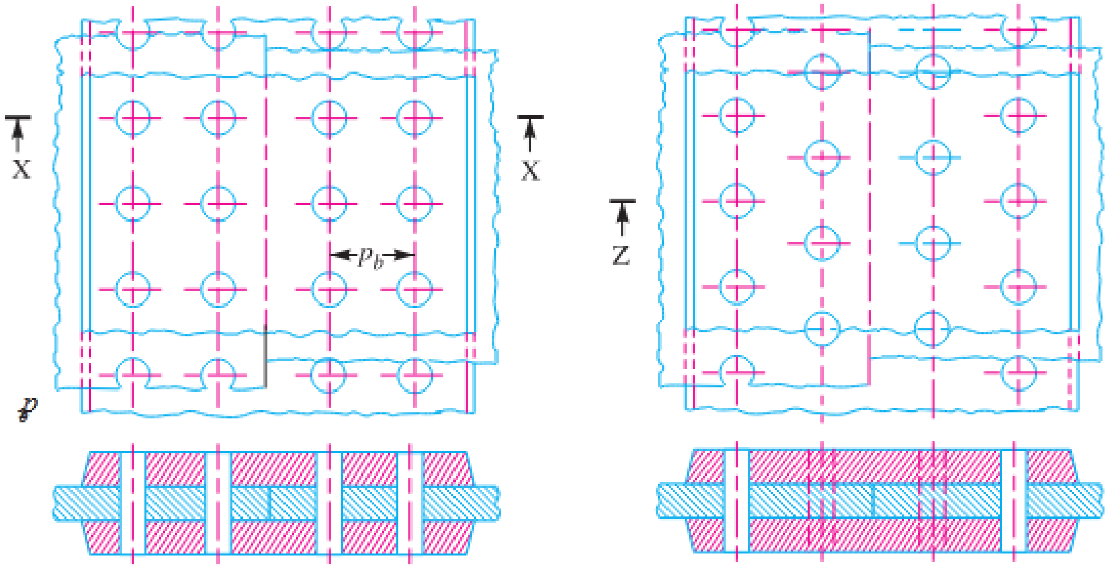


(*a*) Chain riveting. (*b*) Zig-zag riveting.

Triple riveted lap joint.

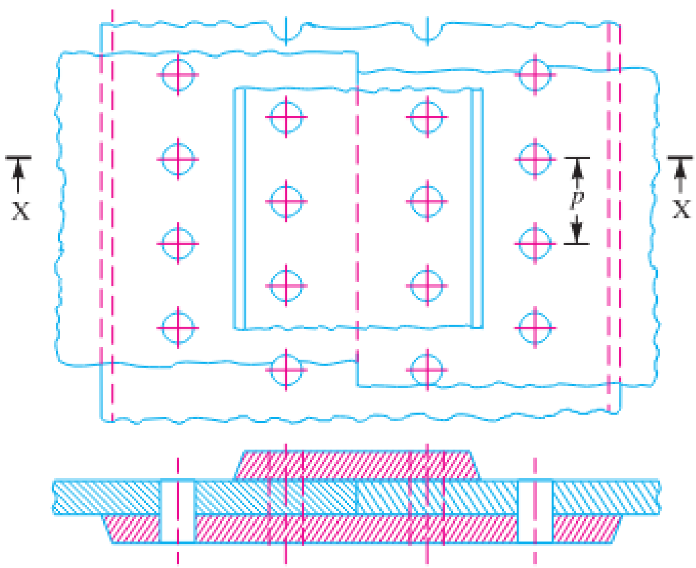


Single riveted double strap butt joint.



(*a*) Chain riveting. (*b*) Zig-zag riveting.

Double riveted double strap (equal) butt joints.

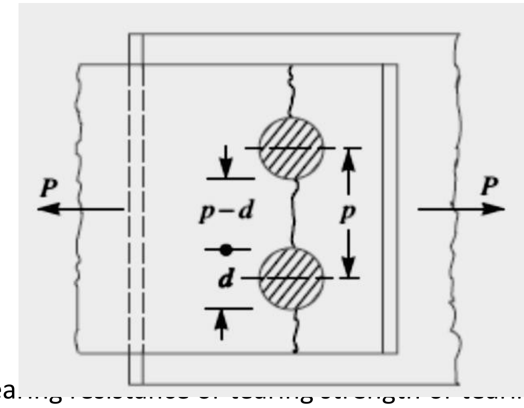


. Double riveted double strap (unequal) butt joint with zig-zag riveting.

<u>Important terms of Riveted joints</u>:

1. **Pitch (p)**: It is the distance from the centre of one rivet to the centre of the next rivet measured parallel to the seam as shown in Fig(a) It is usually denoted by p
2. **Back pitch (P_b)**: The Distance between two adjacent rows of rivets.
3. **Diagonal pitch(P_d)**: It is the distance between the centers of the rivets in adjacent rows of zigzag Riveted joint as shown in Fig. (c) It is usually denoted by p_d.
4. **Margin (m)**: It is the distance between center of a rivet hole and nearest edge of the plate.

2.6 Modes of Failures of a Riveted Joint



1. **Tearing of the plate at the section weakened by holes**: Due to the tensile stresses in the main plates, the main plate or cover plates may tear off across a row of rivets as shown in Fig. In such cases, we consider only one pitch length of the plate, since every rivet is responsible for that much length of the plate only.

The resistance offered by the plate against tearing is known as tea[illegible]g value of the plate.

Let, p = Pitch of the rivets,
d = Diameter of the rivet hole,
t = Thickness of the plate, and
σ_t = Permissible tensile stress for the plate material.

We know that tearing area per pitch length,

$$A_t = (p - d)\, t$$

Tearing resistance or pull required to tear off the plate per pitch length,

$P_t = A_t . \sigma_t = (p - d)\, t .\, \sigma_t$

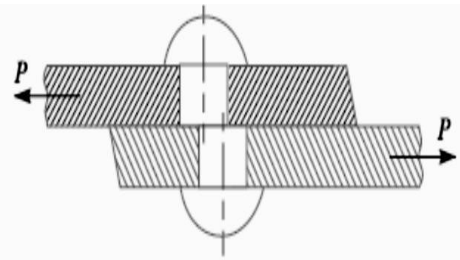
When the tearing resistance (P_t) is greater than the applied load (P) per pitch length, then this type of failure will not occur.

2. Shearing of the rivets:

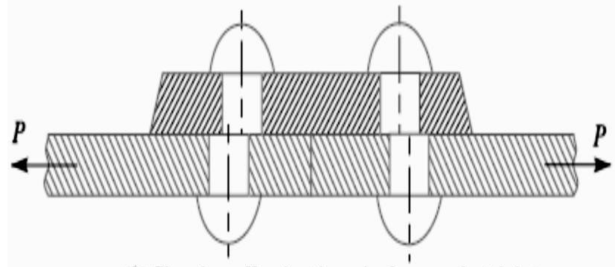
The plates which are connected by the rivets exert shear stress on the rivets, and if the rivets are unable to resist the stress, they are sheared off as shown in Fig.

It may be noted that the rivets are in single shear in a lap joint and in a single cover butt joint, as shown in Fig.(a) and (b)

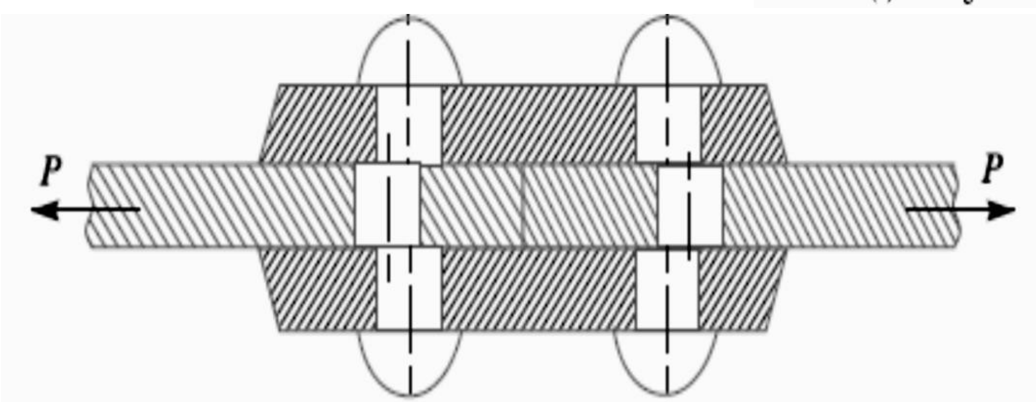
But the rivets are in double shear in a double cover butt joint as shown in Fig(c). The resistance offered by a rivet to be sheared off is known as shearing resistance or shearing strength or shearing value of the rivet.



(a) Shearing off a rivet in a lap joint.



(b) Shearing off a rivet in a single cover butt joint.



Let d = Diameter of the rivet hole,

τ = Safe permissible shear stress for the rivet material,

n = Number of rivets per pitch length.

We know that shearing area,

$A_s = (\pi/4) \times d^2$ ... (In single shear)

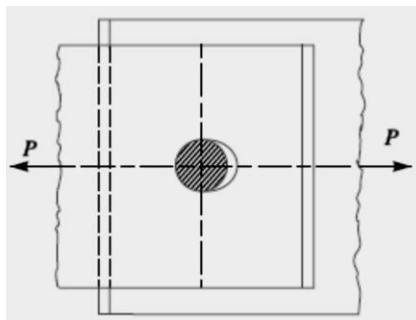
$= 2 \times (\pi/4) \times d^2$ ... (Theoretically, in double shear)

Shearing resistance required to shear off the rivet per pitch length,

$$P_s = n \times (\pi/4) \times d^2 \times \tau \quad \text{...(In single shear)}$$
$$= n \times 2 \times (\pi/4) \times d^2 \times \tau \quad \text{...(Theoretically, in double shear)}$$

When the shearing resistance (P_s) is greater than the applied load (P) per pitch length, then this type of failure will occur.

3. **<u>Crushing of the plate or rivets:</u>** Sometimes, the rivets do not actually shear off under the tensile stress, but are crushed as shown in Fig. Due to this, the rivet hole becomes of an oval shape and hence the joint becomes loose. The failure of rivets in such a manner is also known as bearing failure. The area which resists this action is the projected area of the hole or rivet on diametral plane.



The resistance offered by a rivet to be crushed is known as crushing resistance or crushing strength orbearing value of the rivet.

Let d = Diameter of the rivet hole,

t = Thickness of the plate,
σ_c = Safe permissible crushing stress for the rivet or plate material, and n = Number of rivets per pitch length under crushing.
We know that crushing area per rivet (i.e. projected area per rivet),
$$A_c = d.\ t$$

$\therefore$Total crushing area = n. d. t
and crushing resistance or pull required to crush the rivet per pitch length,
$$P_c = n.\ d.\ t.\ \sigma_c$$

When the crushing resistance (P_c) is greater than the applied load (P) per pitch length, then this type of failure will occur.
Note: The number of rivets under shear shall be equal to the number of rivets under crushing.
<u>Unwin's Formula</u>: As a Common Practice for plate thickness greater than 8 mm, the diameter of rivet hole is determined by: $d = 6\sqrt{t}$ (t = thickness of plate)

<u>2.7 Determine strength & efficiency of riveted joints.</u>

<u>Strength of a Riveted Joint:</u>

The strength of a joint may be defined as the maximum force, which it can transmit, without causing it to fail.
We have seen that P_t, P_s and P_c are the pulls required to tear off the plate, shearing off the rivet and crushing off the rivet. A little consideration will show that if we go on increasing the pull on a riveted joint, itwill fail when the

least of these three pulls is reached, because a higher value of the other pulls will never reach since the joint has failed, either by tearing off the plate, shearing off the rivet or crushing off the rivet.
If the joint is continuous as in case of boilers, the strength is calculated per pitch length. But if the joint is small, the strength is calculated for the whole length of the plate.

Efficiency of a Riveted Joint:

The efficiency of a riveted joint is defined as the ratio of the strength of riveted joint to the strength of the un-riveted or solid plate. We have already discussed that strength of the riveted joint

$$= \textbf{Least of } P_t\text{, } P_s \textbf{ and } P_c$$

Strength of the un-riveted or solid plate per pitch length,

$$P = p \cdot t \cdot \sigma_t$$

∴ Efficiency of the riveted joint,

$$\eta = \frac{\text{Least of } P_t, P_s \text{ and } P_c}{p \times t \times \sigma_t}$$

Where, σ_t = Permissible tensile stress of the plate material
p= Pitch of the rivets,
t = Thickness of the plate

Q.1: A double riveted lap joint is made between 15 mm thick plates. The rivet diameter and pitch are 25 mm and 75 mm respectively. If the ultimate stresses are 400 MPa in tension, 320 MPa in shear and 640 MPa in crushing, find the minimum force per pitch which will rupture the joint. If the above joint is subjected to a load such that the factor of safety is 4, find out the actual stresses developed in the plates and the rivets.

Solution. Given : $t = 15$ mm ; $d = 25$ mm ; $p = 75$ mm ; $\sigma_{tu} = 400$ MPa $= 400$ N/mm^2 ; $\tau_u = 320$ MPa $= 320$ N/mm^2 ; $\sigma_{cu} = 640$ MPa $= 640$ N/mm^2

Minimum force per pitch which will rupture the joint

Since the ultimate stresses are given, therefore we shall find the ultimate values of the resistances of the joint. We know that ultimate tearing resistance of the plate per pitch,

$$P_{tu} = (p - d)t \times \sigma_{tu} = (75 - 25)15 \times 400 = 300\ 000 \text{ N}$$

Ultimate shearing resistance of the rivets per pitch,

$$P_{su} = n \times \frac{\pi}{4} \times d^2 \times \tau_u = 2 \times \frac{\pi}{4}(25)^2\, 320 = 314\ 200 \text{ N} \quad ...(\because n = 2)$$

and ultimate crushing resistance of the rivets per pitch,

$$P_{cu} = n \times d \times t \times \sigma_{cu} = 2 \times 25 \times 15 \times 640 = 480\ 000 \text{ N}$$

From above we see that the minimum force per pitch which will rupture the joint is 300 000 N or 300 kN. **Ans.**

Actual stresses produced in the plates and rivets

Since the factor of safety is 4, therefore safe load per pitch length of the joint

$$= 300\ 000/4 = 75\ 000 \text{ N}$$

Let σ_{ta}, τ_a and σ_{ca} be the actual tearing, shearing and crushing stresses produced with a safe load of 75 000 N in tearing, shearing and crushing.

We know that actual tearing resistance of the plates (P_{ta}),

$$75\ 000 = (p - d)\, t \times \sigma_{ta} = (75 - 25)15 \times \sigma_{ta} = 750\, \sigma_{ta}$$

$$\therefore \quad \sigma_{ta} = 75\ 000 / 750 = 100 \text{ N/mm}^2 = 100 \text{ MPa} \quad \textbf{Ans.}$$

Actual shearing resistance of the rivets (P_{sa}),

$$75\ 000 = n \times \frac{\pi}{4} \times d^2 \times \tau_a = 2 \times \frac{\pi}{4}(25)^2\, \tau_a = 982\, \tau_a$$

$$\therefore \quad \tau_a = 75000 / 982 = 76.4 \text{ N/mm}^2 = 76.4 \text{ MPa} \quad \textbf{Ans.}$$

and actual crushing resistance of the rivets (P_{ca}),

$$75\ 000 = n \times d \times t \times \sigma_{ca} = 2 \times 25 \times 15 \times \sigma_{ca} = 750\, \sigma_{ca}$$

$$\therefore \quad \sigma_{ca} = 75000 / 750 = 100 \text{ N/mm}^2 = 100 \text{ MPa} \quad \textbf{Ans.}$$

Q.2: Find the efficiency of the following riveted joints:

1. Single riveted lap joint of 6 mm plates with 20 mm diameter rivets having a pitch of 50 mm. 2. Double riveted lap joint of 6 mm plates with 20 mm diameter rivets having a pitch of 65 mm. Assume Permissible tensile stress in plate = 120 MPa Permissible shearing stress in rivets = 90 MPa Permissible crushing stress in rivets = 180 MPa.

Solution. Given : $t = 6$ mm ; $d = 20$ mm ; $\sigma_t = 120$ MPa $= 120$ N/mm^2 ; $\tau = 90$ MPa $= 90$ N/mm^2 ; $\sigma_c = 180$ MPa $= 180$ N/mm^2

1. ***Efficiency of the first joint***

Pitch, $p = 50$ mm ...(Given)

First of all, let us find the tearing resistance of the plate, shearing and crushing resistances of the rivets.

(*i*) ***Tearing resistance of the plate***

We know that the tearing resistance of the plate per pitch length,

$$P_t = (p - d)\, t \times \sigma_t = (50 - 20)\, 6 \times 120 = 21\ 600 \text{ N}$$

(*ii*) ***Shearing resistance of the rivet***

Since the joint is a single riveted lap joint, therefore the strength of one rivet in single shear is taken. We know that shearing resistance of one rivet,

$$P_s = \frac{\pi}{4} \times d^2 \times \tau = \frac{\pi}{4}\, (20)^2\, 90 = 28\ 278 \text{ N}$$

(*iii*) ***Crushing resistance of the rivet***

Since the joint is a single riveted, therefore strength of one rivet is taken. We know that crushing resistance of one rivet,

$$P_c = d \times t \times \sigma_c = 20 \times 6 \times 180 = 21\ 600 \text{ N}$$

$\therefore$ Strength of the joint

$$= \text{Least of } P_t, P_s \text{ and } P_c = 21\ 600 \text{ N}$$

We know that strength of the unriveted or solid plate,

$$P = p \times t \times \sigma_t = 50 \times 6 \times 120 = 36\ 000 \text{ N}$$

$\therefore$ Efficiency of the joint,

$$\eta = \frac{\text{Least of } P_t, P_s \text{ and } P_c}{P} = \frac{21\ 600}{36\ 000} = 0.60 \text{ or } 60\% \quad \textbf{Ans.}$$

2. ***Efficiency of the second joint***

Pitch, $p = 65$ mm ...(Given)

(*i*) ***Tearing resistance of the plate,***

We know that the tearing resistance of the plate per pitch length,

$$P_t = (p - d)\ t \times \sigma_t = (65 - 20)\, 6 \times 120 = 32\ 400 \text{ N}$$

(*ii*) ***Shearing resistance of the rivets***

Since the joint is double riveted lap joint, therefore strength of two rivets in single shear is taken. We know that shearing resistance of the rivets,

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau = 2 \times \frac{\pi}{4}\, (20)^2\, 90 = 56\ 556 \text{ N}$$

(*iii*) ***Crushing resistance of the rivet***

Since the joint is double riveted, therefore strength of two rivets is taken. We know that crushing resistance of rivets,

$$P_c = n \times d \times t \times \sigma_c = 2 \times 20 \times 6 \times 180 = 43\ 200 \text{ N}$$

$\therefore$ Strength of the joint

$$= \text{Least of } P_t, P_s \text{ and } P_c = 32\ 400 \text{ N}$$

We know that the strength of the unriveted or solid plate,

$$P = p \times t \times \sigma_t = 65 \times 6 \times 120 = 46\,800 \text{ N}$$

$\therefore$ Efficiency of the joint,

$$\eta = \frac{\text{Least of } P_t, P_s \text{ and } P_c}{P} = \frac{32\,400}{46\,800} = 0.692 \text{ or } 69.2\% \quad \textbf{Ans.}$$

Q.3: Design a double riveted lap joint for MS Plates having a thickness 9.5 mm. Calculate the efficiency ofthe joint. The permissible stresses are: σ_t = 90 MPa, τ_s = 75 MPa, σ_c = 150 MPa.

2.8 Design riveted joints for pressure vessel.

Design of Longitudinal Butt Joint for a Boiler

According to Indian Boiler Regulations (I.B.R), the following procedure should be adopted for the design of longitudinal butt joint for a boiler.

1. Thickness of boiler shell.

First of all, the thickness of the boiler shell is determined by using the thin cylindrical formula, *i.e*.

$$t = \frac{P.D}{2\,\sigma_t \times \eta_l} + 1 \text{ mm as corrosion allowance}$$

Where t = Thickness of the boiler shell,

P = Steam pressure in boiler,

D = Internal diameter of boiler

σ_t = Permissible tensile stress, and

η_l = Efficiency of the longitudinal joint.

The following points may be noted:

(a) The thickness of the boiler shell should not be less than 7 mm.

(b) The efficiency of the joint may be taken from the following table.

Indian Boiler Regulations (I.B.R.) allows a maximum efficiency of 85% for the best joint.

(c) According to I.B.R., the factor of safety should not be less than 4.

2. Diameter of rivets.

After finding out the thickness of the boiler shell (*t*), the diameter of the rivet hole (*d*) may be determined by using Unwin's empirical formula,

i.e. $d = 6\sqrt{t}$, (when *t* is greater than 8 mm)

But if the thickness of plate is less than 8 mm, then the diameter of the rivet hole may be calculated by equating the shearing resistance of the rivets to crushing resistance. In no case, the diameter of rivet hole should not be less than the thickness of the plate, because there will be danger of punch crushing.

3. Pitch of rivets.

The pitch of the rivets is obtained by equating the tearing resistance of the plate to the shearing resistance of the rivets. It may noted that;

(a) The pitch of the rivets should not be less than 2d, which is necessary for the formation of head.

(b) The maximum value of the pitch of rivets for a longitudinal joint of a boiler as per I.B.R. is

$$p_{max} = C \times t + 41.28 \text{ mm}$$

where, t = Thickness of the shell plate in mm,

C = Constant.

- The value of the constant C may be taken from DDB. If the pitch of rivets as obtained by equating the tearing resistance to the shearing resistance is more than p_{max}, then the value of p_{max} is taken.

4. Distance between the rows of rivets.

The distance between the rows of rivets as specified by Indian Boiler Regulations is as follows:

(a) For equal number of rivets in more than one row for lap joint or butt joint, the distance between the rows of rivets (p_b) should not be less than

0.33 p + 0.67 d ……for zig-zig riveting, and

2d …….for chain riveting.

(b) For joints in which the number of rivets in outer rows is **half** the number of rivets in inner rows and if the inner rows are chain riveted, the distance between the outer rows and the next rows should not be less than **0.33 p + 0.67 or 2d**, whichever is greater.

The distance between the rows in which there are full number of rivets shall not be less than 2d.

(c) For joints in which the number of rivets in outer rows is **half** the number of rivets in inner rows and if the inner rows are zig-zig riveted, the distance between the outer rows and the next rows shall not be less than 0.2 p + 1.15 d. The distance between the rows in which there are full number of rivets (zig-zag) shall not be less than **0.165 p + 0.67d**.

Note : In the above discussion, p is the pitch of the rivets in the outer rows.

5. Thickness of butt strap.

According to I.B.R., the thicknesses for butt strap (t_1) are as given below:

(a) The thickness of butt strap, in no case, shall be less than 10 mm.

(b) **t_t = 1.125 t**, for ordinary (chain riveting) single butt strap.

$$t_1 = 1.125\, t \left(\frac{p-d}{p-2d} \right)$$

For single butt straps, every alternate rivet in outer rows being omitted.

t_1 = 0.625 t, for double butt-straps of equal width having ordinary riveting (chain riveting).

$$t_1 = 0.625\, t \left(\frac{p-d}{p-2d} \right)$$

For double butt straps of equal width having every alternate rivet in the outer rows being omitted.

(c) For unequal width of butt straps, the thicknesses of butt strap are

t_1 = 0.75 t, for wide strap on the inside, and

t_1 = 0.625 t, for narrow strap on the outside.

6. Margin.

The margin (m) is taken as 1.5 d.

Design of Circumferential Lap Joint for a Boiler

1. Thickness of the shell and diameter of rivets. The thickness of the boiler shell and the diameter of the rivet will be same as for longitudinal joint.

2. Number of rivets. Since it is a lap joint, therefore the rivets will be in single shear.

∴ Shearing resistance of the rivets

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau \quad \text{...}(i)$$

where n = Total number of rivets.

Knowing the inner diameter of the boiler shell (D), and the pressure of steam (P), the total shearing load acting on the circumferential joint,

$$W_s = \frac{\pi}{4} \times D^2 \times P \quad \text{...}(ii)$$

From equations (*i*) and (*ii*), we get

$$n \times \frac{\pi}{4} \times d^2 \times \tau = \frac{\pi}{4} \times D^2 \times P$$

$$\therefore \quad n = \left(\frac{D}{d}\right)^2 \frac{P}{\tau}$$

.3.Pitch of rivets. If the efficiency of the longitudinal joint is known, then the efficiency of the circumferential joint may be obtained. It is generally taken as 50% of tearing efficiency in longitudinal joint, but if more than one circumferential joints is used, then it is 62% for the intermediate joints.

Knowing the efficiency of the circumferential lap joint (η_c), the pitch of the rivets for the lap joint.

(p_1) may be obtained by using the relation

$$\eta_c = \frac{p_1 - d}{p_1}$$

The number of rows of rivets for the circumferential joint may be obtained

from the following relation :

4. *Number of rows.* The number of rows of rivets for the circumferential joint may be obtained from the following relation :

$$\text{Number of rows} = \frac{\text{Total number of rivets}}{\text{Number of rivets in one row}}$$

and the number of rivets in one row

$$= \frac{\pi (D + t)}{p_1}$$

where D = Inner diameter of shell.

5. After finding out the number of rows, the type of the joint (*i.e.* single riveted or double riveted etc.) may be decided. Then the number of rivets in a row and pitch may be re-adjusted. In order to have a leak-proof joint, the pitch for the joint should be checked from Indian Boiler Regulations.

6. The distance between the rows of rivets (*i.e.* back pitch) is calculated by using the relations as discussed in the previous article.

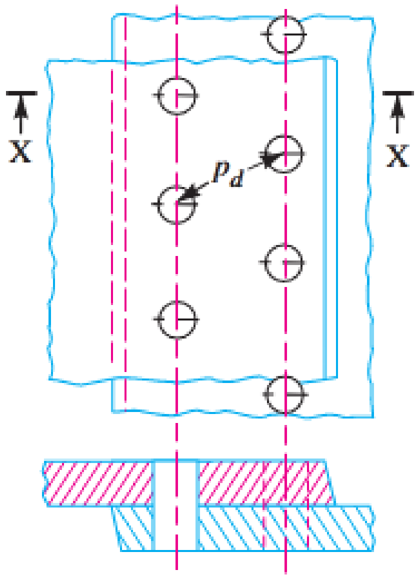
7. After knowing the distance between the rows of rivets (p_b), the overlap of the plate may be fixed by using the relation,

$$\text{Overlap} = (\text{No. of rows of rivets} - 1)\, p_b + m$$

where m = Margin.

2.9 Numerical on Riveted Joints.

Q 4 .A double riveted lap joint with zig-zag riveting is to be designed for 13 mm thick plates. Assume σt = 80 MPa ; τ = 60 MPa ; and σc = 120 MPa State how the joint will fail and find the efficiency of the joint



(*c*) Double riveted lap joint (Zig-zag riveting).

Solution. Given : t = 13 mm ; σ_t = 80 MPa = 80 N/mm^2 ; τ = 60 MPa = 60 N/mm^2 ; σ_c = 120 MPa = 120 N/mm^2

1. *Diameter of rivet*

Since the thickness of plate is greater than 8 mm, therefore diameter of rivet hole,

$$d = 6\sqrt{t} = 6\sqrt{13} = 21.6 \text{ mm}$$

From Table 9.3, we find that according to IS : 1928 – 1961 (Reaffirmed 1996), the standard size of the rivet hole (d) is 23 mm and the corresponding diameter of the rivet is 22 mm. **Ans.**

2. *Pitch of rivets*

Let p = Pitch of the rivets.

Since the joint is a double riveted lap joint with zig-zag riveting [See Fig.) therefore there are two rivets per pitch length, *i.e.* n = 2. Also, in a lap joint, the rivets are in single shear.

We know that tearing resistance of the plate,

$$P_t = (p - d)t \times \sigma_t = (p - 23)\ 13 \times 80 = (p - 23)\ 1040 \text{ N} \quad ...(i)$$

and shearing resistance of the rivets,

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau = 2 \times \frac{\pi}{4} (23)^2\ 60 = 49\ 864 \text{ N} \quad ...(ii)$$

...($\because$ There are two rivets in single shear)

From equations *(i)* and *(ii)*, we get

$$p - 23 = 49864 / 1040 = 48 \quad \text{or} \quad p = 48 + 23 = 71 \text{ mm}$$

The maximum pitch is given by,

$$p_{max} = C \times t + 41.28 \text{ mm}$$

From Table 9.5, we find that for 2 rivets per pitch length, the value of C is 2.62.

$$\therefore \quad p_{max} = 2.62 \times 13 + 41.28 = 75.28 \text{ mm}$$

Since p_{max} is more than p, therefore we shall adopt

$$p = 71 \text{ mm} \quad \textbf{Ans.}$$

3. *Distance between the rows of rivets*

We know that the distance between the rows of rivets (for zig-zag riveting),

$$p_b = 0.33\, p + 0.67\, d = 0.33 \times 71 + 0.67 \times 23 \text{ mm}$$
$$= 38.8 \text{ say } 40 \text{ mm} \quad \textbf{Ans.}$$

4. *Margin*

We know that the margin,

$$m = 1.5\, d = 1.5 \times 23 = 34.5 \text{ say } 35 \text{ mm} \quad \textbf{Ans.}$$

Failure of the joint

Now let us find the tearing resistance of the plate, shearing resistance and crushing resistance of the rivets.

We know that tearing resistance of the plate,

$$P_t = (p - d)\, t \times \sigma_t = (71 - 23)13 \times 80 = 49\ 920 \text{ N}$$

Shearing resistance of the rivets,

$$P_s = n \times \frac{\pi}{4} \times d^2 \times \tau = 2 \times \frac{\pi}{4} (23)^2\ 60 = 49\ 864 \text{ N}$$

and crushing resistance of the rivets,

$$P_c = n \times d \times t \times \sigma_c = 2 \times 23 \times 13 \times 120 = 71\ 760 \text{ N}$$

The least of P_t, P_s and P_c is $P_s = 49\ 864$ N. Hence the joint will fail due to shearing of the rivets. **Ans.**

Efficiency of the joint

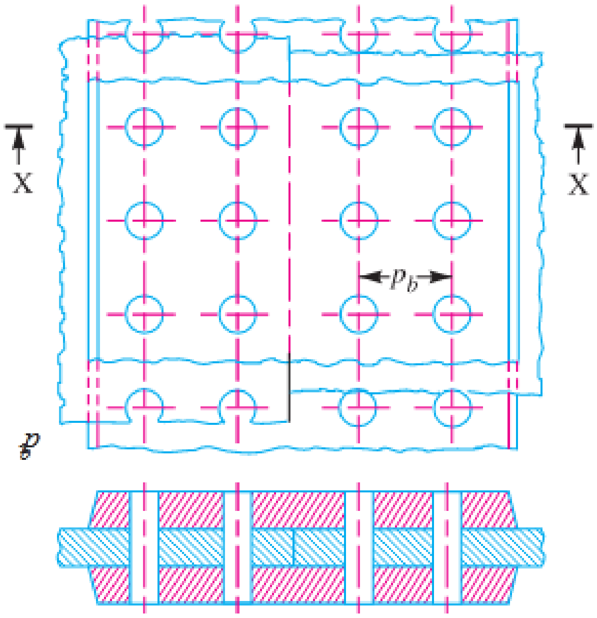
We know that strength of the unriveted or solid plate,

$$P = p \times t \times \sigma_t = 71 \times 13 \times 80 = 73\ 840 \text{ N}$$

$\therefore$ Efficiency of the joint,

$$\eta = \frac{P_s}{P} = \frac{49\ 864}{73\ 840} = 0.675 \text{ or } 67.5\% \quad \textbf{Ans.}$$

Q 5. .Design a double riveted butt joint with two cover plates for the longitudinal seam of a boiler shell 1.5 m in diameter subjected to a steam pressure of 0.95 N/mm 2 . Assume joint efficiency as 75%, allowable tensile stress in the plate 90 MPa ; compressive stress 140 MPa ; and shear stress in the rivet 56 MPa.



(*a*) Chain riveting.

Solution. Given : D = 1.5 m = 1500 mm ; P = 0.95 N/mm^2 ; η_l = 75% = 0.75 ; σ_t = 90 MPa = 90 N/mm^2 ; σ_c = 140 MPa = 140 N/mm^2 ; τ = 56 MPa = 56 N/mm^2

1. *Thickness of boiler shell plate*

We know that thickness of boiler shell plate,

$$t = \frac{P.D}{2\sigma_t \times \eta_l} + 1 \text{ mm} = \frac{0.95 \times 1500}{2 \times 90 \times 0.75} + 1 = 11.6 \text{ say } 12 \text{ mm} \quad \textbf{Ans.}$$

2. *Diameter of rivet*

Since the thickness of the plate is greater than 8 mm, therefore the diameter of the rivet hole,

$$d = 6\sqrt{t} = 6\sqrt{12} = 20.8 \text{ mm}$$

From Table 9.3, we see that according to IS : 1928 – 1961 (Reaffirmed 1996), the standard diameter of the rivet hole (d) is 21 mm and the corresponding diameter of the rivet is 20 mm. **Ans.**

3. *Pitch of rivets*

Let p = Pitch of rivets.

The pitch of the rivets is obtained by equating the tearing resistance of the plate to the shearing resistance of the rivets.

We know that tearing resistance of the plate,

$$P_t = (p - d)\, t \times \sigma_t = (p - 21)12 \times 90 = 1080\,(p - 21)\text{N} \qquad ...(i)$$

Since the joint is double riveted double strap butt joint, as shown in Fig. therefore there are two rivets per pitch length (*i.e.* $n = 2$) and the rivets are in double shear. Assuming that the rivets in double shear are 1.875 times stronger than in single shear, we have

Shearing strength of the rivets,

$$P_s = n \times 1.875 \times \frac{\pi}{4} \times d^2 \times \tau = 2 \times 1.875 \times \frac{\pi}{4} (21)^2 \times 56 \text{ N}$$

$$= 72\ 745 \text{ N} \qquad \ldots(ii)$$

From equations *(i)* and *(ii)*, we get

$$1080\,(p - 21) = 72\ 745$$

$$\therefore \quad p - 21 = 72\ 745 / 1080 = 67.35 \text{ or } p = 67.35 + 21 = 88.35 \text{ say } 90 \text{ mm}$$

According to I.B.R., the maximum pitch of rivets for longitudinal joint of a boiler is given by

$$p_{max} = C \times t + 41.28 \text{ mm}$$

From Table 9.5, we find that for a double riveted double strap butt joint and two rivets per pitch length, the value of C is 3.50.

$$\therefore \quad p_{max} = 3.5 \times 12 + 41.28 = 83.28 \text{ say } 84 \text{ mm}$$

Since the value of p is more than p_{max}, therefore we shall adopt pitch of the rivets,

$$p = p_{max} = 84 \text{ mm} \quad \textbf{Ans.}$$

4. *Distance between rows of rivets*

Assuming zig-zag riveting, the distance between the rows of the rivets (according to I.B.R.),

$$p_b = 0.33\,p + 0.67\,d = 0.33 \times 84 + 0.67 \times 21 = 41.8 \text{ say } 42 \text{ mm} \quad \textbf{Ans.}$$

5. *Thickness of cover plates*

According to I.B.R., the thickness of each cover plate of equal width is

$$t_1 = 0.625\,t = 0.625 \times 12 = 7.5 \text{ mm} \quad \textbf{Ans.}$$

6. *Margin*

We know that the margin,

$$m = 1.5\,d = 1.5 \times 21 = 31.5 \text{ say } 32 \text{ mm} \quad \textbf{Ans.}$$

Let us now find the efficiency for the designed joint.

Tearing resistance of the plate,

$$P_t = (p - d)\,t \times \sigma_t = (84 - 21)12 \times 90 = 68\ 040 \text{ N}$$

Shearing resistance of the rivets,

$$P_s = n \times 1.875 \times \frac{\pi}{4} \times d^2 \times \tau = 2 \times 1.875 \times \frac{\pi}{4} (21)^2 \times 56 = 72\ 745 \text{ N}$$

and crushing resistance of the rivets,

$$P_c = n \times d \times t \times \sigma_c = 2 \times 21 \times 12 \times 140 = 70\ 560 \text{ N}$$

Since the strength of riveted joint is the least value of P_t, P_s or P_c, therefore strength of the riveted joint,

$$P_t = 68\ 040 \text{ N}$$

We know that strength of the un-riveted plate,

$$P = p \times t \times \sigma_t = 84 \times 12 \times 90 = 90\ 720 \text{ N}$$

∴ Efficiency of the designed joint,

$$\eta = \frac{P_t}{P} = \frac{68\ 040}{90\ 720} = 0.75 \text{ or } 75\% \quad \textbf{Ans.}$$

Chapter-3

DESIGN OF SHAFTS AND KEYS

3.1 State function of shafts.

Shafts:

A shaft is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) setup within the shaft permits the power to be transferred to various machines linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys, gears etc., are mounted on it. These members along with the forces exerted upon them causes the shaft to bending.

In other words, we may say that a shaft is used for the transmission of torque and bending moment. The various members are mounted on the shaft by means of keys or splines. The shafts are usually cylindrical,but may be square or cross-shaped in section. They are solid in cross-section but sometimes hollow shafts are also used. An **axle,** though similar in shape to the shaft, is a stationary machine element and is used for the transmission of bending moment only. It simply acts as a support for some rotating body such as hoisting drum, a car wheel or a rope sheave. A **spindle** is a short shaft that imparts motion either to a cutting tool (*e.g*. drill press spindles) or to a work piece (*e.g*. lathe spindles).

Types of Shafts

The following two types of shafts are important from the subject point of view:

***Transmission shafts*.** These shafts transmit power between the source and the machines absorbing power. The counter shafts, line shafts, over head shafts and all factory shafts are transmission shafts. Since these shafts carry machine parts such as pulleys, gears etc., therefore they are subjected to bendingin addition to twisting.

***Machine shafts*.** These shafts form an integral part of the machine itself. The crank shaft is an example ofmachine shaft.

3.2 State materials for shafts.

The material used for shafts should have the following properties :

1. It should have high strength.
2. It should have good machinability.
3. It should have low notch sensitivity factor.
4. It should have good heat treatment properties.
5. It should have high wear resistant properties.

The material used for ordinary shafts is carbon steel of grades 40 C 8, 45 C 8, 50 C 4 and 50 C 12.

When a shaft of high strength is required, then alloy steel such as nickel, nickel-chromium or chrome-vanadium steel is used.

The mechanical properties of these grades of carbon steel are given in the following table.

Mechanical properties of steels used for shafts.

Indian standard designation	*Ultimate tensile strength, MPa*	*Yield strength, MPa*
40 C 8	560 - 670	320
45 C 8	610 - 700	350
50 C 4	640 - 760	370
50 C 12	700 Min.	390

3.3 Design solid & hollow shafts

Stresses in Shafts

The following stresses are induced in the shafts:

- Shear stresses due to the transmission of torque (*i.e.* due to torsional load).
- Bending stresses (tensile or compressive) due to the forces acting upon machine elements like gears,pulleys etc. as well as due to the weight of the shaft itself.
- Stresses due to combined torsional and bending loads.Design of Shafts

The shafts may be designed on the basis of

1. Strength, and

2. Rigidity and stiffness.

In designing shafts on the basis of strength, the following cases may be considered:

(a) Shafts subjected to twisting moment or torque only,
(b) Shafts subjected to bending moment only,
(c) Shafts subjected to combined twisting and bending moments, and
(d) Shafts subjected to axial loads in addition to combined torsional and bending loads.

Shafts Subjected to Twisting Moment OnlySolid shaft:

When the shaft is subjected to a twisting moment (or torque) only, then the diameter of the shaft may be obtained by using the torsion equation. We know that

$$\frac{T}{J}=\frac{\tau}{r}$$

Where T = Twisting moment (or torque) acting upon the shaft,

J = Polar moment of inertia of the shaft about the axis of rotation,

τ = Torsional shear stress, and

r = Distance from neutral axis to the outer most fibre

= d / 2; where d is the diameter of the shaft.

We know that for round solid shaft, polar moment of inertia,

$$J=\frac{\pi}{32}d^4$$

Then we get, $$T=\frac{\pi d^3}{16}\tau$$

From this equation, diameter of the solid shaft (d) may be obtained.

Hollow shaft:

We also know that for hollow shaft, polar moment of inertia,

$$J=\frac{\pi}{32}\left[(d_0)^4-(d_i)^4\right]$$

Where d_o and d_i = Outside and inside diameter of the shaft, and $r = d_0 / 2$.

Substituting these values in equation ***(i)***, we have

$$\frac{T}{\frac{\pi}{32}\left[(d_o)^4-(d_i)^4\right]}=\frac{\tau}{\frac{d_o}{2}} \quad \text{or} \quad T=\frac{\pi}{16}\times\tau\left[\frac{(d_o)^4-(d_i)^4}{d_o}\right]$$

Let k = Ratio of inside diameter and outside diameter of the shaft = d_i / d_o

Now the equation ***(iii)*** may be written as

$$T = \frac{\pi}{16} \times \tau \times \frac{(d_o)^4}{d_o}\left[1-\left(\frac{d_i}{d_o}\right)^4\right] = \frac{\pi}{16} \times \tau\,(d_o)^3\,(1-k^4)$$

From the equations, the outside and inside diameter of a hollow shaft may be determined.

It may be noted that

1. The hollow shafts are usually used in marine work. These shafts are stronger per kg of material and they may be forged on a mandrel, thus making the material more homogeneous than would be possible for a solid shaft. When a hollow shaft is to be made equal in strength to a solid shaft, the twisting moment of both the shafts must be same. In other words, for the same material of both the shafts,

$$T = \frac{\pi}{16} \times \tau\left[\frac{(d_o)^4 - (d_i)^4}{d_o}\right] = \frac{\pi}{16} \times \tau \times d^3$$

$$\therefore \qquad \frac{(d_o)^4 - (d_i)^4}{d_o} = d^3 \quad \text{or} \quad (d_o)^3\,(1-k^4) = d^3$$

---

2. The twisting moment (T) may be obtained by using the following relation:

We know that the power transmitted (in watts) by the shaft,

$$P = \frac{2\pi N \times T}{60} \quad \text{or} \quad T = \frac{P \times 60}{2\pi N}$$

Where T = Twisting moment in N-m, and

N = Speed of the shaft in r.p.m.

3. In case of belt drives, the twisting moment (T) is given by

$T = (T_1 - T_2)\,R$

Where T_1 and T_2 = Tensions in the tight side and slack side of the belt respectively, and R = Radius of the pulley.

Q1.A solid shaft is transmitting 1 MW at 240 r.p.m. Determine the diameter of the shaft if the maximum torque transmitted exceeds the mean torque by 20%. Take the maximum allowable shear stress as 60 MPa.

Given : $P = 1\text{ MW} = 1 \times 10^6\text{ W}$; $N = 240$ r.p.m. ; $T_{max} = 1.2\,T_{mean}$; $\tau = 60\text{ MPa} = 60\text{ N/mm}^2$

Let d = Diameter of the shaft.

We know that mean torque transmitted by the shaft,

$$T_{mean} = \frac{P \times 60}{2\pi N} = \frac{1 \times 10^6 \times 60}{2\pi \times 240} = 39\,784\text{ N-m} = 39\,784 \times 10^3\text{ N-mm}$$

∴ Maximum torque transmitted,

$$T_{max} = 1.2\, T_{mean} = 1.2 \times 39\,784 \times 10^3 = 47\,741 \times 10^3 \text{ N-mm}$$

We know that maximum torque transmitted (T_{max}),

$$47\,741 \times 10^3 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 60 \times d^3 = 11.78\, d^3$$

∴ $d^3 = 47\,741 \times 10^3 / 11.78 = 4053 \times 10^3$

or $d = 159.4$ say 160 mm

Q2 Find the diameter of a solid steel shaft to transmit 20 kW at 200 r.p.m. The ultimate shear stress for the steel may be taken as 360 MPa and a factor of safety as 8.If a hollow shaft is to be used in place of the solid shaft, find the inside and outside diameter when the ratio of inside to outside diameters is 0.5.

Given : $P = 20$ kW $= 20 \times 10^3$ W ; $N = 200$ r.p.m. ; $\tau_u = 360$ MPa $= 360$ N/mm^2 ; $F.S. = 8$; $k = d_i / d_o = 0.5$

We know that the allowable shear stress,

$$\tau = \frac{\tau_u}{F.S.} = \frac{360}{8} = 45 \text{ N/mm}^2$$

Let d = Diameter of the solid shaft.

We know that torque transmitted by the shaft,

$$T = \frac{P \times 60}{2\pi N} = \frac{20 \times 10^3 \times 60}{2\pi \times 200} = 955 \text{ N-m} = 955 \times 10^3 \text{ N-mm}$$

We also know that torque transmitted by the solid shaft (T),

$$955 \times 10^3 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 45 \times d^3 = 8.84\, d^3$$

∴ $d^3 = 955 \times 10^3 / 8.84 = 108\,032$ or $d = 47.6$ say 50 mm.

Let d_i = Inside diameter, and

d_o = Outside diameter.

We know that the torque transmitted by the hollow shaft (T),

$$955 \times 10^3 = \frac{\pi}{16} \times \tau\, (d_o)^3\ (1 - k^4)$$

$$= \frac{\pi}{16} \times 45\, (d_o)^3\ [1 - (0.5)^4] = 8.3\, (d_o)^3$$

∴ $(d_o)^3 = 955 \times 10^3 / 8.3 = 115\,060$ or $d_o = 48.6$ say 50 mm

$d_i = 0.5\, d_o = 0.5 \times 50 = 25$ mm

Shafts Subjected to Bending Moment Only

a) Solid Shaft:

When the shaft is subjected to a bending moment only, then the maximum stress (tensile orcompressive) is given by the bending equation. We know that

Where M = Bending moment,

$$\frac{M}{I} = \frac{\sigma_b}{y}$$

I = Moment of inertia of cross-sectional area of the shaft about the axis of rotation,

σ_b = Bending stress, and

y = Distance from neutral axis to the outer-most fibre.

We know that for a round solid shaft, moment of inertia,

$$I = \frac{\pi}{64} \times d^4 \quad \text{and} \quad y = \frac{d}{2}$$

Substituting these values in equation

$$\frac{M}{\frac{\pi}{64} \times d^4} = \frac{\sigma_b}{\frac{d}{2}} \quad \text{or} \quad M = \frac{\pi}{32} \times \sigma_b \times d^3$$

From this equation, diameter of the solid shaft (d) may be obtained.

b) Hollow Shaft:

We also know that for a hollow shaft, moment of inertia,

$$I = \frac{\pi}{64}\left[(d_o)^4 - (d_i)^4\right] = \frac{\pi}{64}(d_o)^4\,(1 - k^4) \qquad \text{...(where } k = d_i / d_o\text{)}$$

And $y = d_o / 2$

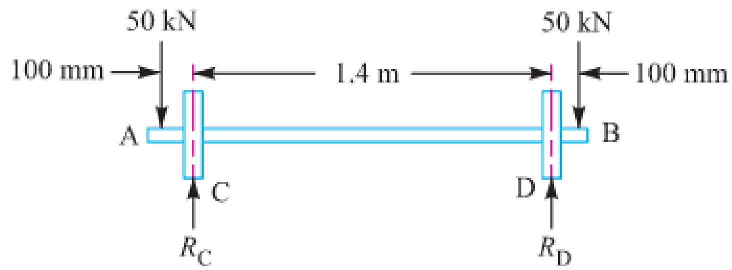
Again substituting these values in equation, we have

$$\frac{M}{\frac{\pi}{64}(d_o)^4\,(1 - k^4)} = \frac{\sigma_b}{\frac{d_o}{2}} \quad \text{or} \quad M = \frac{\pi}{32} \times \sigma_b\,(d_o)^3\,(1 - k^4)$$

From this equation, the outside diameter of the shaft (d_o) may be obtained.

Q3 A pair of wheels of a railway wagon carries a load of 50 kN on each axle box, acting at a distance of 100 mm outside the wheel base. The gauge of the rails is 1.4 m. Find the diameter of the axle between the wheels, if the stress is not to exceed 100 MPa.

Given : $W = 50\text{ kN} = 50 \times 10^3\text{ N}$; $L = 100\text{ mm}$; $x = 1.4\text{ m}$; $\sigma_b = 100\text{ MPa} = 100\text{ N/mm}^2$



The axle with wheels is shown in Fig. 14.1.

A little consideration will show that the maximum bending moment acts on the wheels at C and D. Therefore maximum bending moment,

$$*M = W.L = 50 \times 10^3 \times 100 = 5 \times 10^6\text{ N-mm}$$

Let d = Diameter of the axle.

We know that the maximum bending moment (M),

$$5 \times 10^6 = \frac{\pi}{32} \times \sigma_b \times d^3 = \frac{\pi}{32} \times 100 \times d^3 = 9.82\, d^3$$

$$\therefore \quad d^3 = 5 \times 10^6 / 9.82 = 0.51 \times 10^6 \text{ or } d = 79.8 \text{ say } 80\text{ mm } \textbf{Ans.}$$

Shafts Subjected to Combined Twisting Moment and Bending Moment

When the shaft is subjected to combined twisting moment and bending moment, then the shaft must bedesigned on the basis of the two moments simultaneously. Various theories have been suggested to account for the elastic failure of the materials when they are subjected to various types of combined stresses. The following two theories are important from the subject point of view:

1. Maximum shear stress theory or Guest's theory: It is used for ductile materials such as mild steel.
2. Maximum normal stress theory or Rankine's theory : It is used for brittle materials such as cast iron.

Let τ = Shear stress induced due to twisting moment, and
σ_b = Bending stress (tensile or compressive) induced due to bending moment.

a) Solid Shaft:

According to maximum shear stress theory, the maximum shear stress in the shaft,

$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$$

Substituting the values of σ_b and τ

$$\tau_{max} = \frac{1}{2}\sqrt{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left(\frac{16T}{\pi d^3}\right)^2} = \frac{16}{\pi d^3}\left[\sqrt{M^2 + T^2}\right]$$

or

$$\frac{\pi}{16} \times \tau_{max} \times d^3 = \sqrt{M^2 + T^2}$$

$$T_e = \sqrt{M^2 + T^2} = \frac{\pi}{16} \times \tau \times d^3$$

The expression **T_e**

is known as ***equivalent twisting moment*** and is denoted by T_e.

The equivalent twisting moment may be defined as that twisting moment, which when acting alone, produces the same shear stress (τ) as the actual twisting moment. By limiting the maximum shear stress (τ_{max}) equal to the allowable shear stress (τ) for the material, theequation **(*i*)** may be written as

From this expression, diameter of the shaft (d*)* may be evaluated.

$$T_e = \sqrt{M^2 + T^2} = \frac{\pi}{16} \times \tau \times d^3$$

Now according to maximum normal stress theory, the maximum normal stress in the shaft,

$$\sigma_{b(max)} = \frac{1}{2}\sigma_b + \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$$

$$= \frac{1}{2} \times \frac{32M}{\pi d^3} + \frac{1}{2}\sqrt{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left(\frac{16T}{\pi d^3}\right)^2}$$

$$= \frac{32}{\pi d^3}\left[\frac{1}{2}(M + \sqrt{M^2 + T^2})\right]$$

or $$\frac{\pi}{32} \times \sigma_{b\,(max)} \times d^3 = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

the

The above expression is known as **equivalent bending moment** (M_e).

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] = \frac{\pi}{32} \times \sigma_b \times d^3$$

b) Hollow shaft:

$$T_e = \sqrt{M^2 + T^2} = \frac{\pi}{16} \times \tau\,(d_o)^3\,(1 - k^4)$$

$$M_e = \tfrac{1}{2}\left(M + \sqrt{M^2 + T^2}\right) - \frac{\pi}{32} \times \sigma_b\,(d_o)^3\,(1 - k^4)$$

It is suggested that diameter of the shaft may be obtained by using both the theories and the larger ofthe two values is adopted.

Q4. A solid circular shaft is subjected to a bending moment of 3000 N-m and a torque of 10 000 N-m. The shaft is made of 45 C 8 steel having ultimate tensile stress of 700 MPa and a ultimate shear stress of 500 MPa. Assuming a factor of safety as 6, determine the diameter of the shaft

Given : $M = 3000$ N-m $= 3 \times 10^6$ N-mm ; $T = 10\ 000$ N-m $= 10 \times 10^6$ N-mm ; $\sigma_{tu} = 700$ MPa $= 700$ N/mm^2 ; $\tau_u = 500$ MPa $= 500$ N/mm^2

We know that the allowable tensile stress,

$$\sigma_t \text{ or } \sigma_b = \frac{\sigma_{tu}}{F.S.} = \frac{700}{6} = 116.7 \text{ N/mm}^2$$

and allowable shear stress,

$$\tau = \frac{\tau_u}{F.S.} = \frac{500}{6} = 83.3 \text{ N/mm}^2$$

Let d = Diameter of the shaft in mm.

According to maximum shear stress theory, equivalent twisting moment,

$$T_e = \sqrt{M^2 + T^2} = \sqrt{(3 \times 10^6)^2 + (10 \times 10^6)^2} = 10.44 \times 10^6 \text{ N-mm}$$

We also know that equivalent twisting moment (T_e),

$$10.44 \times 10^6 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 83.3 \times d^3 = 16.36\ d^3$$

$$\therefore \quad d^3 = 10.44 \times 10^6 / 16.36 = 0.636 \times 10^6 \text{ or } d = 86 \text{ mm}$$

According to maximum normal stress theory, equivalent bending moment,

$$M_e = \tfrac{1}{2}\left(M + \sqrt{M^2 + T^2}\right) = \tfrac{1}{2}(M + T_e)$$

$$= \tfrac{1}{2}(3 \times 10^6 + 10.44 \times 10^6) = 6.72 \times 10^6 \text{ N-mm}$$

We also know that the equivalent bending moment (M_e),

$$6.72 \times 10^6 = \frac{\pi}{32} \times \sigma_b \times d^3 = \frac{\pi}{32} \times 116.7 \times d^3 = 11.46\ d^3$$

$$\therefore \quad d^3 = 6.72 \times 10^6 / 11.46 = 0.586 \times 10^6 \text{ or } d = 83.7 \text{ mm}$$

Taking the larger of the two values, we have

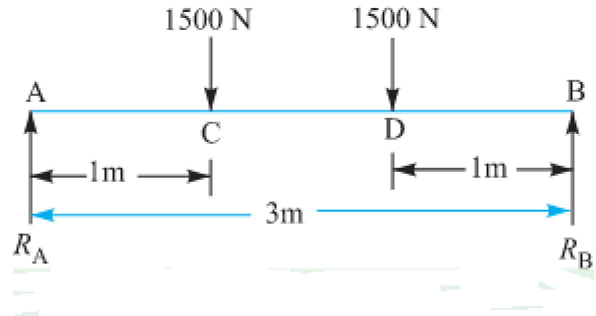
$$d = 86 \text{ say } 90 \text{ mm}$$

Q 5 A shaft made of mild steel is required to transmit 100 kW at 300 r.p.m. The supported length of the shaft is 3 metres. It carries two pulleys each weighing 1500 N supported at a distance of 1 metre from the ends respectively. Assuming the safe value of stress, determine the diameter of the shaft.

Given : $P = 100$ kW $= 100 \times 10^3$ W ; $N = 300$ r.p.m. ; $L = 3$ m ; $W = 1500$ N

We know that the torque transmitted by the shaft,

$$T = \frac{P \times 60}{2\pi N} = \frac{100 \times 10^3 \times 60}{2\pi \times 300} = 3183 \text{ N-m}$$



The shaft carrying the two pulleys is like a simply supported beam as shown in Fig. 14.3. The reaction at each support will be 1500 N, *i.e.*

$$R_A = R_B = 1500 \text{ N}$$

A little consideration will show that the maximum bending moment lies at each pulley *i.e.* at *C* and *D*.

$\therefore$ Maximum bending moment,

$$M = 1500 \times 1 = 1500 \text{ N-m}$$

Let d = Diameter of the shaft in mm.

We know that equivalent twisting moment,

$$T_e = \sqrt{M^2 + T^2} = \sqrt{(1500)^2 + (3183)^2} = 3519 \text{ N-m}$$

$$= 3519 \times 10^3 \text{ N-mm}$$

We also know that equivalent twisting moment (T_e),

$$3519 \times 10^3 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 60 \times d^3 = 11.8\, d^3 \quad \text{...(Assuming } \tau = 60 \text{ N/mm}^2\text{)}$$

$\therefore$ $d^3 = 3519 \times 10^3 / 11.8 = 298 \times 10^3$ or $d = 66.8$ say 70 mm.

<u>Design of Shafts on the basis of Rigidity:</u>

Sometimes the shafts are to be designed on the basis of rigidity. We shall consider the following two types of rigidity.

1. **<u>Torsional rigidity</u>.** The torsional rigidity is important in the case of camshaft of an I.C. engine where the timing of the valves would be affected. The permissible amount of twist should not exceed 0.25° per metre length of such shafts. For line shafts or transmission shafts, deflections 2.5 to 3 degree per metre length may be used as limiting value. The widely used deflection for the shafts is limited to 1 degree in a length equal to twenty times the diameter of the shaft. The torsional deflection may be obtained by using the torsion equation,

$$\frac{T}{J} = \frac{G \cdot \theta}{L} \quad \text{or} \quad \theta = \frac{T \cdot L}{J \cdot G}$$

where
θ = Torsional deflection or angle of twist in radians,
T = Twisting moment or torque on theshaft,
J = Polar moment of inertia of the cross-sectional area about the axis of rotation,
G = Modulus of rigidity for the shaft material, and
L = Length of the shaft.

2. **<u>Lateral rigidity.</u>** It is important in case of transmission shafting and shafts running at high speed, where small lateral deflection would cause huge out-of-balance forces.
The lateral rigidity is also important for maintaining proper bearing clearances and for correct gear teeth alignment. If the shaft is of uniform cross-section, then the lateral deflection of a shaft may be obtained by using the deflection formulae as in Strength of Materials. But when the shaft is of variable cross-section, then the lateral deflection may be determined from the fundamental equation for the elastic curve of a beam, *i.e*.

$$\frac{d^2y}{dx^2} = \frac{M}{EI}$$

3.4 State standard size of shaft as per I.S.

The standard sizes of transmission shafts are :

- 25 mm to 60 mm with 5 mm steps;
- 60 mm to 110 mm with 10 mm steps ;
- 110 mm to 140 mm with 15 mm steps ;
- 140 mm to 500 mm with 20 mm steps.
- The standard length of the shafts are 5 m, 6 m and 7 m.

Q 5.A steel spindle transmits 4 kW at 800 r.p.m. The angular deflection should not exceed 0.25° per metre of the spindle. If the modulus of rigidity for the material of the spindle is 84 GPa, find the diameter of the spindle and the shear stress induced in the spindle.

Solution. Given : $P = 4$ kW $= 4000$ W ; $N = 800$ r.p.m. ; $\theta = 0.25° = 0.25 \times \frac{\pi}{180} = 0.0044$ rad ; $L = 1$ m $= 1000$ mm ; $G = 84$ GPa $= 84 \times 10^9$ N/m^2 $= 84 \times 10^3$ N/mm^2

Diameter of the spindle

Let d = Diameter of the spindle in mm.

We know that the torque transmitted by the spindle,

$$T = \frac{P \times 60}{2\pi N} = \frac{4000 \times 60}{2\pi \times 800} = 47.74 \text{ N-m} = 47\ 740 \text{ N-mm}$$

We also know that $\frac{T}{J} = \frac{G \times \theta}{L}$ or $J = \frac{T \times l}{G \times \theta}$

or $$\frac{\pi}{32} \times d^4 = \frac{47\ 740 \times 1000}{84 \times 10^3 \times 0.0044} = 129\ 167$$

$\therefore$ $d^4 = 129\ 167 \times 32 / \pi = 1.3 \times 10^6$ or $d = 33.87$ say 35 mm **Ans.**

Shear stress induced in the spindle

Let τ = Shear stress induced in the spindle.

We know that the torque transmitted by the spindle (T),

$$47\ 740 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times \tau\ (35)^3 = 8420\ \tau$$

$\therefore$ $\tau = 47\ 740 / 8420 = 5.67$ N/mm^2 $= 5.67$ MPa **Ans.**

Q 6.Compare the weight, strength and stiffness of a hollow shaft of the same external diameter as that of solid shaft. The inside diameter of the hollow shaft being half the external diameter. Both the shafts have the same material and length.

Solution. Given : $d_o = d$; $d_i = d_o / 2$ or $k = d_i / d_o = 1 / 2 = 0.5$

Comparison of weight

We know that weight of a hollow shaft,

$$W_H = \text{Cross-sectional area} \times \text{Length} \times \text{Density}$$

$$= \frac{\pi}{4}\left[(d_o)^2 - (d_i)^2\right] \times \text{Length} \times \text{Density} \qquad ...(i)$$

and weight of the solid shaft,

$$W_S = \frac{\pi}{4} \times d^2 \times \text{Length} \times \text{Density} \qquad ...(ii)$$

Since both the shafts have the same material and length, therefore by dividing equation (*i*) by equation (*ii*), we get

$$\frac{W_H}{W_S} = \frac{(d_o)^2 - (d_i)^2}{d^2} = \frac{(d_o)^2 - (d_i)^2}{(d_o)^2} \qquad ...(\because d = d_o)$$

$$= 1 - \frac{(d_i)^2}{(d_o)_2} = 1 - k^2 = 1 - (0.5)^2 = 0.75 \textbf{ Ans.}$$

Comparison of strength

We know that strength of the hollow shaft,

$$T_H = \frac{\pi}{16} \times \tau\,(d_o)^3\,(1 - k^4) \qquad ...(iii)$$

and strength of the solid shaft,

$$T_S = \frac{\pi}{16} \times \tau \times d^3 \qquad ...(iv)$$

Dividing equation (*iii*) by equation (*iv*), we get

$$\frac{T_H}{T_S} = \frac{(d_o)^3\,(1 - k^4)}{d^3} = \frac{(d_o)^3\,(1 - k^4)}{(d_o)^3} = 1 - k^4 \qquad ...(\because d = d_o)$$

$$= 1 - (0.5)^4 = 0.9375 \textbf{ Ans.}$$

Comparison of stiffness

We know that stiffness

$$= \frac{T}{\theta} = \frac{G \times J}{L}$$

$\therefore$ Stiffness of a hollow shaft,

$$S_H = \frac{G}{L} \times \frac{\pi}{32}\left[(d_o)^4 - (d_i)^4\right] \qquad ...(v)$$

and stiffness of a solid shaft,

$$S_S = \frac{G}{L} \times \frac{\pi}{32} \times d^4 \qquad ...(vi)$$

Dividing equation (v) by equation (vi), we get

$$\frac{S_H}{S_S} = \frac{(d_o)^4 - (d_i)^4}{d^4} = \frac{(d_o)^4 - (d_i)^4}{(d_o)^4} = 1 - \frac{(d_i)^4}{(d_o)^4} \qquad ...(\because d = d_o)$$

$$= 1 - k^4 = 1 - (0.5)^4 = 0.9375 \text{ Ans.}$$

Design of keys:

3.5 State function of keys, types of keys & material of keys.

A key is a piece of mild steel inserted between the shaft and hub or boss of the pulley to connect these together in order to prevent relative motion between them. It is always inserted parallel to the axis of the shaft. Keys are used as temporary fastenings and are subjected to considerable crushing and shearing stresses. A keyway is a slot or recess in a shaft and hub of the pulley to accommodate a key.

Types of Keys

The following types of keys are important from the subject point of view:

1. Sunk keys,
2. ***Saddle keys,***
3. Tangent keys,
4. ***Round keys, and***
5. Splines.

Sunk Keys:

The sunk keys are provided half in the keyway of the shaft and half in the keyway of the hub or bossof the pulley. The sunk keys are of the following types :

1. Rectangular sunk key.

A rectangular sunk key is shown in Fig. The usual proportions of this key are :

Width of key, w = d / 4 ; and

thickness of key,

t = 2w / 3 = d/6

Where d = Diameter of the shaft or diameter of the hole in the hub. The key has taper 1 in 100 on the top side only.

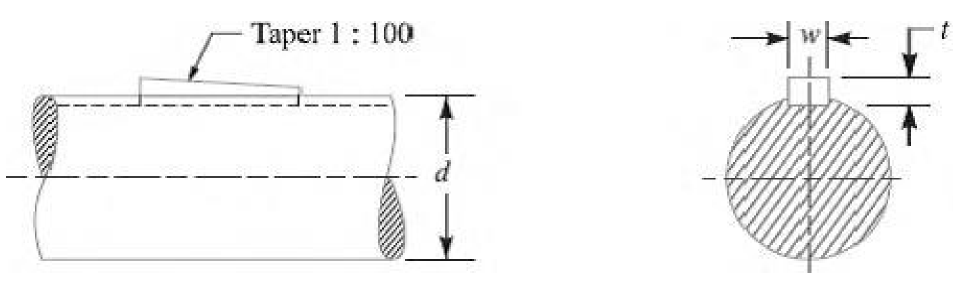


Fig. Sunk Key

2. Square sunk key. The only difference between a rectangular sunk key and a square sunk

key is that its width and thickness are equal, i.e. w = t = d / 4
3. Parallel sunk key. The parallel sunk keys may be of rectangular or square section uniform in width and thickness throughout. It may be noted that a parallel key is a taper less and is used where the pulley, gear or other mating piece is required to slide along the shaft.
4. Gib-head key. It is a rectangular sunk key with a head at one end known as **gib head.** It is usually provided to facilitate the removal of key. A gib head key is shown in Fig.

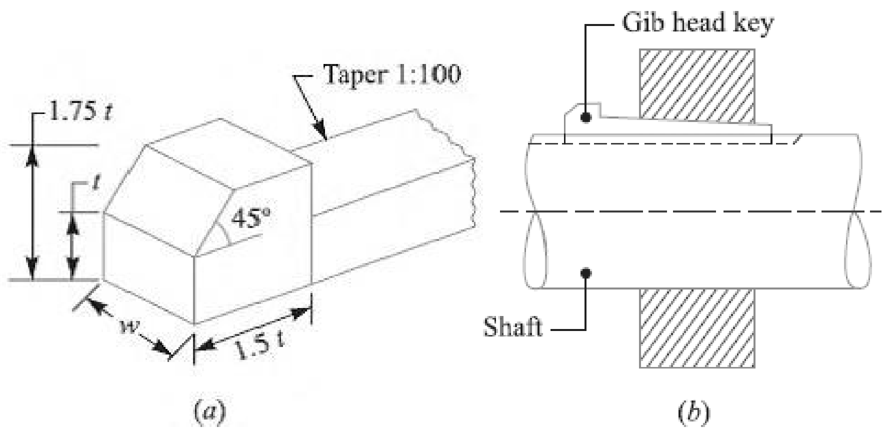


Fig. Gib head key and its use

The usual proportions of the gib head key are:

Width, w = d / 4 ; and

thickness at large end, t = 2w / 3 = d /6.

5. <u>Feather key.</u> A key attached to one member of a pair and which permits relative axial movement is known as **feather key.** It is a special type of parallel key which transmits a turning moment and also permits axial movement. It is fastened either to the shaft or hub, the key being a sliding fit in the key way of the moving piece.

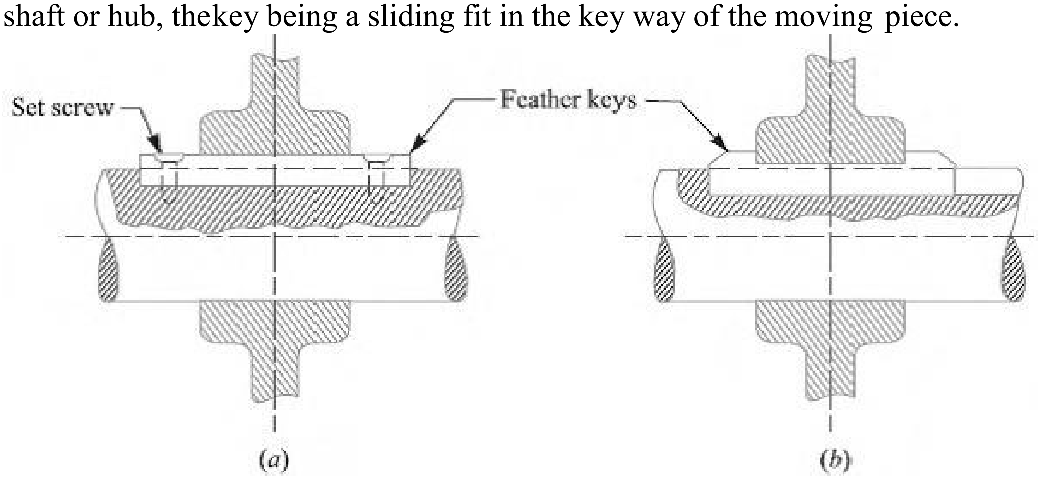


Fig. Feather Keys

6. Woodruff key.

The woodruff key is an easily adjustable key. It is a piece from a cylindrical disc having segmental cross-section. A woodruff key is capable of tilting in a recess milled out in the shaft by a cutter having the same curvature as the disc from which the key is made. This key is largely used in machine tool and automobile construction.

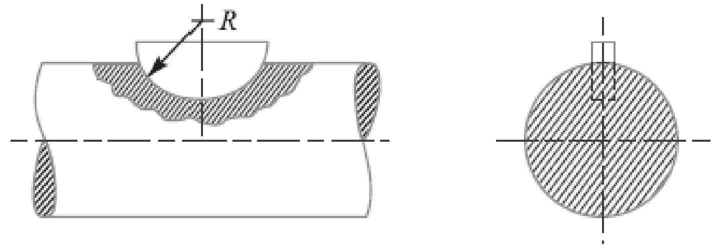


Fig. Woodruff

KeyThe main advantages of a woodruff key are as follows:

1. It accommodates itself to any taper in the hub or boss of the mating piece.

2. It is useful on tapering shaft ends. Its extra depth in the shaft prevents any tendency to turnover in its keyway.

The disadvantages are:

1. The depth of the keyway weakens the shaft

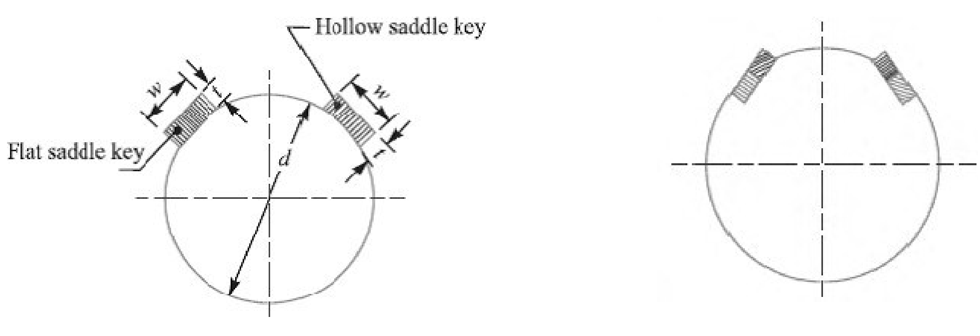
2. It can not be used as a feather.

Saddle keys:

A saddle keys are of the following types

1. flat saddle key

2. hollow saddle key



A **flat saddle key** is a type of key which fits in the hub and is flat on the shaft as shown in fig. It is likely to slip round the shaft under load. Therefore it is used for comparatively light loads.

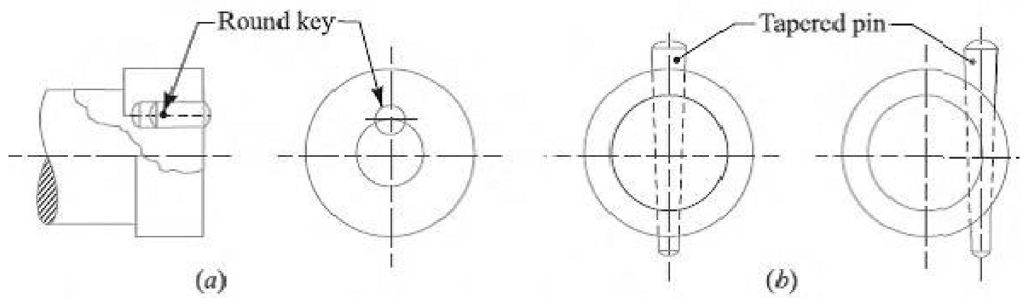
A **hollow saddle key** is a taper key which fits in a keyway in the hub and the bottom of the key is shaped to fit the curved surface of the shaft. Since hollow saddle keys hold on by friction, therefore these are suitable for light loads. It is usually used as a temporary fastening in fixing and setting eccentrics, cams etc.

Tangent Keys

The tangent keys are fitted in pair at right angles as shown in Fig. Each key is to withstand torsion in one direction only. These are used in large heavy duty shafts.

Round Keys

The round keys, as shown in Fig. (a) are circular in section and fit into holes drilled partly in the shaft and partly in the hub. They have the advantage that their keyways may be drilled and reamed after the mating parts have been assembled. Round keys are usually consideredto be most appropriate for low power drives.



Material Of Keys.

- Typically, shaft keys are made from either medium carbon steel or stainless steel. But they can be made from many different types of material such as aluminium alloy, bronze, copper, and brass to suit different application environments.

3.6 Failure Of Key

Stresses in Keys:

Forces acting on a Sunk Key

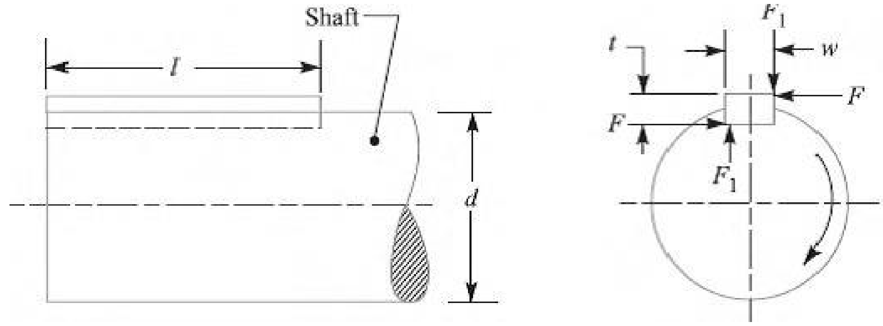
When a key is used in transmitting torque from a shaft to a rotor or hub, the following two types of forces act on the key:

1. Forces (F1) due to fit of the key in its keyway, as in a tight fitting straight key or in a tapered key driven in place. These forces produce compressive stresses in the key which are difficult to determine in magnitude.

2. Forces (F) due to the torque transmitted by the shaft. These forces produce shearing and compressive (or crushing) stresses in the key.

The forces acting on a key for a clockwise torque being transmitted from a shaft to a hub areshown in Fig.

In designing a key, forces due to fit of the key are neglected and it is assumed that thedistribution of forces along the length of key is uniform.



3.7 Design rectangular sunk key considering its failure against shear & crushing

Strength of a Sunk Key

A key connecting the shaft and hub is shown in Fig. Let

T = Torque transmitted by the shaft,

F = Tangential force acting at the circumference of the shaft, d = Diameter of shaft,

l = Length of key, w = Width of key.

t = Thickness of key, and

τ and σ_c = Shear and crushing stresses for the material of key.

A little consideration will show that due to the power transmitted by the shaft, the key may fail due to shearing or crushing. Considering shearing of the key, the tangential shearing force acting at the circumference of the shaft,

F = Area resisting shearing × Shear stress = l × w × τ

Therefore, Torque transmitted by the shaft,

$$T = F \times \frac{d}{2} = l \times w \times \tau \times \frac{d}{2} \qquad \text{...}(i)$$

Considering crushing of the key, the tangential crushing force acting at the circumference

o

fthe shaft,

F = Area resisting crushing × Crushing stress

$$= l \times \frac{t}{2} \times \sigma_c$$

Therefore, Torque transmitted by the shaft,

$$T = F \times \frac{d}{2} = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} \qquad \text{...}(ii)$$

The key is equally strong in shearing and crushing, if

$$l \times w \times \tau \times \frac{d}{2} - l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2}$$

Or

$$\frac{w}{t} - \frac{\sigma_c}{2\tau}$$

The permissible crushing stress for the usual key material is at least twice the permissible shearingstress. Therefore from the above equation, we have w = t. In other words, a square key is equally strong in shearing and crushing.

In order to find the length of the key to transmit full power of the shaft, the shearing strength of the keyis equal to the torsional shear strength of the shaft. We know that the shearing strength of key,

$$T = l \times w \times \tau \times \frac{d}{2}$$

And torsional shear strength of the shaft,

$$T = \frac{\pi}{16} \times \tau_1 \times d^3$$

From the above

$$l \times w \times \tau \times \frac{d}{2} = \frac{\pi}{16} \times \tau_1 \times d^3$$

$$l = \frac{\pi}{8} \times \frac{\tau_1 d^2}{w \times \tau} = \frac{\pi d}{2} \times \frac{\tau_1}{\tau} = 1.571\, d \times \frac{\tau_1}{\tau}$$

When the key material is same as that of the shaft, then $\tau = \tau_1$. So, $l = 1.571\, d$.

Effect of Keyway

A little consideration will show that the keyway cut into the shaft reduces the load carrying capacity of the shaft. This is due to the stress concentration near the corners of the keyway and reduction in the cross-sectional area of the shaft. It other words, the torsional strength of the shaft is reduced. The following relation for the weakening effect of the keyway is based on the experimental results by H.F. Moore.

$$e = 1 - 0.2\left(\frac{w}{d}\right) - 1.1\left(\frac{h}{d}\right)$$

where e = Shaft strength factor. It is the ratio of the strength of the shaft with keyway to the strength of the same shaft without keyway,

w = Width of keyway,

d = Diameter of shaft, and

h = Depth of keyway = $\dfrac{\text{Thickness of key } (t)}{2}$

It is usually assumed that the strength of the keyed shaft is 75% of the solid shaft, which is somewhat higher than the value obtained by the above relation.

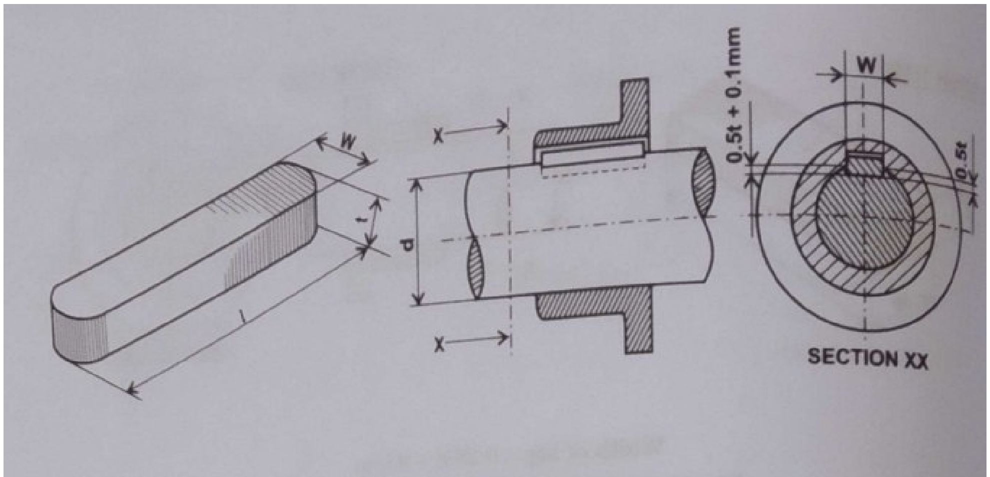
In case the keyway is too long and the key is of sliding type, then the angle of twist is increased in the ratio k_θ as given by the following relation :

$$k_\theta = 1 + 0.4\left(\frac{w}{d}\right) + 0.7\left(\frac{h}{d}\right)$$

where k_θ = Reduction factor for angular twist.

3.9 State specification of parallel key, gib-head key, taper key as per I.S

PARALLEL KEY

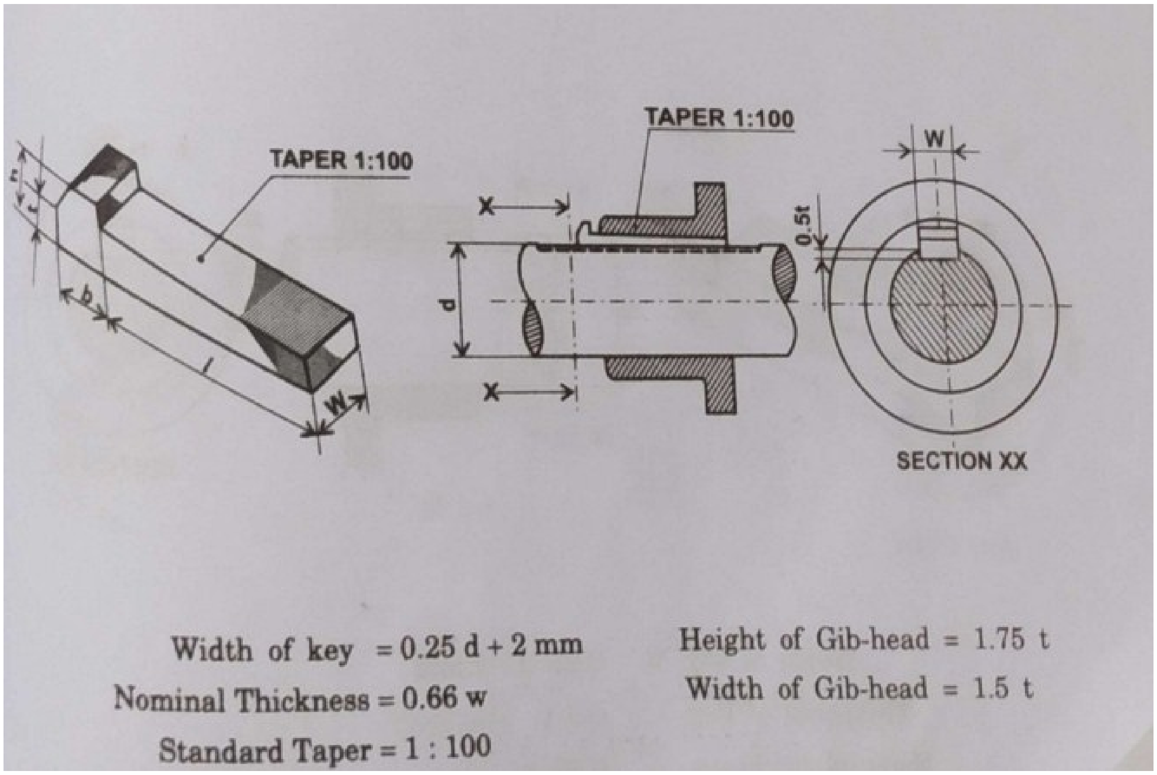


Width of key = 0.25 d + 2 mm

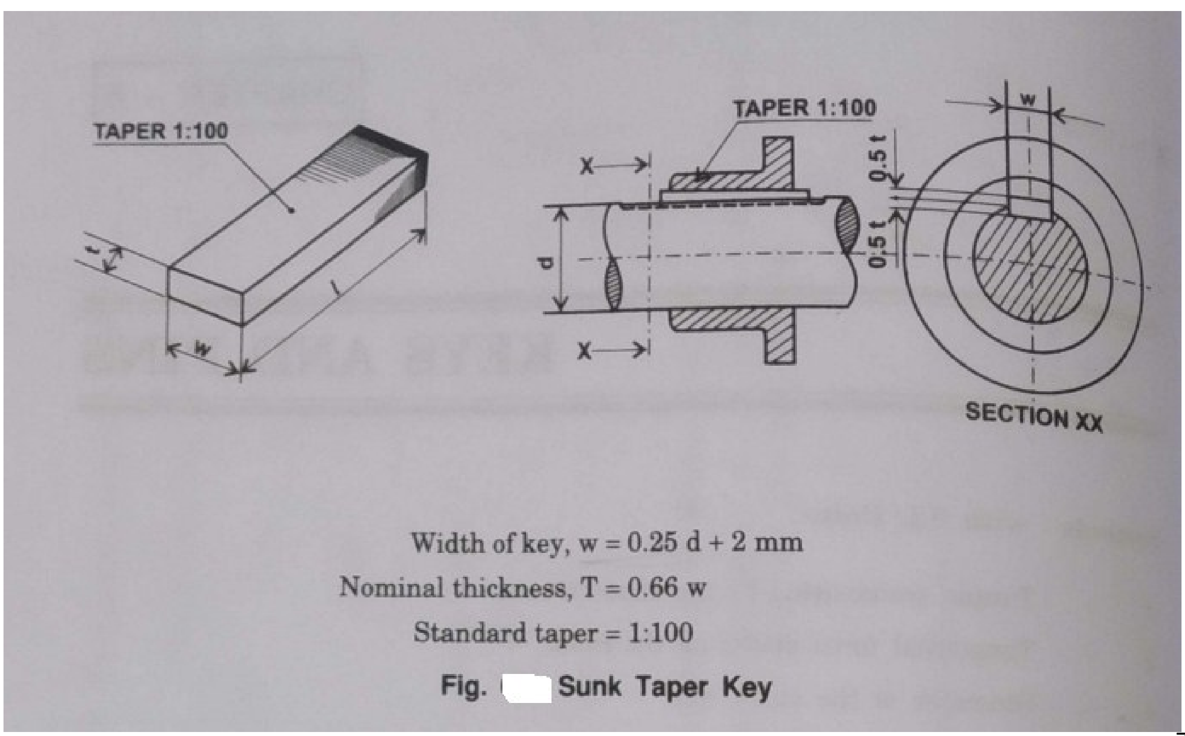
Nominal thickness = 0.66 w

Fig. : Feather or Parallel Key

GIB-HEAD KEY



TAPER KEY



Q1.Design the rectangular key for a shaft of 50 mm diameter. The shearing and crushing stresses for the key material are 42 MPa and 70 MPa.

Given : $d = 50$ mm ; $\tau = 42$ MPa $= 42$ N/mm^2 ; $\sigma_c = 70$ MPa $= 70$ N/mm^2

The rectangular key is designed as discussed below:

From Table 13.1, we find that for a shaft of 50 mm diameter,

Width of key, $w = 16$ mm

and thickness of key, $t = 10$ mm

The length of key is obtained by considering the key in shearing and crushing.

Let l = Length of key.

Considering shearing of the key. We know that shearing strength (or torque transmitted) of the key,

$$T = l \times w \times \tau \times \frac{d}{2} = l \times 16 \times 42 \times \frac{50}{2} = 16\,800\, l \text{ N-mm} \qquad \textbf{(i)}$$

and torsional shearing strength (or torque transmitted) of the shaft,

$$T = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 42\,(50)^3 = 1.03 \times 10^6 \text{ N-mm} \qquad \textbf{(ii)}$$

From equations **(i)** and **(ii)** we have

$$l = 1.03 \times 10^6 / 16\,800 = 61.31 \text{ mm}$$

Now considering crushing of the key. We know that shearing strength (or torque transmitted) of the key,

$$T = l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} = l \times \frac{10}{2} \times 70 \times \frac{50}{2} = 8750\, l \text{ N-mm} \qquad \textbf{(iii)}$$

From equations **(ii)** and **(iii)**, we have

$$l = 1.03 \times 10^6 / 8750 = 117.7 \text{ mm}$$

Taking larger of the two values, we have length of key,

$$l = 117.7 \text{ say } 120 \text{ mm}$$

Q2.A 45 mm diameter shaft is made of steel with yield strength of 400 MPa. A parallel key of size 14 mm wide and 9 mm thick made of steel with yield strength of 340 MPa is to be used. Find the required length of key, if the shaft is loaded to transmit the maximum permissible torque. Use maximum shear stress theory and assume a factor of safety of 2.

Given : $d = 45$ mm ; σ_{yt} for shaft = 400 MPa = 400 N/mm^2 ; $w = 14$ mm ; $t = 9$ mm ; σ_{yt} for key = 340 MPa = 340 N/mm^2; $F.S. = 2$

Let l = Length of key.

According to maximum shear stress theory (See Art. 5.10), the maximum shear stress for the shaft,

$$\tau_{max} = \frac{\sigma_{yt}}{2 \times F.S.} = \frac{400}{2 \times 2} = 100 \text{ N/mm}^2$$

and maximum shear stress for the key,

$$\tau_k = \frac{\sigma_{yt}}{2 \times F.S.} = \frac{340}{2 \times 2} = 85 \text{ N/mm}^2$$

We know that the maximum torque transmitted by the shaft and key,

$$T = \frac{\pi}{16} \times \tau_{max} \times d^3 = \frac{\pi}{16} \times 100\,(45)^3 = 1.8 \times 10^6 \text{ N-mm}$$

First of all, let us consider the failure of key due to shearing. We know that the maximum torque transmitted (T),

$$1.8 \times 10^6 = l \times w \times \tau_k \times \frac{d}{2} = l \times 14 \times 85 \times \frac{45}{2} = 26\,775\, l$$

$\therefore$ $l = 1.8 \times 10^6 / 26\,775 = 67.2$ mm

Now considering the failure of key due to crushing. We know that the maximum torque transmitted by the shaft and key (T),

$$1.8 \times 10^6 = l \times \frac{t}{2} \times \sigma_{ck} \times \frac{d}{2} = l \times \frac{9}{2} \times \frac{340}{2} \times \frac{45}{2} = 17\,213\, l$$

$$\ldots \left(\text{Taking } \sigma_{ck} = \frac{\sigma_{yt}}{F.S.}\right)$$

$\therefore$ $l = 1.8 \times 10^6 / 17\,213 = 104.6$ mm

Taking the larger of the two values, we have

$l = 104.6$ say 105 mm.

Chapter-4

DESIGN OF COUPLING

4.1 Shaft Coupling

Shafts are usually available up to 7 meters length due to inconvenience in transport. In order to have a greater length, it becomes necessary to join two or more pieces of the shaft by means of a coupling.
Shaft couplings are used in machinery for several purposes, the most common of which are the following:

1. To provide for the connection of shafts of units those are manufactured separately such as a motor and generator and to provide for disconnection for repairs or alternations.
2. To provide for misalignment of the shafts or to introduce mechanical flexibility.
3. To reduce the transmission of shock loads from one shaft to another.
4. To introduce protection against overloads.
5. It should have no projecting parts.

4.2 Requirements of a good shaft coupling

A good shaft coupling should have the following requirements:

1. It should be easy to connect or disconnect.
2. It should transmit the full power from one shaft to the other shaft without losses.
3. It should hold the shafts in perfect alignment.
4. It should reduce the transmission of shock loads from one shaft to another shaft.
5. It should have no projecting parts

4.3 Types of Shafts Couplings

Shaft couplings are divided into two main groups as follows:

1. **Rigid coupling.** It is used to connect two shafts which are perfectly aligned. Following types of rigid coupling are important from the subject point of view:
(a) Sleeve or muff coupling.
(b) Clamp or split-muff or compression coupling, and
(c) Flange coupling.

2. **Flexible coupling.** It is used to connect two shafts having both lateral and angular misalignment. Following types of flexible coupling are important from the subject point of view:
(a) Bushed pin type coupling,
(b) Universal coupling, and
(c) Oldham coupling.

4.4 Design of Sleeve or Muff-Coupling

It is the simplest type of rigid coupling, made of cast iron. It consists of a hollow cylinder whose inner diameter is the same as that of the shaft. It is fitted over the ends of the two shafts by means of a gib head key, as shown in Fig.

The power is transmitted from one shaft to the other shaft by means of a key and a sleeve. It is, therefore, necessary that all the elements must be strong enough to transmit the torque.

The usual proportions of a cast iron sleeve coupling are as follows:
Outer diameter of the sleeve, **D = 2d + 13 mm**
And length of the sleeve, **L = 3.5 d**
Where, d = diameter of the shaft.

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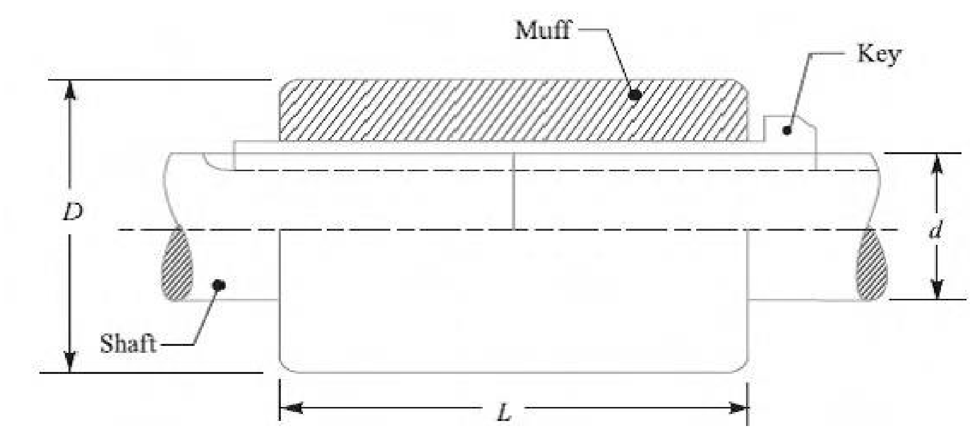


In designing a sleeve or muff-coupling, the following procedure may be adopted

1. Design for sleeve

The sleeve is designed by considering it as a hollow shaft
Let

T = Torque to be transmitted by the coupling, and
τ_c = Permissible shear stress for the material of the sleeve which is cast iron.

The safe value of shear stress for cast iron may be taken as 14 MPa.

We know that torque transmitted by a hollow section,
.

$$T = \frac{\pi}{16} \times \tau_c \left(\frac{D^4 - d^4}{D} \right) = \frac{\pi}{16} \times \tau_c \times D^3 \,(1 - k^4) \qquad \ldots (\because k = d/D)$$

From this expression, the induced shear stress in the sleeve may be checked

2. Design for key

The key for the coupling may be designed in the similar way as discussed in pervious chapter.

The width and thickness of the coupling key is obtained from the proportions.
The length of the coupling key is at least equal to the length of the sleeve (i.e. 3.5 d).
The coupling key is usually made into two parts so that the length of the key in each shaft,

$$l = \frac{L}{2} = \frac{3.5\,d}{2}$$

After fixing the length of key in each shaft, the induced shearing and crushing stresses may be checked. We know that torque transmitted,

$$T = l \times w \times \tau \times \frac{d}{2} \quad \text{... (Considering shearing of the key)}$$

$$= l \times \frac{t}{2} \times \sigma_c \times \frac{d}{2} \quad \text{... (Considering crushing of the key)}$$

Note: The depth of the keyway in each of the shafts to be connected should be exactly the same and the diameters should also be same. If these conditions are not satisfied, then the key will be bedded on one shaft while in the other it will be loose. In order to prevent this, the key is made in two parts which may be driven from the same end for each shaft or they may be driven from opposite ends.

Q1.Design and make a neat dimensioned sketch of a muff coupling which is used to connect two steel shafts transmitting 40 kW at 350 r.p.m. The material for the shafts and key is plain carbon steel for which allowable shear and crushing stresses may be taken as 40 MPa and 80 MPa respectively. The material for the muff is cast iron for which the allowable shear stress may be assumed as 15 MPa.

Solution:
Given: P = 40 kW = 40 × 10^3 W; N = 350 r.p.m.; τs = 40 MPa = 40 N/mm2; σcs = 80 MPa = 80 N/mm^2; σc = 15 MPa = 15 N/mm^2.

$$T - \frac{P \times 60}{2\,\pi N} - \frac{40 \times 10^3 \times 60}{2\,\pi \times 350} - 1100 \text{ N-m}$$

$$= 1100 \times 10^3 \text{ N-mm}$$

We also know that the torque transmitted (T),

$$1100 \times 10^3 = \frac{\pi}{16} \times \tau_s \times d^3 = \frac{\pi}{16} \times 40 \times d^3 = 7.86\,d^3$$

$\therefore \quad d^3 = 1100 \times 10^3/7.86 = 140 \times 10^3$ or d = 52 say 55 mm **Ans.**

1. Design for sleeve

We know that outer diameter of the muff,
D = 2d + 13 mm = 2 × 55 + 13 = 123 say 125 mm **Ans.**

Length of the muff,
L = 3.5 d = 3.5 × 55 = 192.5 say 195 mm **Ans.**

Let us now check the induced shear stress in the muff.

Let τc be the induced shear stress in the muff which is made of cast iron. Since the muff is considered to be a hollow shaft,

Therefore the torque transmitted (T),

$$1100 \times 10^3 = \frac{\pi}{16} \times \tau_c \left(\frac{D^4 - d^4}{D} \right) = \frac{\pi}{16} \times \tau_c \left[\frac{(125)^4 - (55)^4}{125} \right]$$

$$= 370 \times 103\ \tau_c$$

$$\therefore \quad \tau_c = 1100 \times 10^3 / 370 \times 10^3 = 2.97 \text{ N/mm}^2$$

Since the induced shear stress in the muff (cast iron) is less than the permissible shear stress of 15 N/mm2, therefore the design of muff is safe.

3. Design for key

From Design data Book, we find that for a shaft of 55 mm diameter,
Width of key, w = 18 mm **Ans.**

Since the crushing stress for the key material is twice the shearing stress, therefore a square key may be used.
Then, Thickness of key, t = w = 18 mm **Ans.**

We know that length of key in each shaft,
l = L / 2 = 195 / 2 = 97.5 mm **Ans.**

Let us now check the induced shear and crushing stresses in the key.

First of all, let us consider shearing of the key.

We know that torque transmitted (T),

$$1100 \times 10^3 = l \times w \times \tau_s \times \frac{d}{2} = 97.5 \times 18 \times \tau_s \times \frac{55}{2} = 48.2 \times 10^3\ \tau_s$$

$$\tau_s = 1100 \times 10^3 / 48.2 \times 10^3 = 22.8 \text{ N/mm}^2$$

Now considering crushing of the key.

We know that torque transmitted (*T*),

$$1100 \times 10^3 = l \times \frac{t}{2} \times \sigma_{cs} \times \frac{d}{2} = 97.5 \times \frac{18}{2} \times \sigma_{cs} \times \frac{55}{2} = 24.1 \times 10^3\ \sigma_{cs}$$

$$\sigma_{cs} = 1100 \times 10^3 / 24.1 \times 10^3 = 45.6 \text{ N/mm}^2$$

Since the induced shear and crushing stresses are less than the permissible stresses, therefore the design of key is safe.

4.5 Design of Clamp or Compression Coupling.

It is also known as **split muff coupling.** In this case, the muff or sleeve is made into two halves and are bolted together as shown in Fig. The halves of the muff are made of cast iron.

The shaft ends are made to a butt each other and a single key is fitted directly in the keyways of both the shafts. One-half of the muff is fixed from below and the other half is placed from above. Both the halves are held together by means of mild steel studs or bolts and nuts. The number of bolts may be two, four or six. The nuts are recessed into the bodies of the muff castings.

This coupling may be used for heavy duty and moderate speeds. The advantage of this coupling is that the position of the shafts need not be changed for assembling or disassembling of the coupling.

The usual proportions of the muff for the clamp or compression coupling are: Diameter of the muff or sleeve,

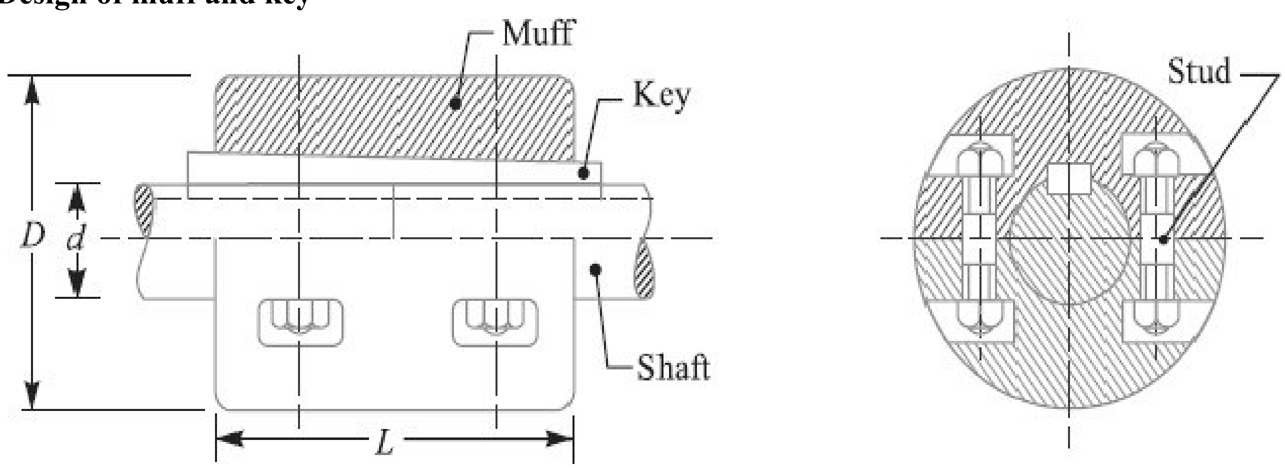
$$D = 2d + 13 \text{ mm}$$

Length of the muff or sleeve, $L = 3.5\ d$

Where d = Diameter of the shaft.

In the clamp or compression coupling, the power is transmitted from one shaft to the other by means of key and the friction between the muff and shaft. In designing this type of coupling, the following procedure may be adopted.

1. Design of muff and key



The muff and key are designed in the similar way as discussed in muff coupling.

2. Design of clamping bolts

Let T = Torque transmitted by the shaft,
d = Diameter of shaft,
d_b = Root or effective diameter of bolt, n = Number of bolts,
σt = Permissible tensile stress for bolt material,
μ = Coefficient of friction between the muff and shaft, and
L = Length of muff.

We know that the force exerted by each bolt

$$= \frac{\pi}{4}(d_b)^2 \sigma_t$$

Then, Force exerted by the bolts on each side of the shaft

$$= \frac{\pi}{4}(d_b)^2 \sigma_t \times \frac{n}{2}$$

Let p be the pressure on the shaft and the muff surface due to the force, then for uniform pressure distribution over the surface,
Then, Frictional force between each shaft and muff,

$$F = \mu \times \text{pressure} \times \text{area} = \mu \times p \times \frac{1}{2} \times \pi d \times L$$

$$= \mu \times \frac{\frac{\pi}{4}(d_b)^2 \sigma_t \times \frac{n}{2}}{\frac{1}{2} L \times d} \times \frac{1}{2} \pi d \times L$$

$$= \mu \times \frac{\pi}{4}(d_b)^2 \sigma_t \times \frac{n}{2} \times \pi = \mu \times \frac{\pi^2}{8}(d_b)^2 \sigma_t \times n$$

$$T = F \times \frac{d}{2} = \mu \times \frac{\pi^2}{8}(d_b)^2 \sigma_t \times n \times \frac{d}{2} = \frac{\pi^2}{16} \times \mu\,(d_b)^2 \sigma_t \times n \times d$$

And the torque that can be transmitted by the coupling,
From this relation, the root diameter of the bolt (d_b) may be evaluated

Q2.Design a clamp coupling to transmit 30 kW at 100 r.p.m. The allowable shear stress for the shaft and key is 40 MPa and the number of bolts connecting the two halves are six. The permissible tensile stress for the bolts is 70 MPa. The coefficient of friction between the muff and the shaft surface may be taken as 0.3.

Given : $P = 30$ kW $= 30 \times 10^3$ W ; $N = 100$ r.p.m. ; $\tau = 40$ MPa $= 40$ N/mm^2 ; $n = 6$; $\sigma_t = 70$ MPa $= 70$ N/mm^2 ; $\mu = 0.3$

1. Design for shaft

Let d = Diameter of shaft.

We know that the torque transmitted by the shaft,

$$T = \frac{P \times 60}{2\,\pi N} = \frac{30 \times 10^3 \times 60}{2\,\pi \times 100} = 2865 \text{ N-m} = 2865 \times 10^3 \text{ N-mm}$$

We also know that the torque transmitted by the shaft (T),

$$2865 \times 10^3 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 40 \times d^3 = 7.86\, d^3$$

$\therefore$ $d^3 = 2865 \times 10^3 / 7.86 = 365 \times 10^3$ or $d = 71.4$ say 75 mm

2. Design for muff

We know that diameter of muff,

$$D = 2d + 13 \text{ mm} = 2 \times 75 + 13 = 163 \text{ say } 165 \text{ mm}$$

and total length of the muff,

$$L = 3.5\, d = 3.5 \times 75 = 262.5 \text{ mm}$$

3. Design for key

The width and thickness of the key for a shaft diameter of 75 mm (from Table 13.1) are as follows :

Width of key, w = 22 mm

Thickness of key, t = 14 mm

and length of key = Total length of muff = 262.5 mm

4. Design for bolts

Let d_b = Root or core diameter of bolt.

We know that the torque transmitted (T),

$$2865 \times 10^3 = \frac{\pi^2}{16} \times \mu (d_b)^2\, \sigma_t \times n \times d = \frac{\pi^2}{16} \times 0.3\, (d_b)^2\; 70 \times 6 \times 75 = 5830 (d_b)^2$$

$\therefore$ $(d_b)^2 = 2865 \times 10^3 / 5830 = 492$ or $d_b = 22.2$ mm

From Table 11.1, we find that the standard core diameter of the bolt for coarse series is 23.32 mm and the nominal diameter of the bolt is 27 mm (M 27).

Chapter-5

DESIGN OF CLOSED COIL HELICAL SPRING

Spring:

Spring is defined as an elastic machine element (flexible element) that deflects under the action of load and returns to its original shape when load is removed.

Important functions and applications of spring :

1. Springs are used to absorb shocks and vibrations eg: vehicle suspension springs, railway buffers tocontrol energy, buffer springs in elevators and vibration mounts for machinery.
2. Measuring forces : Spring balances, gages
3. Storing of energy in clocks ,toys ,cameras, circuit breakers ,starters
4. Springs are used to apply force and control motion.

5.1 Materials used for helical spring.

One of the important considerations in spring design is the choice of the spring material. Some of the common spring materials are given below.

Hard-drawn wire: This is cold drawn, cheapest spring steel. Normally used for low stress and static load. The material is not suitable at subzero temperatures or at temperatures above 120 ^{0} C.
Oil-tempered wire:
It is a cold drawn, quenched, tempered, and general purpose spring steel. However, it is not suitable for fatigue or sudden loads, at subzero temperatures and at temperatures above 180 ^{0} C. When we go for highly stressed conditions then alloy steels are useful.
Chrome Vanadium:
This alloy spring steel is used for high stress conditions and at high temperature up to 220 ^{0} C. It is good for fatigue resistance and long endurance for shock and impact loads.
Chrome Silicon:
This material can be used for highly stressed springs. It offers excellent service for long life, shock loading and for temperature up to 250 ^{0} C.
Music wire:
This spring material is most widely used for small springs. It is the toughest and has highest tensile strength and can withstand repeated loading at high stresses. However, it cannot be used at subzero temperatures or at temperatures above 120 ^{0} C. Normally when we talk about springs we will find that the music wire is a common choice for springs.
Stainless steel:
Widely used alloy spring materials.
Phosphor Bronze / Spring Brass:
It has good corrosion resistance and electrical conductivity. That's the reason it is commonly used for contacts in electrical switches. Spring brass can be used at subzero temperatures.

5.2 Standard size spring wire. (SWG)

British Standard Wire Gauge (often abbreviated to **Standard Wire Gauge or SWG**) is a unit for denoting wire size given by BS 3737:1964. It is also known as the Imperial Wire Gauge or British Standard Gauge.
Standard Wire Gauge (SWG) a notation used for the diameters of metal rods or thickness of metal.

Standard Size of Spring Wire

The standard size of spring wire may be selected from the following table :

Standard wire gauge (SWG) number and corresponding diameter of spring wire.

SWG	*Diameter (mm)*	*SWG*	*Diameter (mm)*	*SWG*	*Diameter (mm)*	*SWG*	*Diameter (mm)*
7/0	12.70	7	4.470	20	0.914	33	0.2540
6/0	11.785	8	4.064	21	0.813	34	0.2337
5/0	10.973	9	3.658	22	0.711	35	0.2134
4/0	10.160	10	3.251	23	0.610	36	0.1930
3/0	9.490	11	2.946	24	0.559	37	0.1727
2/0	8.839	12	2.642	25	0.508	38	0.1524
0	8.229	13	2.337	26	0.457	39	0.1321
1	7.620	14	2.032	27	0.4166	40	0.1219
2	7.010	15	1.829	28	0.3759	41	0.1118
3	6.401	16	1.626	29	0.3454	42	0.1016
4	5.893	17	1.422	30	0.3150	43	0.0914
5	5.385	18	1.219	31	0.2946	44	0.0813
6	4.877	19	1.016	32	0.2743	45	0.0711

5.3 Terms used in compression spring.

Helical springs.

The helical springs are made up of a wire coiled in the form of a helix and are primarily intended for compressive or tensile loads. The cross-section of the wire from which the spring is made may be circular, square or rectangular. The two forms of helical springs are compression helical spring as shown in Fig (a) and tension helical spring as shown in Fig (b)

(*a*) Compression helical spring. (*b*) Tension helical spring.

The helical springs are said to be closely coiled when the spring wire is coiled so close that the plane containing each turn is nearly at right angles to the axis of the helix and the wire is subjected to torsion. In other words, in a closely coiled helical spring, the helix angle is very small, it is usually less than 10°. The major stresses produced in helical springs are shear stresses due to twisting. The load applied is parallel to or along the axis of the spring.

In open coiled helical springs, the spring wire is coiled in such a way that there is a gap between the two consecutive turns, as a result of which the helix angle is large. Since the application of open coiled helical springs are limited, therefore our discussion shall confine to closely coiled helical springs only.

The helical springs have the following advantages:
(a) These are easy to manufacture.
(b) These are available in wide range.
(c) These are reliable.
(d) These have constant spring rate.
(e) Their performance can be predicted more accurately.
(f) Their characteristics can be varied by changing dimensions.

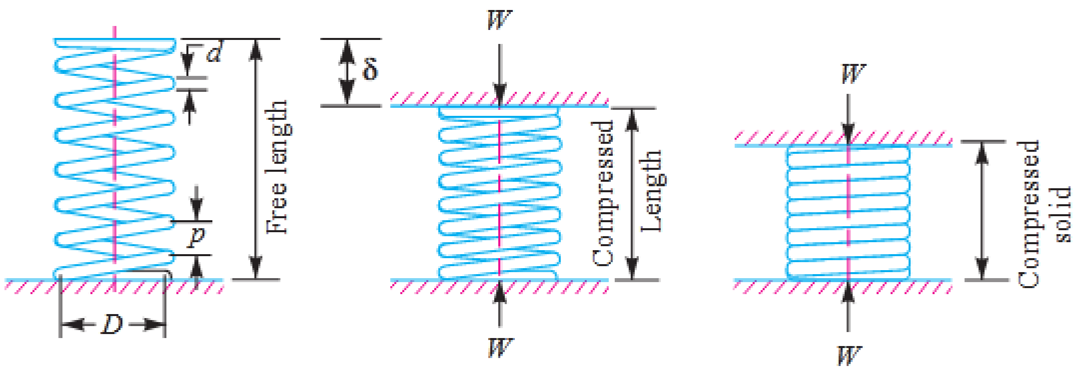
SOLID LENGTH:

When the compression spring is compressed until the coils come in contact with each other, then the spring is said to be solid. The solid length of a spring is the product of total number of coils and the diameter of the wire.

$$L_S = n'.d$$

where n' = Total number of coils, and

d = Diameter of the wire.



FREE LENGTH:

The free length of a compression spring, as shown in Fig, is the length of the spring in the free or unloaded condition. It is equal to the solid length plus the maximum deflection or compression of the spring and the clearance between the adjacent coils (when fully compressed).

Mathematically,

Free length of the spring,

L_F = Solid length + Maximum compression + *Clearance between adjacent coils (or clash allowance)

$$= n'.d + \delta_{max} + 0.15\,\delta_{max}$$

The following relation may also be used to find the free length of the spring, *i.e.*

$$L_F = n'.d + \delta_{max} + (n' - 1) \times 1 \text{ mm}$$

In this expression, the clearance between the two adjacent coils is taken as 1 mm.

SPRING INDEX:

The spring index is defined as the ratio of the mean diameter of the coil to the diameter of the wire. Mathematically,

Spring index, C = D / d

Where, D = Mean diameter of the coil, and d = Diameter of the wire.

SPRING RATE:

The spring rate (or stiffness or spring constant) is defined as the load required per unit deflection of the spring.

Mathematically,

Spring rate, $k = W / \delta$

where W = Load, and

δ = Deflection of the spring.

PITCH :

The pitch of the coil is defined as the axial distance between adjacent coils in uncompressed state. Mathematically,

$$\text{Pitch of the coil,} \quad p = \frac{\text{Free length}}{n' - 1}$$

The pitch of the coil may also be obtained by using the following relation, *i.e.*

$$\text{Pitch of the coil,} \quad p = \frac{L_F - L_S}{n'} + d$$

where L_F = Free length of the spring,

L_S = Solid length of the spring,

n' = Total number of coils, and

d = Diameter of the wire.

STRESSES IN HELICAL SPRING :

Consider a helical compression spring made of circular wire and subjected to an axial load W, as shownin Fig.

Let D = Mean diameter of the spring coil,

d = Diameter of the spring wire,

n = Number of active coils,

G = Modulus of rigidity for the spring material,

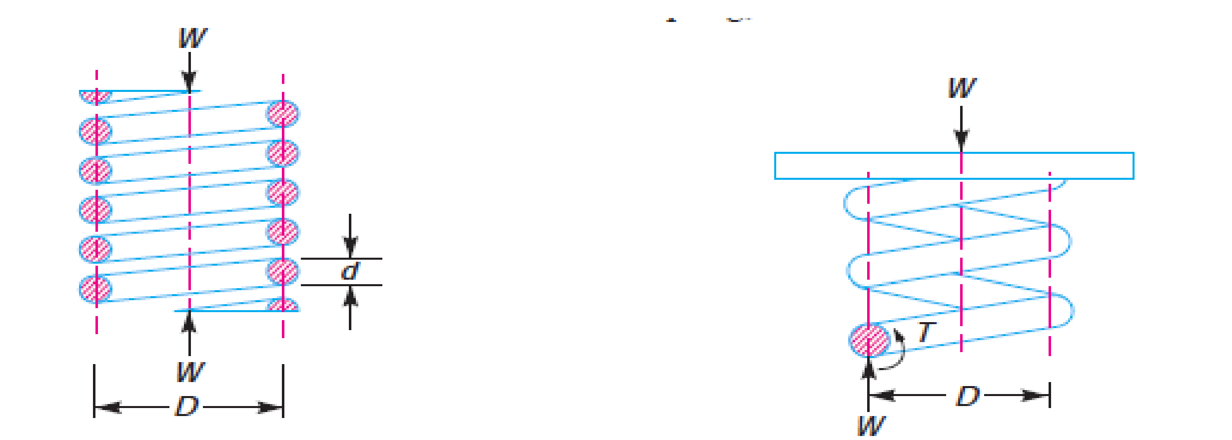
W = Axial load on the spring,

τ = Maximum shear stress induced in the wire,

C = Spring index = D/d,

p = Pitch of the coils, and

δ = Deflection of the spring, as a result of an axial load W.



(*a*) Axially loaded helical spring.

(*b*) Free body diagram showing that wire is subjected to torsional shear and a direct shear.

Now consider a part of the compression spring as shown in Fig (b).The load W tends to rotate the wire due to the twisting moment (T) set up in the wire. Thus torsional shear stress is induced in the wire. A little consideration will show that part of the Spring,as shown in Fig (b), is in equilibrium under the action of two forces W and the twisting moment T.

We know that the twisting moment,

$$T = W \times \frac{D}{2} = \frac{\pi}{16} \times \tau_1 \times d^3$$

$$\tau_1 = \frac{8W.D}{\pi d^3} \qquad \text{...}(i)$$

The torsional shear stress diagram is shown in Fig (a).

In addition to the torsional shear stress ($\tau 1$) induced in the wire, the following stresses also act on the wire:

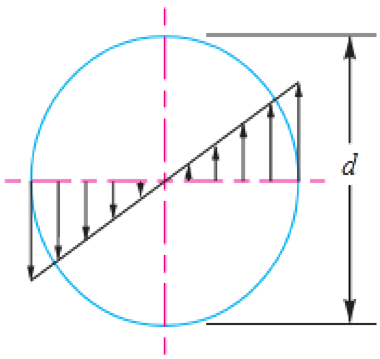
1. Direct shear stress due to the load W, and
2. Stress due to curvature of wire

We know that direct shear stress due to the load W,

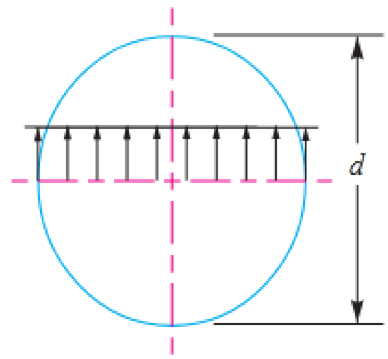
$$\tau_2 = \frac{\text{Load}}{\text{Cross-sectional area of the wire}}$$

$$= \frac{W}{\frac{\pi}{4} \times d^2} = \frac{4W}{\pi d^2} \qquad \text{...}(ii)$$

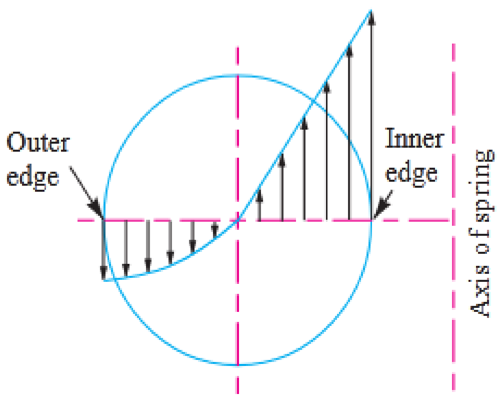
The direct shear stress diagram is shown in Fig. (b) and the resultant diagram of torsional shear stress and direct shear stress is shown in Fig (c).



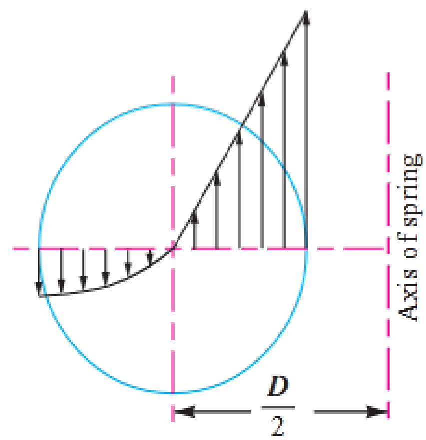
(a) Torsional shear stress diagram.



(b) Direct shear stress diagram.



(c) Resultant torsional shear and direct shear stress diagram.



(d) Resultant torsional shear, direct shear and curvature shear stress diagram.

We know that the resultant shear stress induced in the wire,

$$\tau = \tau_1 \pm \tau_2 = \frac{8W.D}{\pi\, d^3} \pm \frac{4W}{\pi\, d^2}$$

The ***positive*** sign is used for the inner edge of the wire and ***negative*** sign is used for the outer edge of the wire. Since the stress is maximum at the inner edge of the wire, therefore

Maximum shear stress induced in the wire,

= Torsional shear stress + Direct shear stress

$$= \frac{8W.D}{\pi\, d^3} + \frac{4W}{\pi\, d^2} = \frac{8W.D}{\pi\, d^3}\left(1 + \frac{d}{2D}\right)$$

$$= \frac{8\,W.D}{\pi\,d^3}\left(1 + \frac{1}{2C}\right) = K_S \times \frac{8\,W.D}{\pi\,d^3} \qquad \text{...}(iii)$$

... (Substituting $D/d = C$)

where K_S = Shear stress factor $= 1 + \dfrac{1}{2C}$

From the above equation, it can be observed that the effect of direct shear $\left(\dfrac{8\,WD}{\pi\,d^3} \times \dfrac{1}{2C}\right)$ is appreciable for springs of small spring index C. Also we have neglected the effect of wire curvature in equation (*iii*). It may be noted that when the springs are subjected to static loads, the effect of wire curvature may be neglected, because yielding of the material will relieve the stresses.

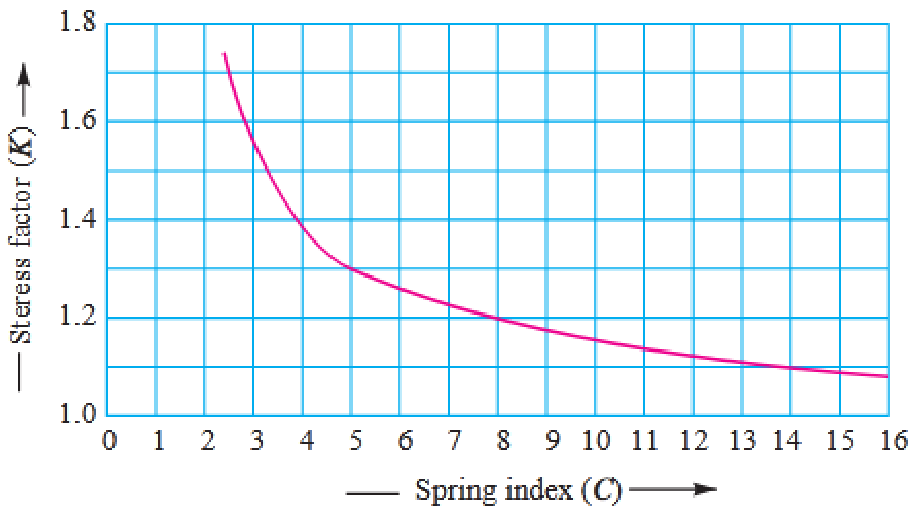
In order to consider the effects of both direct shear as well as curvature of the wire, a Wahl's stress factor (K) introduced by A.M. Wahl may be used. The resultant diagram of torsional shear, direct shear and curvature shear stress is shown in Fig. (*d*).

∴ Maximum shear stress induced in the wire,

$$\tau = K \times \frac{8\,W.D}{\pi\,d^3} = K \times \frac{8\,W.C}{\pi\,d^2} \qquad \text{...}(iv)$$

where $$K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C}$$

The values of K for a given spring index (C) may be obtained from the graph as shown in Fig



Wahl's stress factor for helical springs.

We see from Fig. that Wahl's stress factor increases very rapidly as the spring index decreases. The spring mostly used in machinery have spring index above 3.

Note: The Wahl's stress factor (K) may be considered as composed of two sub-factors, K_S and K_C, such that

$$K = K_S \times K_C$$

where K_S = Stress factor due to shear, and

K_C = Stress concentration factor due to curvature.

5.5 Deflection of helical spring of circular wire.

In the previous article, we have discussed the maximum shear stress developed in the wire. We know that

Total active length of the wire,

$$l = \text{Length of one coil} \times \text{No. of active coils} = \pi D \times n$$

Let θ = Angular deflection of the wire when acted upon by the torque T.

$\therefore$ Axial deflection of the spring,

$$\delta = \theta \times D/2 \qquad \text{...}(i)$$

We also know that

$$\frac{T}{J} = \frac{\tau}{D/2} = \frac{G.\theta}{l}$$

$$\therefore \qquad \theta = \frac{T\,l}{J.G} \qquad \text{...}\left(\text{considering } \frac{T}{J} = \frac{G.\theta}{l}\right)$$

where J = Polar moment of inertia of the spring wire

$$= \frac{\pi}{32} \times d^4, \; d \text{ being the diameter of spring wire.}$$

and G = Modulus of rigidity for the material of the spring wire.

Now substituting the values of l and J in the above equation, we have

$$\theta = \frac{T\,l}{J.G} = \frac{\left(W \times \frac{D}{2}\right)\pi\, D.n}{\frac{\pi}{32} \times d^4\, G} = \frac{16 W.D^2.n}{G.d^4} \qquad \ldots(ii)$$

Substituting this value of θ in equation (*i*), we have

$$\delta = \frac{16 W.D^2.n}{G.d^4} \times \frac{D}{2} = \frac{8\,W.D^3.n}{G.d^4} = \frac{8\,W.C^3.n}{G.d} \qquad \ldots (\because C = D/d)$$

and the stiffness of the spring or spring rate,

$$\frac{W}{\delta} = \frac{G.d^4}{8\,D^3.n} = \frac{G.d}{8\,C^3.n} = \text{constant}$$

5.6 Surge in spring

When one end of a helical spring is resting on a rigid support and the other end is loaded suddenly, then all the coils of the spring will not suddenly deflect equally, because some time is required for the propagation of stress along the spring wire.

In the beginning, the end coils of the spring in contact with the applied load take up whole of the deflection and then it transmits a large part of its deflection to the adjacent coils. In this way, a wave of compression propagates through the coils to the supported end from where it is reflected back to the deflected end. This wave of compression travels along the spring indefinitely. If the applied load is of fluctuating type as in the case of valve spring in internal combustion engines and if the time interval between the load applications is equal to the time required for the wave to travel from one end to the other end, then resonance will occur. This results in very large deflections of the coils and correspondingly very high stresses. Under these conditions; it is just possible that the spring may fail. This phenomenon is called ***surge.***

It has been found that the natural frequency of spring should be at least twenty times the frequency of application of a periodic load in order to avoid resonance with all harmonic frequencies up to twentieth order. The natural frequency for springs clamped between two plates is given by

$$f_n = \frac{d}{2\pi\, D^2.n}\sqrt{\frac{6\,G.g}{\rho}} \text{ cycles/s}$$

where d = Diameter of the wire,
D = Mean diameter of the spring,
n = Number of active turns,
G = Modulus of rigidity,
g = Acceleration due to gravity, and
ρ = Density of the material of the spring.

The surge in springs may be eliminated by using the following methods :

1. By using friction dampers on the centre coils so that the wave propagation dies out.
2. By using springs of high natural frequency.
3. By using springs having pitch of the coils near the ends different than at the centre to have different natural frequencies.

NUMERICALS:

Q1. Design a helical compression spring for a maximum load of 1000 N for a deflection of 25 mm using the value of spring index as 5. The maximum permissible shear stress for spring wire is 420 MPa and modulus of rigidity is84 kN/mm 2.

Take Wahl's factor, $K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C}$, *where C = Spring index.*

Solution. Given : W = 1000 N ; δ = 25 mm ; $C = D/d = 5$; τ = 420 MPa = 420 N/mm^2 ; G = 84 kN/mm^2 = 84 × 10^3 N/mm^2

1. Mean diameter of the spring coil

Let D = Mean diameter of the spring coil, and
d = Diameter of the spring wire.

We know that Wahl's stress factor,

$$K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C} = \frac{4 \times 5 - 1}{4 \times 5 - 4} + \frac{0.615}{5} = 1.31$$

and maximum shear stress (τ),

$$420 = K \times \frac{8\,W.C}{\pi\,d^2} = 1.31 \times \frac{8 \times 1000 \times 5}{\pi\,d^2} = \frac{16\,677}{d^2}$$

$$\therefore \quad d^2 = 16\,677 / 420 = 39.7 \quad \text{or} \quad d = 6.3 \text{ mm}$$

From Table 23.2, we shall take a standard wire of size *SWG* 3 having diameter (d) = 6.401 mm.

∴ Mean diameter of the spring coil,

$$D = C.d = 5\,d = 5 \times 6.401 = 32.005 \text{ mm} \quad \textbf{Ans.} \qquad \ldots (\because C = D/d = 5)$$

and outer diameter of the spring coil,

$$D_o = D + d = 32.005 + 6.401 = 38.406 \text{ mm} \quad \textbf{Ans.}$$

2. Number of turns of the coils

Let n = Number of active turns of the coils.

We know that compression of the spring (δ),

$$25 = \frac{8W.C^3.n}{G.d} = \frac{8 \times 1000\,(5)^3 n}{84 \times 10^3 \times 6.401} = 1.86\,n$$

$\therefore$ $n = 25 / 1.86 = 13.44$ say 14 **Ans.**

For squared and ground ends, the total number of turns,

$$n' = n + 2 = 14 + 2 = 16 \text{ **Ans.**}$$

3. *Free length of the spring*

We know that free length of the spring

$$= n'.d + \delta + 0.15\,\delta = 16 \times 6.401 + 25 + 0.15 \times 25$$

$$= 131.2 \text{ mm}$$ **Ans.**

4. *Pitch of the coil*

We know that pitch of the coil

$$= \frac{\text{Free length}}{n' - 1} = \frac{131.2}{16 - 1} = 8.75 \text{ mm}$$ **Ans.**

Q2 A helical spring is made from a wire of 6 mm diameter and has outside diameter of 75 mm. If the permissible shear stress is 350 MPa and modulus of rigidity 84 kN/mm2, find the axial load which the spring can carry and the deflection per active turn.

Solution. Given : $d = 6$ mm ; $D_o = 75$ mm ; $\tau = 350$ MPa $= 350$ N/mm^2 ; $G = 84$ kN/mm^2 $= 84 \times 10^3$ N/mm^2

We know that mean diameter of the spring,

$$D = D_o - d = 75 - 6 = 69 \text{ mm}$$

$\therefore$ Spring index, $C = \frac{D}{d} = \frac{69}{6} = 11.5$

Let W = Axial load, and

δ / n = Deflection per active turn.

1. *Neglecting the effect of curvature*

We know that the shear stress factor,

$$K_S = 1 + \frac{1}{2C} = 1 + \frac{1}{2 \times 11.5} = 1.043$$

and maximum shear stress induced in the wire (τ),

$$350 = K_S \times \frac{8\,W.D}{\pi\,d^3} = 1.043 \times \frac{8\,W \times 69}{\pi \times 6^3} = 0.848\,W$$

$\therefore$ $W = 350 / 0.848 = 412.7$ N **Ans.**

We know that deflection of the spring,

$$\delta = \frac{8\,W.D^3.n}{G.d^4}$$

$\therefore$ Deflection per active turn,

$$\frac{\delta}{n} = \frac{8\,W.D^3}{G.d^4} = \frac{8 \times 412.7\,(69)^3}{84 \times 10^3 \times 6^4} = 9.96 \text{ mm } \textbf{Ans.}$$

2. Considering the effect of curvature

We know that Wahl's stress factor,

$$K = \frac{4C - 1}{4C - 4} + \frac{0.615}{C} = \frac{4 \times 11.5 - 1}{4 \times 11.5 - 4} + \frac{0.615}{11.5} = 1.123$$

We also know that the maximum shear stress induced in the wire (τ),

$$350 = K \times \frac{8W.C}{\pi\,d^2} = 1.123 \times \frac{8 \times W \times 11.5}{\pi \times 6^2} = 0.913\,W$$

$$\therefore \qquad W = 350 / 0.913 = 383.4 \text{ N } \textbf{Ans.}$$

and deflection of the spring,

$$\delta = \frac{8\,W.D^3.n}{G.d^4}$$

$\therefore$ Deflection per active turn,

$$\frac{\delta}{n} = \frac{8\,W.D^3}{G.d^4} = \frac{8 \times 383.4\,(69)^3}{84 \times 10^3 \times 6^4} = 9.26 \text{ mm } \textbf{Ans.}$$

Module 1 Introduction

2 Marks Question

1. Define the terms load
2. What are the types of Load?
3. Define the terms stress and strain.
4. What do you mean by factor of safety?
5. Define working stress, yield stress, ultimate stress
6. What do you mean by (a) Resilience (b) Proof resilience, and (c) Modulus of resilience
7. Classify engineering Material.
8. What is the difference between Ductility and Brittleness?
9. What is the difference between Ductility and Malleability?
10. What is the difference between Hardness and Toughness?
11. What do you mean by Creep?

5/10 Marks Questions

1. What is Machine Design and describe the Classification of Machine Design.
2. Describe the General procedure of Machine Design.
3. Describe Factors Governing Machine Design
4. Describe at least ten(10) mechanical properties of material.
5. With Neat Sketch Describe strain curve for M.S & C.I.
6. Describe The Physical Properties Of Material.

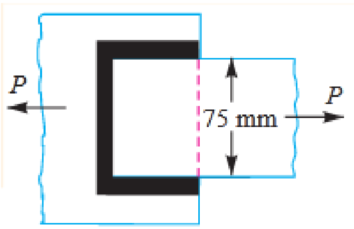
Module 2 Design of fastening elements

2 Marks Question

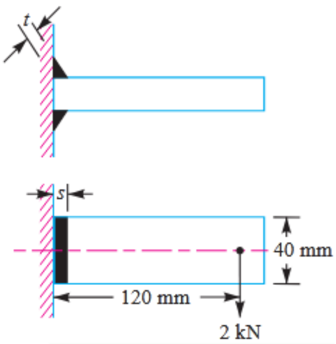
1. What do you understand by the term welded joint?
2. State types of welded joint?
3. What is an eccentric loaded welded joint?
4. Classify the type of Joint.
5. What Do you Mean by Caulking And Fullering?
6. What are the modes of Failure of Riveted Joint?
7. What is Pitch, Back Pitch and Diagonal pitch in Riveted Joint?
8. What do you mean by stress Concentration Factor?

5/10 Marks Questions

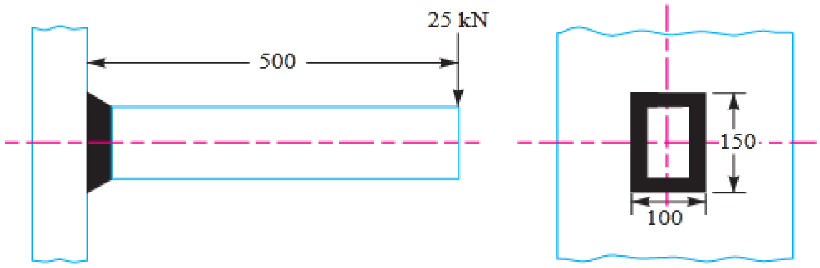
1. What are the advantages of welded joints over other joints?
2. What are the assumptions made in the design of welded joint?
3. What is an eccentric loaded welded joint? Discuss the procedure for designing such a joint.
4. A plate 100 mm wide and 12.5 mm thick is to be welded to another plate by means of parallel fillet welds. The plates are subjected to a load of 50 kN. Find the length of the weld so that the maximum stress does not exceed 56 MPa. Consider the joint first under static loading and then under fatigue loading.
5. A plate 75 mm wide and 12.5 mm thick is joined with another plate by a single transverse weld and a double parallel fillet weld as shown in Fig. The maximum tensile and shear stresses are 70MPa and56 MPa respectively.
   Find the length of each parallel fillet weld, if the joint is subjected to both static and fatigue loading.



6. A welded joint as shown in Fig, is subjected to an eccentric load of 2 kN. Find the size of weld, if the maximum shear stress in the weld is 25 MPa.

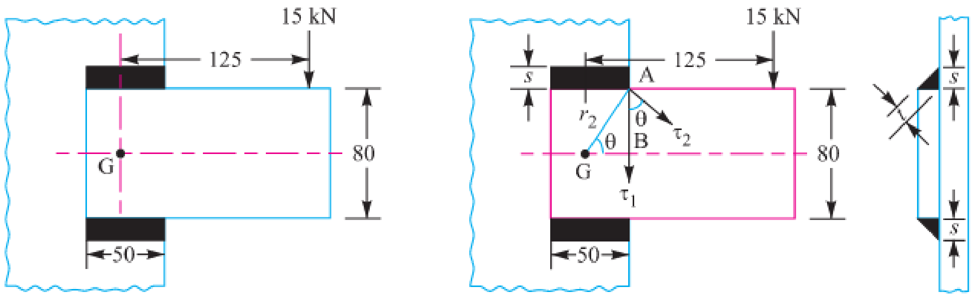


7. A rectangular cross-section bar is welded to a support by means of fillet welds as shown in Fig.Determine the size of the welds, if the permissible shear stress in the weld is limited to 75 MPa



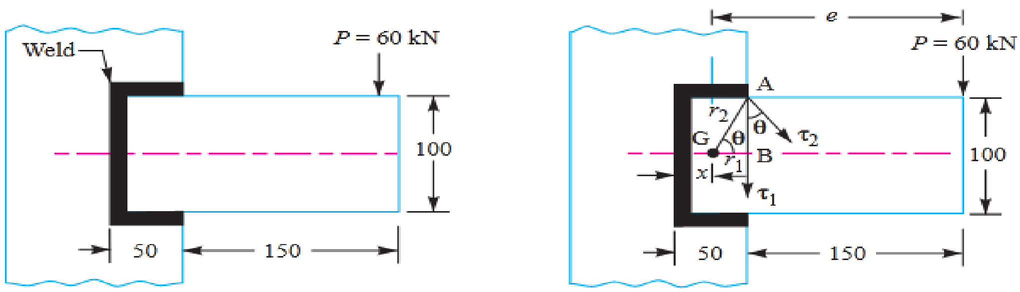
a. All dimensions in mm

8. A bracket carrying a load of 15 kN is to be welded as shown in Fig .Find the size of weld required if the allowable shear stress is not to exceed 80 MPa.



a. All dimensions in mm.

9. A rectangular steel plate is welded as a cantilever to a vertical column and supports a single concentrated load P, as shown in Fig. Determine the weld size if shear stress in the same is not to exceed 140 MPa.



All dimensions in mm.

10. Explain the Failure of Riveted Joint.
11. What is Strength of a Riveted Joint and Efficiency of a Riveted Joint?
12. A double riveted lap joint is made between 15 mm thick plates. The rivet diameter and pitch are 25 mm and 75 mm respectively. If the ultimate stresses are 400 MPa in tension, 320 MPa in shear and 640 MPa in crushing, find the minimum force per pitch which will rupture the joint.
    If the above joint is subjected to a load such that the factor of safety is 4, find out the actualstresses developed in the plates and the rivets.
13. Design a double riveted butt joint with two cover plates for the longitudinal seam of a boiler shell 1.5 m in diameter subjected to a steam pressure of 0.95 N/mm2. Assume

joint efficiency as 75%, allowable tensile stress in the plate 90 MPa; compressive stress 140 MPa; and shear stress in the rivet 56 MPa.

14. A double riveted lap joint with zig-zag riveting is to be designed for 13 mm thick plates. Assume σt = 80 MPa ; τ = 60 MPa ; and σc = 120 MPa
    State how the joint will fail and find the efficiency of the joint
15. A steam boiler is to be designed for a working pressure of 2.5 N/mm2 with its inside diameter 1.6 m. Give the design calculations for the longitudinal and circumferential joints for the following working stresses for steel plates and rivets : In tension = 75 MPa ; In shear = 60 MPa; In crushing = 125 MPa.

CHAPTER-3 DESIGN OF SHAFTS AND KEYS

2 Marks Question

1. Distinguish between axle and shaft.
2. What types of stresses are induced in shafts?
3. What are the standard sizes of transmissions shafts?
4. What do you understand by torsional rigidity and lateral rigidity?
5. Discuss the various types of shafts
6. Define equivalent twisting moment and equivalent bending moment.
7. What is the function of shaft and key?
8. What is the effect of keyway cut into the shaft?
9. State the Material of Keys.
10. State the types of key.
11. What are the stresses induced on key
12. Draw a Gib Head key with free hand and give its specification

5/10 Marks Questions

1. A solid shaft is transmitting 1 MW at 240 r.p.m. Determine the diameter of the shaft if the maximum torque transmitted exceeds the mean torque by 20%. Take the maximum allowable shear stress as 60 MPa.
2. Find the diameter of a solid steel shaft to transmit 20 kW at 200 r.p.m. The ultimate shear stress for the steel may be taken as 360 MPa and a factor of safety as 8.If a hollow shaft is to be used in place of the solid shaft, find the inside and outside diameter when the ratio of inside to outside diameters is 0.5.
3. A pair of wheels of a railway wagon carries a load of 50 kN on each axle box, acting at a distance of 100 mm outside the wheel base. The gauge of the rails is 1.4 m. Find the diameter of the axle between the wheels, if the stress is not to exceed 100 MPa.
4. A solid circular shaft is subjected to a bending moment of 3000 N-m and a torque of 10 000 N-m. The shaft is made of 45 C 8 steel having ultimate tensile stress of 700 MPa and a ultimate shear stress of 500 MPa. Assuming a factor of safety as 6, determine the diameter of the shaft
5. A shaft made of mild steel is required to transmit 100 kW at 300 r.p.m. The supported length of the shaft is 3 metres. It carries two pulleys each weighing 1500 N supported at a distance of 1 metre from the ends respectively. Assuming the safe value of stress, determine the diameter of the shaft.
6. Design the rectangular key for a shaft of 50 mm diameter. The shearing and crushing stresses for the key material are 42 MPa and 70 MPa.
7. A 45 mm diameter shaft is made of steel with yield strength of 400 MPa. A parallel key of size 14 mm wide and 9 mm thick made of steel with yield strength of 340 MPa is to be used. Find the required length of key, if the shaft is loaded to transmit the maximum permissible torque. Use maximum shear stress theory and assume a factor of safety of 2.

Chapter-4 DESIGN OF COUPLING

2 Marks Question

1. Discuss the function of a coupling?
2. What are the types of coupling?
3. What are the requirements of Good Shaft Coupling?

5/10 Marks Questions

1. Describe, with the help of neat sketches, the types of various shaft couplings such as muff coupling and clamp coupling mentioning the uses of each type.
2. Design and make a neat dimensioned sketch of a muff coupling which is used to connect two steel shafts transmitting 40 kW at 350 r.p.m. The material for the shafts and key is plain carbon steel for which allowable shear and crushing stresses may be taken as 40 MPa and 80 MPa respectively. The material for the muff is cast iron for which the allowable shear stress may be assumed as 15 MPa.
3. Design a clamp coupling to transmit 30 kW at 100 r.p.m. The allowable shear stress for the shaft and key is 40 MPa and the number of bolts connecting the two halves are six. The permissible tensile stress for the bolts is 70 MPa. The coefficient of friction between the muff and the shaft surface may be taken as 0.3.

Chapter-5 DESIGN OF CLOSED COIL HELICAL SPRING

2 Marks Question

1. What is a spring?
2. What is the function of spring?
3. What are the materials for spring?
4. What is the Spring Index and spring rate?
5. What are the Stress induced in helical spring of a circular wire?
6. What do you mean by Free Length and Solid length of spring ?
7. What do you mean by surge in spring?

5/10 Marks Questions

1. Explain what you understand by A.M. Wahl's factor and state its importance in the design of helical springs?
2. Derive the expression of Spring Rate of Helical spring of a circular wire.
3. Design a helical compression spring for a maximum load of 1000 N for a deflection of 25 mm using the value of spring index as 5. The maximum permissible shear stress for spring wire is 420 MPa and modulus of rigidity is84 kN/mm 2.

   Take Wahl's factor, $K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$, *where C = Spring index.*
4. A helical spring is made from a wire of 6 mm diameter and has outside diameter of 75 mm. If the permissible shear stress is 350 MPa and modulus of rigidity 84 kN/mm2, find the axial load which the spring can carry and the deflection per active turn.
5. Design a close coiled helical compression spring for a service load ranging from 2250 N to 2750 N. The axial deflection of the spring for the load range is 6 mm. Assume a spring index of 5. The permissible shear stress intensity is 420 MPa and modulus of rigidity, G = 84 kN/mm 2. Neglect the effect of stress concentration.

GANDHI ACADEMY OF TECHNOLOGY AND ENGINEERING

LECTURE NOTES

ON

AUTOMOBILE-ENGINEERING

6TH SEMESTER

PREPARED BY

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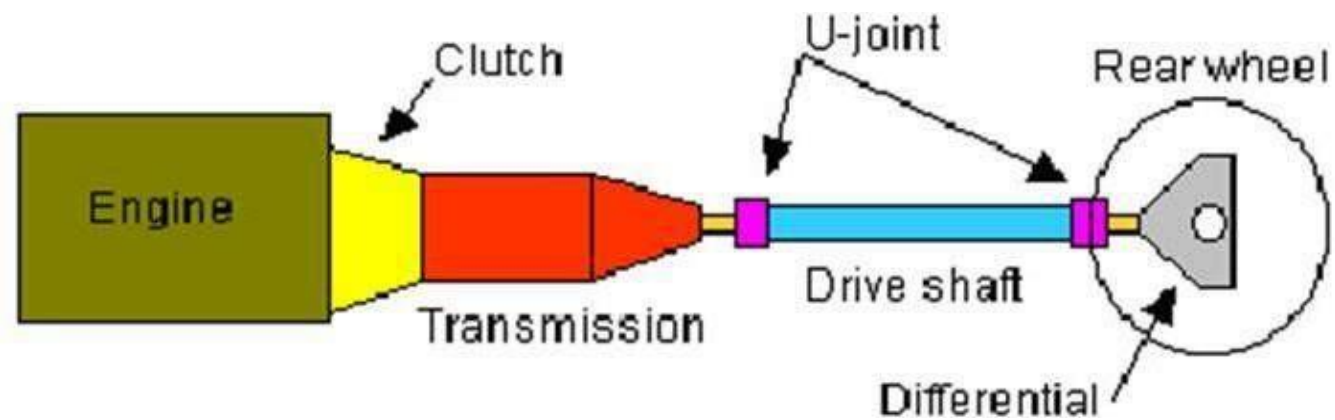
GATE,BERHAMPUR

What is Automobile

- A self propelled vehicle that usually has 4 wheels & internal combustion engine used for land transport (people & items).

Components of Automobile

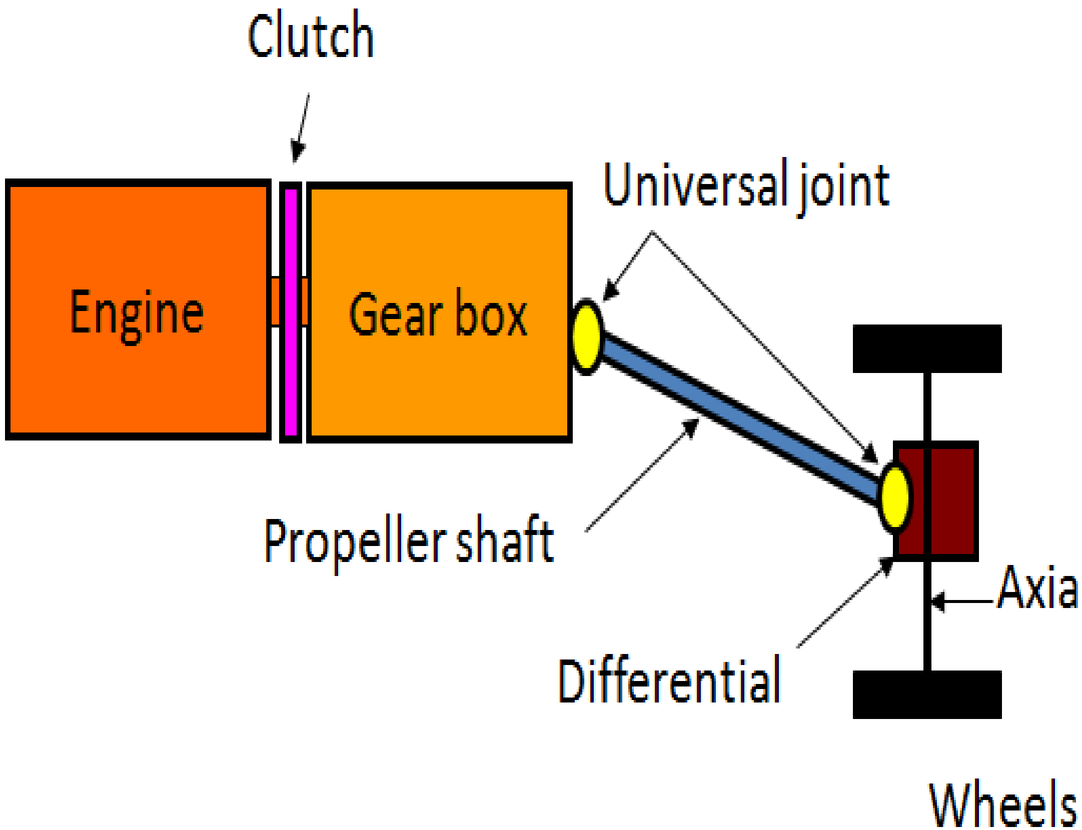
- Basic Structure
- Power plant
- Transmission system
- Auxiliaries
- Controls
- Superstructure



Transfer power from engine to wheels

TRANSMISSION

- Clutch
- Gear box
- Universal joints
- Propeller shaft
- Differential gears
- Axial
- Wheel



POWER TRAIN

Classification of Automobile

1. Purpose:

- Passenger carriers:

- Good carriers:

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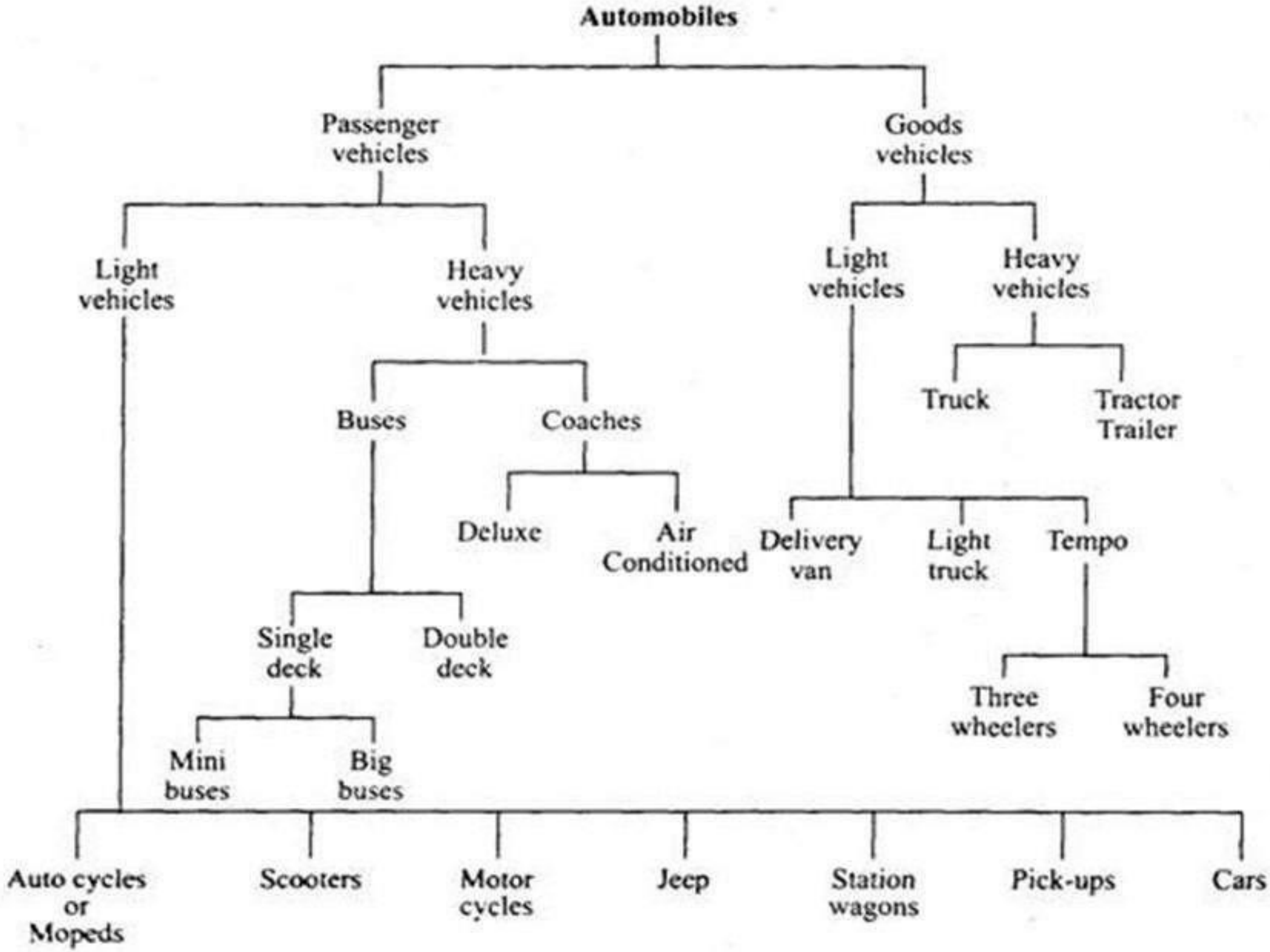
Automobiles
Passenger vehicles
Goods vehicles
Light vehicles
Heavy vehicles
Light vehicles
Heavy vehicles
Truck
Tractor Trailer
Buses
Coaches
Deluxe
Air Conditioned
Delivery van
Light truck
Tempo
Single deck
Double deck
Three wheelers
Four wheelers
Mini buses
Big buses
Auto cycles or Mopeds
Scooters
Motor cycles
Jeep
Station wagons
Pick-ups
Cars

Classification of Automobile

2. Capacity:

- heavy transport vehicles (H.T.V) like truck & buses.
- Light transport vehicles (L.T.V) like cars, jeeps etc.

3. Fuel used:

- petrol vehicles
- Diesel vehicles
- Gas vehicles
- Electric vehicle

4. wheels:

- Two wheelers like scooters, motor cycles etc.
- Three wheelers like autorickshwas, tempo.
- Four wheelers like cars, jeeps.
- Six wheelers like trucks, bus.

5. Body style:

- Closed cars like: saloon, coupe etc.
- Open cars like sports car, convertible car.
- Special style such as estate car, station wagon etc.

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6. Drive:

- Left hand drive e.g. vehicles use in U.S.A
- Right hand vehicle e.g. Indian vehicles.
- Front wheel drive
- Rear wheel drive
- All wheel drive

7. Transmission:

- Manual
- Semi automatic
- Fully automatic

8. Suspension:

- ➢ Conventional: Leaf spring

- ➢ Independent: Coil springs, Pneumatic.

9. Position of engin

- Engine in front

- Engine inside driver's cabine

- Engine in rare side

Parts of Automobile

- Machine portion: Chassis
- Carriage portion: Body

Automobile = Chassis + Body

- Body (carriage portion): portion of an automobile where passengers have their seats or where cargo to be carried is placed.
- Chassis (machine portion): contains almost all the parts of an automobile which are necessary to drive vehicles.

Machine Portion

- Every automobile consists of four basic units:
  - Chassis
  - Transmission
  - Engine
  - Electrical equipments

Transmission

- This unit transmits the power from the engine to the wheels.
- Consists of:
  - ➢ Clutch
  - ➢ Gear box
  - ➢ Final drive
  - ➢ Axles & differential.

Engine :

- Engine is the source of power.
- Consists of following basic system:
  - ➢ Fuel system
  - ➢ Ignition system
  - ➢ Lubrication system
  - ➢ Cooling system

Electrical system

- Consists of:
  - ➢ Battery
  - ➢ Alternators
  - ➢ Ignition system
  - ➢ Lightening system

Chassis

- This part of an automobile supports its body, engine & transmission system.
- The chassis contains all the major units necessary to propel the vehicle, direct its motion, stop it, and allow it to run smoothly over uneven surfaces.

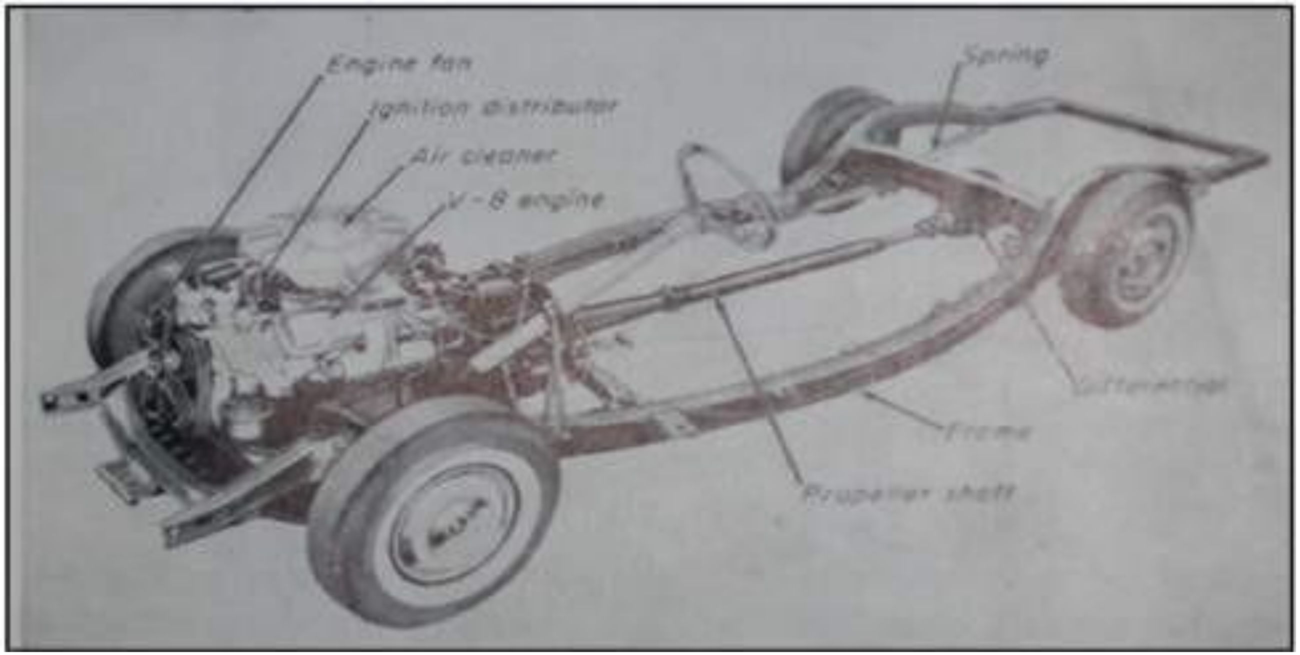
- The chassis of an automobile consists of the following components suitably mounted:

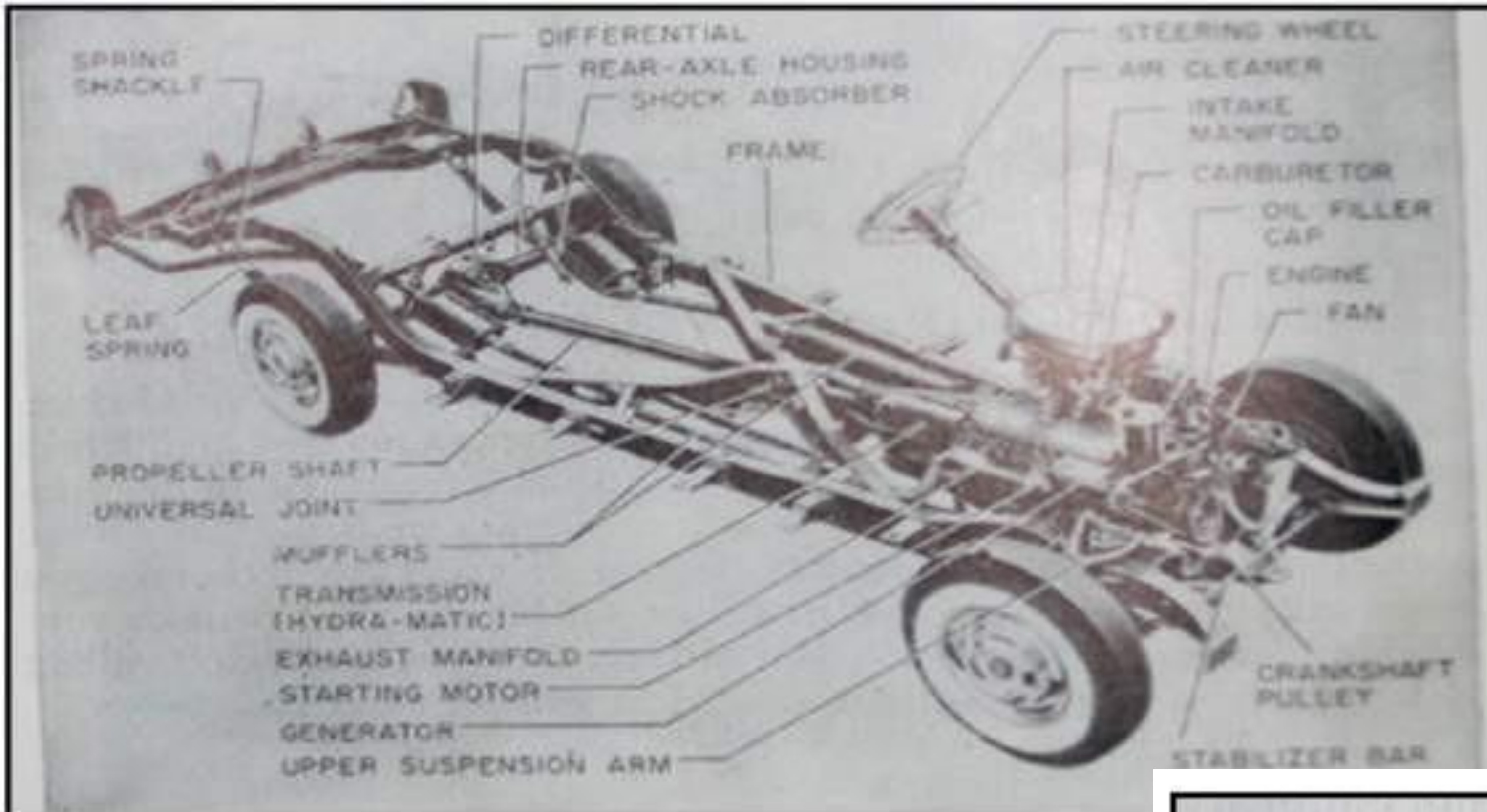
  (i) Frame (ii) Front axle (iii) Steering system (iv) Rear-axle (v) Suspension system (vi) Transmission (vii) Brake system (viii) Engine (ix) Electrical system. The chassis is sub-divided into (i) Power plant (ii) Running gear.

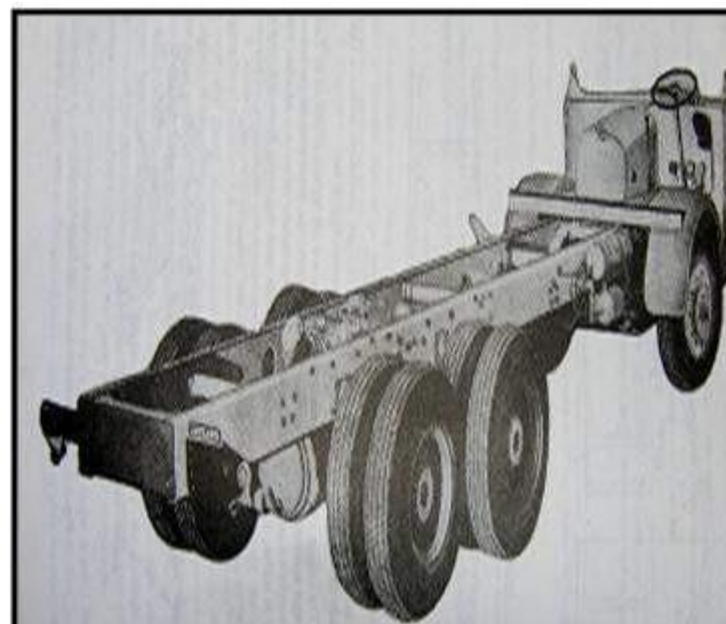
Chassis

All the above mentioned components are mounted in either of the following two ways :

1. Conventional construction: In this case a separate frame is used.
2. Frameless or unitary construction: Here no separate frame is employed.




SPRING SHACKLE
DIFFERENTIAL
REAR-AXLE HOUSING
SHOCK ABSORBER
FRAME
STEERING WHEEL
AIR CLEANER
INTAKE MANIFOLD
CARBURETOR
OIL FILLER CAP
ENGINE
FAN
LEAF SPRING
PROPELLER SHAFT
UNIVERSAL JOINT
MUFFLERS
TRANSMISSION (HYDRA-MATIC)
EXHAUST MANIFOLD
STARTING MOTOR
GENERATOR
UPPER SUSPENSION ARM
CRANKSHAFT PULLEY
STABILIZER BAR

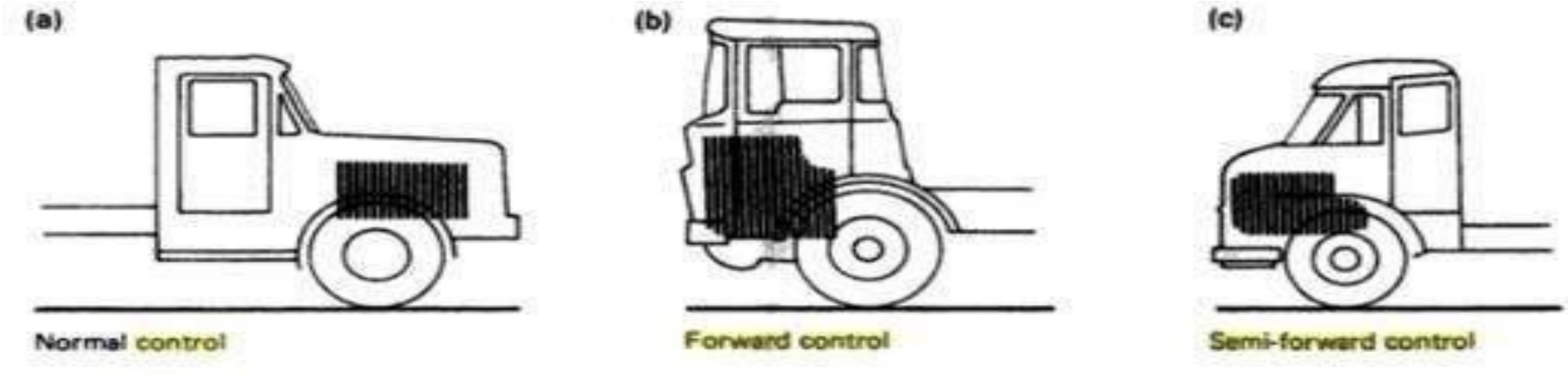


Chassis Classification

(i) Conventional chassis : In this type of chassis, engine is fitted in front of the driver cabin or driver seat such as in cars and previous model of Tata trucks. Here, the driver sits behind the engine (i.e., quite far off from the front axle) and as such he cannot see the road just in front of the front tyres. Owing to this reason slope is provided at the mudguard and bonnet to enable the driver to see close to the wheels as far as possible.

(ii) Semi-forward chassis : This is such a chassis where half portion of the engine is in the driver cabin and remaining half is outside the cabin such as in Standard. Bedford Pick-ups and Tab a trucks.

(iii) Full-forward (or Bus) chassis : In this type of chassis the complete engine is mounted inside the driver cabin.



Types of Chassis Layout

- Based on:

➢ Types of drive:

(i) Front Wheel Drive

(ii) Rear Wheel Drive

(iii) Four Wheel Drive

➢ Power plant location:

(i) Engine at front

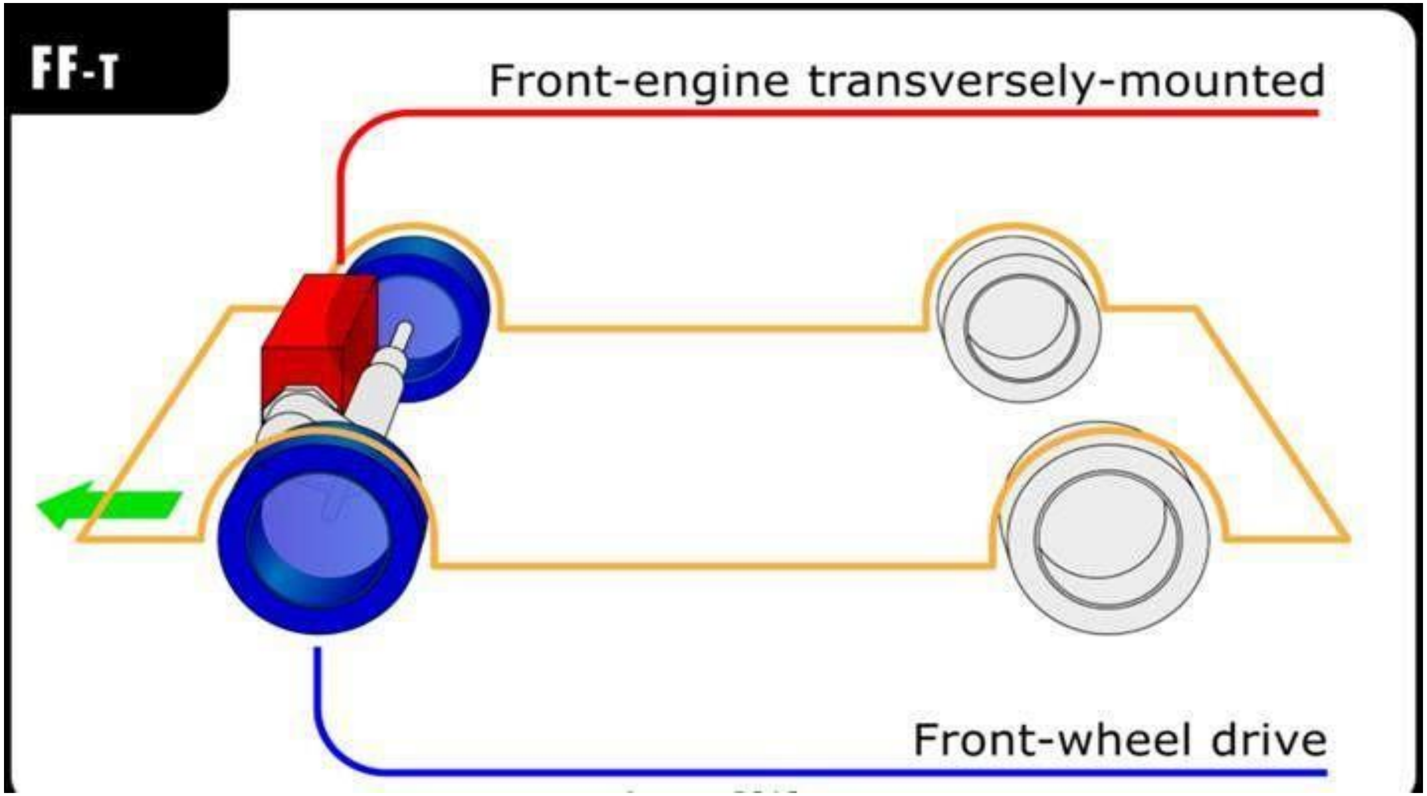
(ii) Engine fitted in front but crosswise

(iii) Engine fitted at the centre of the chassis

(iv)) Engine fitted at the back

Front Wheel Drive Layout

- Front wheel drive layout are those in which the front wheels of the vehicle are driven.
- Generally considered superior to FR (front-engine, rear-wheel-drive layout) cars in conditions such as snow, mud.
- Audi A3 , Audi A4 and Audi A6.



Advantages of Front Wheel Drive

- Interior space: no need to devote interior space for a driveshaft tunnel or rear differential, increasing the volume available for passengers and cargo.
- Weight: Fewer components.
- Fuel Efficiency: Improved fuel efficiency due to less weight.
- Cost: Less material
- Improved drive train efficiency: direct connection between engine and transaxle reduce the mass and mechanical inertia of the drive train.
- Improved Traction & Stability: On wet, snowy, or icy surfaces.

Disadvantages of Front Wheel Drive

- Nose heavy (more weight distribution forward): which makes them prone to understeer especially in high horse power applications.

- High Turning circle: almost always use a Transverse engine installation, which limits the amount by which the front wheels can turn, thus increasing the turning circle of a front-wheel-drive car compared to a rear-wheel-drive one with the same wheelbase.

- Size of the engine: FE transverse engine layout (also known as "east-west") restricts the size of the engine that can be placed in modern engine compartments, so it is rarely adopted by powerful luxury and sports cars.

Disadvantages of Front Wheel Drive

- FE configurations can usually only accommodate Inline-4 and V6 engines, while longer engines such as Inline-6 and 900 big-bore V8 will rarely fit.
- Heavier use of the front tires: it makes heavier use of the front tires causing more wear in the front that in a rear wheel drive layout

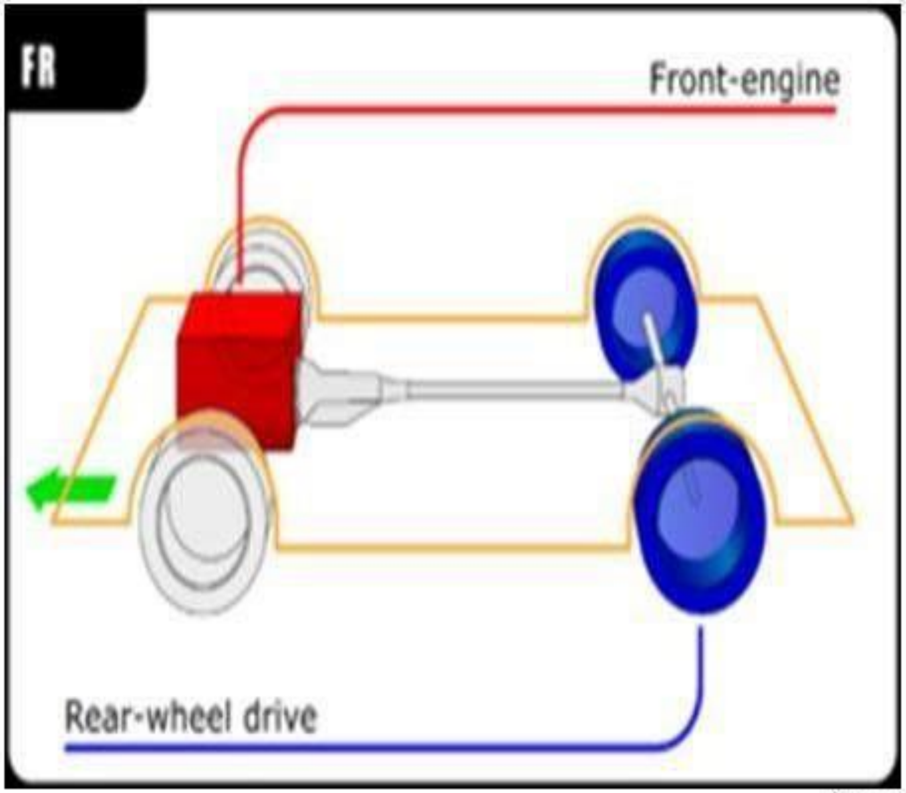
HYUNDAI i10 iRDE

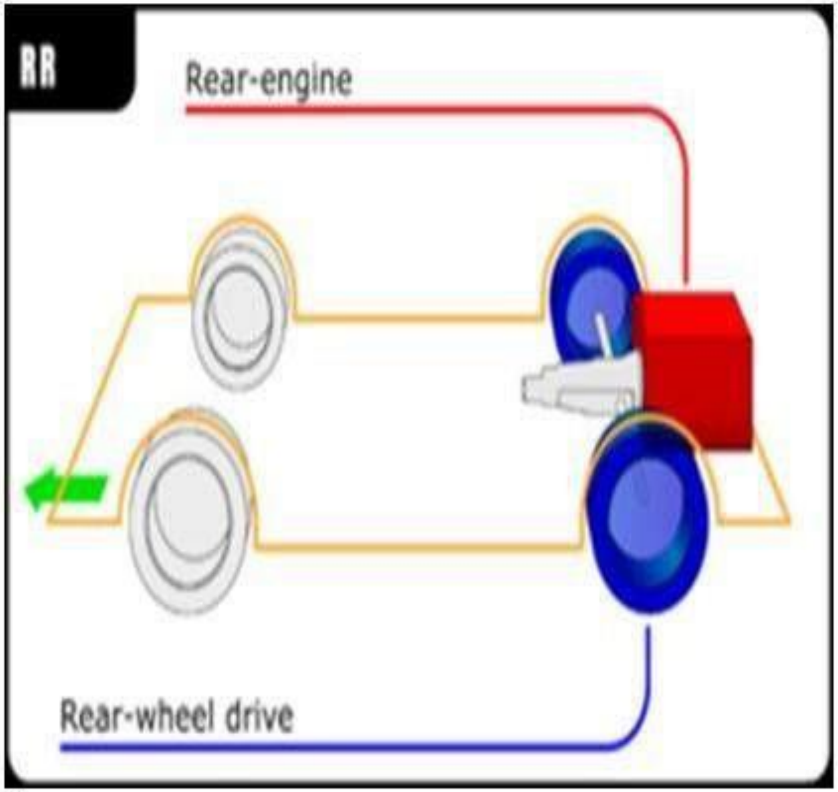
Engine 1086cc, 67PS, 98Nm
Transmission Five-speed manual, front-wheel drive
Performance 15.5 secs 0-100km/h,
Fuel efficiency 14.9kmpl (overall)

intelligent responsive drive engine

Rear Wheel Drive Layout

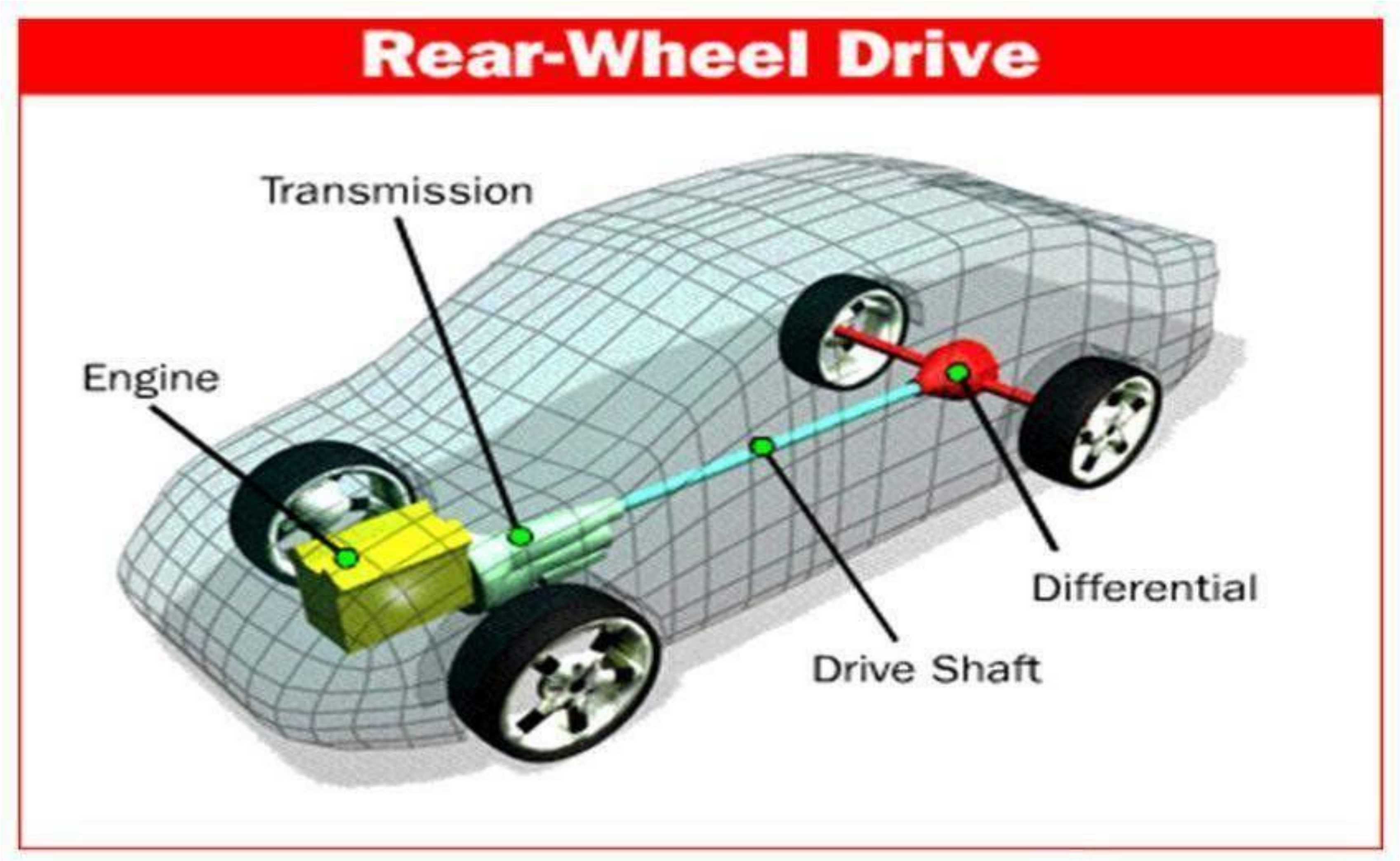
- Rear wheel drive typically places the engine in the front of the vehicle and the driven wheels are located at the rear a configuration known as front engine, rear wheel drive layout (FR layout).





Rear Wheel Drive Layout

- FR layout is often chosen for its simple design & good handling characteristics.



Rear Wheel Drive Layout

Volkswagen Beetle

VW New Beetle

RR Layout

5 generation BMW 3-Series

Rear wheel drive

Advantages of Rear Wheel Drive Layout

- Even weight distribution
- Turning radius As no complicated drive shaft joints are required at the front wheels, it is possible to turn them further than would be possible using front-wheel drive, resulting in a smaller steering radius for a given wheelbase.
- Better handling the more even weight distribution and weight transfer improve the handling of the car.
- Can accommodate more powerful engines as a result of the longitudinal orientation of the drivetrain, such as the Inline-6, 90° big-bore V8, V10 and V12 making the FR a common configuration for luxury and sports cars.

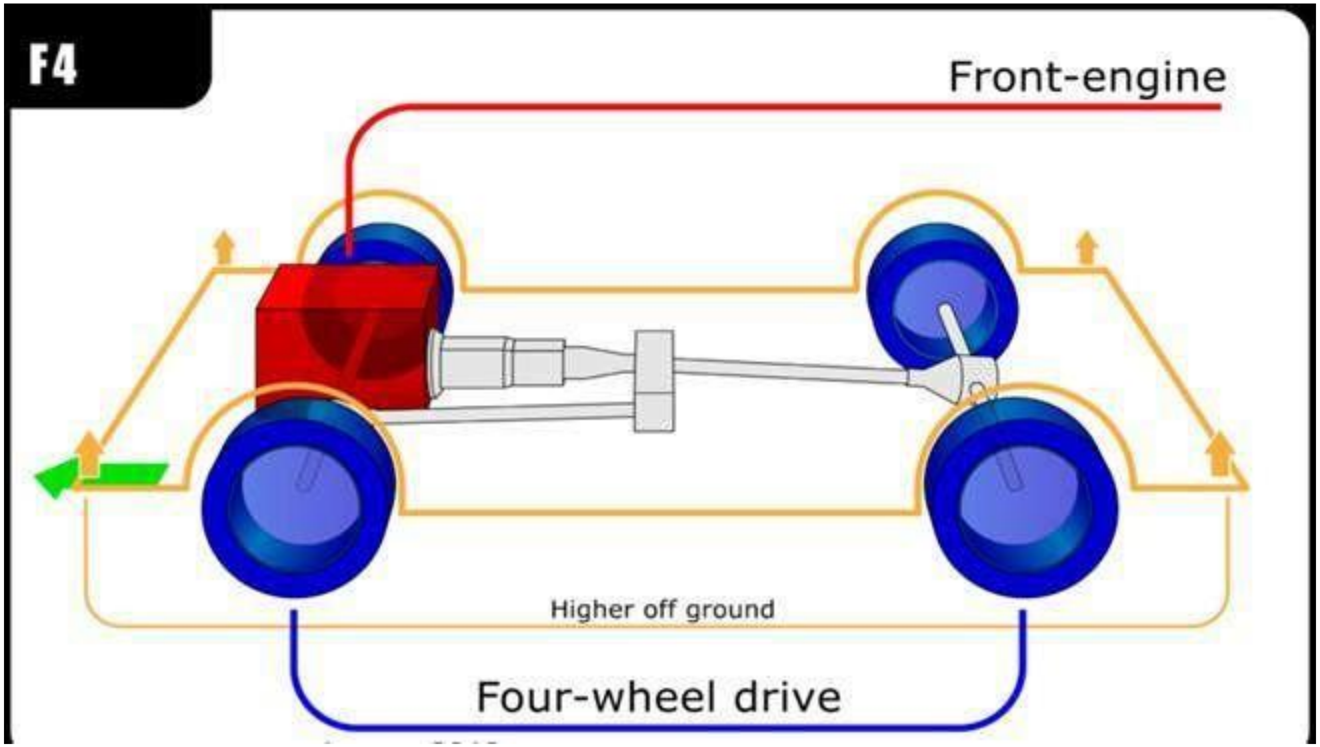
Disadvantages of Rear Wheel Drive Layout

- On snow, ice and sand, rear-wheel drive loses its traction advantage to front- or all-wheel-drive vehicles, which have greater weight on the driven wheels.
- Increased weight The components of a rear-wheel-drive vehicle's power train are less complex, but they are larger.
- Cost of materials and Increased complex assembly of FR layouts.
- Low Mechanical Efficiency- The possibility of a slight loss in the mechanical efficiency of the drivetrain (approximately 17% losses between engine flywheel and road wheels compared to 15% for front-wheel drive)

Body style	4-door saloon
Layout	FR layout
Transmission	5-speed manual

Four wheel drive layout (all wheel drive)

- Most 4WD layout are front engined and are derivatives of earlier front engine, two wheel drive designs.



Four wheel drive layout
(all wheel drive)

- Four-wheel drive, All-wheel drive, AWD, 4WD, or 4x4 ("four by four") is a four-wheeled vehicle with a drivetrain that allows all four wheels to receive torque from the engine simultaneously.

- 4x2 a four-wheel vehicle that transmits engine power to only two axle-ends: the front two in front-wheel drive or the rear two in rear-wheel drive.

Murciélago (M4)

Humvee (HMMWV)

High Mobility Multipurpose Wheeled Vehicl

Subaru Impreza (rally car)

Advantages of Four wheel Drive

- High Traction: Traction is nearly doubled compared to a two-wheel-drive layout.

- Better Weight Distribution: Because additional components are needed to transfer power to the rear wheels, more of the vehicle's weight is located toward the rear. This balances the weight of the engine, which makes all front-wheel drive vehicles heavier in the front.

- Off-Road Capability: Many trucks and SUVs intended for off-road use feature all-wheel or four-wheel drive systems. This allows them to drive over uneven terrain where one or more wheels may come away from the road surface where that cannot provide traction.

- The vehicle can continue to move as long as there is sufficient contact between the road surface and other drive wheels. These all-wheel drive vehicles are also more capable of moving on muddy surfaces.

Disadvantages of Four wheel Drive

- Complex Machinery & Transmission: require more machinery and complex transmission components, and so increase the manufacturing cost of the vehicle and complexity of maintenance procedures and repairs compared to 2WD designs.

- Stopping Distance: While the weight of 4WD vehicles improves their handling, it also increases the distance they require to stop.

- Poor performance in ideal dry conditions: 4WD systems increase power-train mass, rotational inertia and power transmission losses, resulting in a reduction in performance in ideal dry conditions and increased fuel consumption compared to 2WD designs.

Power Plant Location

(i) Engine at front:

(a) conventionally the engines are fitted at front & drive is given to the wheels from the rear.

(b) In another arrangement the engine is fitted in front & drive is also given to the front wheels only as in matador vehicles.

(ii) Engine fitted in front but crosswise: in this arrangement the engine is fitted in front not in conventional way but crosswise as in maruti, B.M.C mini & drive is given to the front wheels only.

(iii)Engine fitted at the centre of the chassis : •In this case, the engine is fitted at the centre of the chassis i.e., under the chassis as in Royal Tiger World master buses previously plied by Delhi Transport Corporation.

(iv) Engine fitted at the back : shows a rear engine drive. Popular vehicles, employing this system are Renault, Dolphin and Volkswagon, where engine is fitted at the rear of the vehicle.

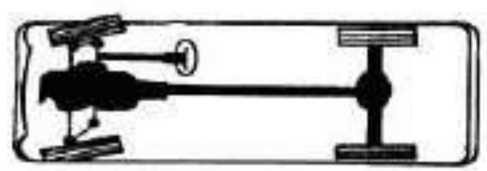


Fig. Conventional drive.

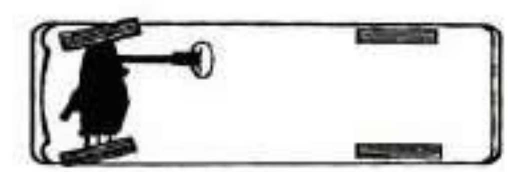


Fig. Front engine drive.

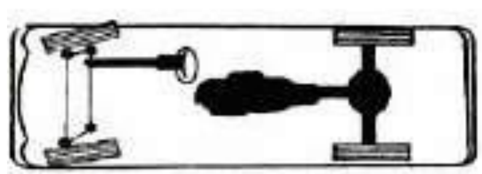


Fig. Centre engine drive.

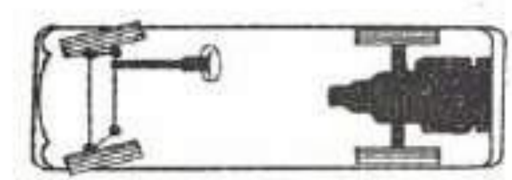


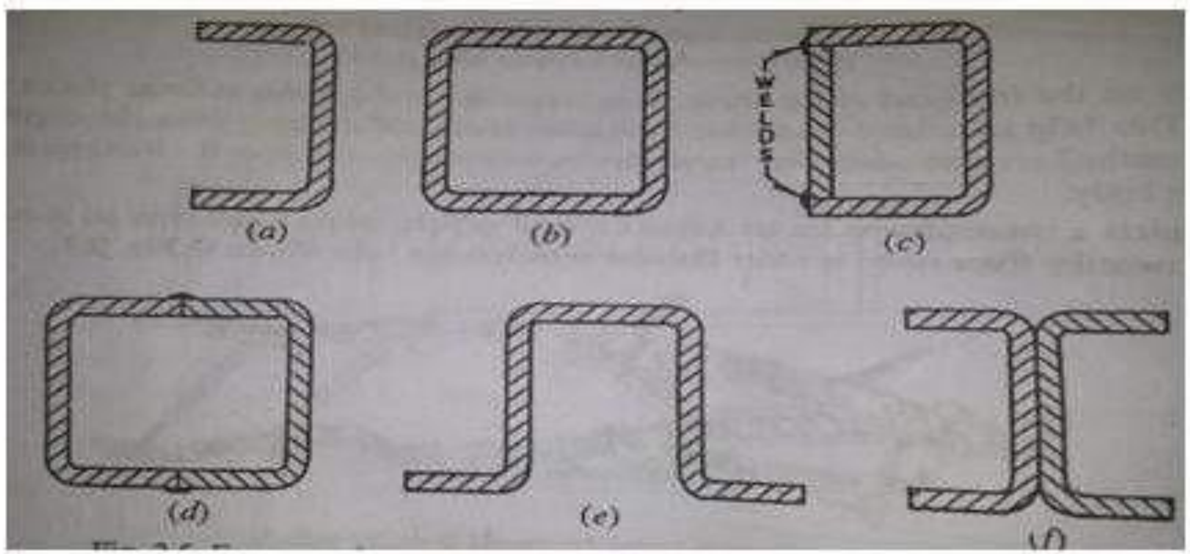
Fig. Rear engine drive.

Frame

- Function of the frame:

1. To support the chassis components & the body.
2. To understand static & dynamic loads without undue deflection or distortion.

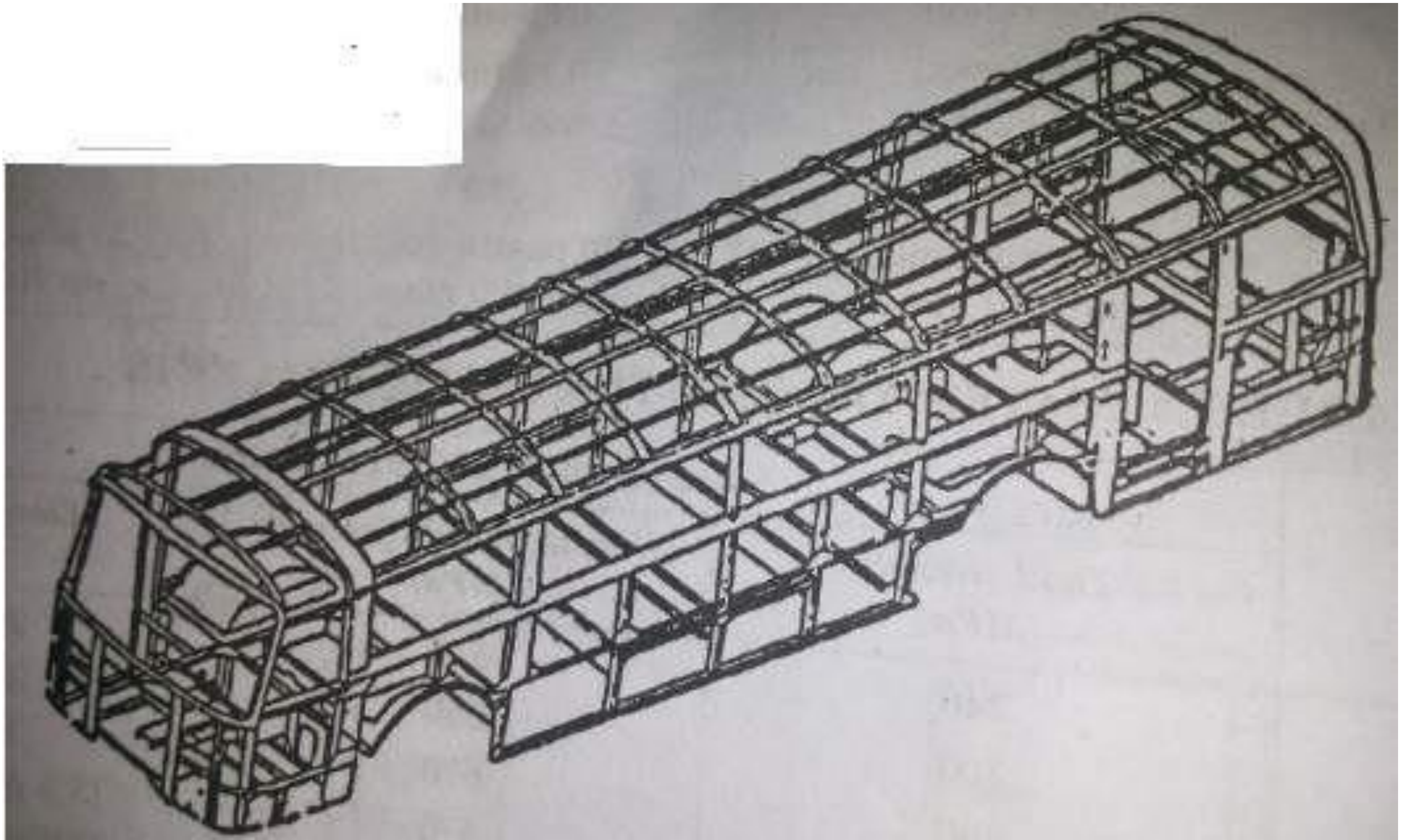
Frame sections



(a) Channel section (b), (c), (d) box section (d) hat section (e) double channel or I section

Frameless Construction

- In this type of construction heavy sides members used in conventional construction are eliminated & the floor is strengthened by cross members & the body all welded together. In some cases the sub frames are also used along with this type of construction.



Need of clutch

- In a car, you need a clutch because by controlling the slippage between them the engine spins all the time, but the car's wheels do not. In order for a car to stop without killing the engine, the wheels need to be disconnected from the engine somehow. The clutch allows us to smoothly engage a spinning engine to a non-spinning transmission.

- A clutch works because of friction between a clutch plate and a flywheel.

Clutch

- In Automobiles, the clutch is used to engage or disengage the engine with the transmission system. It enables the rotary motion of one shaft to be transmitted to the second shaft as and when required.

- The clutch should be able to transmit the maximum torque. It should take drive gradually. During clutch application, the heat generated by the friction of clutch surfaces should be dissipated. During high speeds the clutch should be balanced.

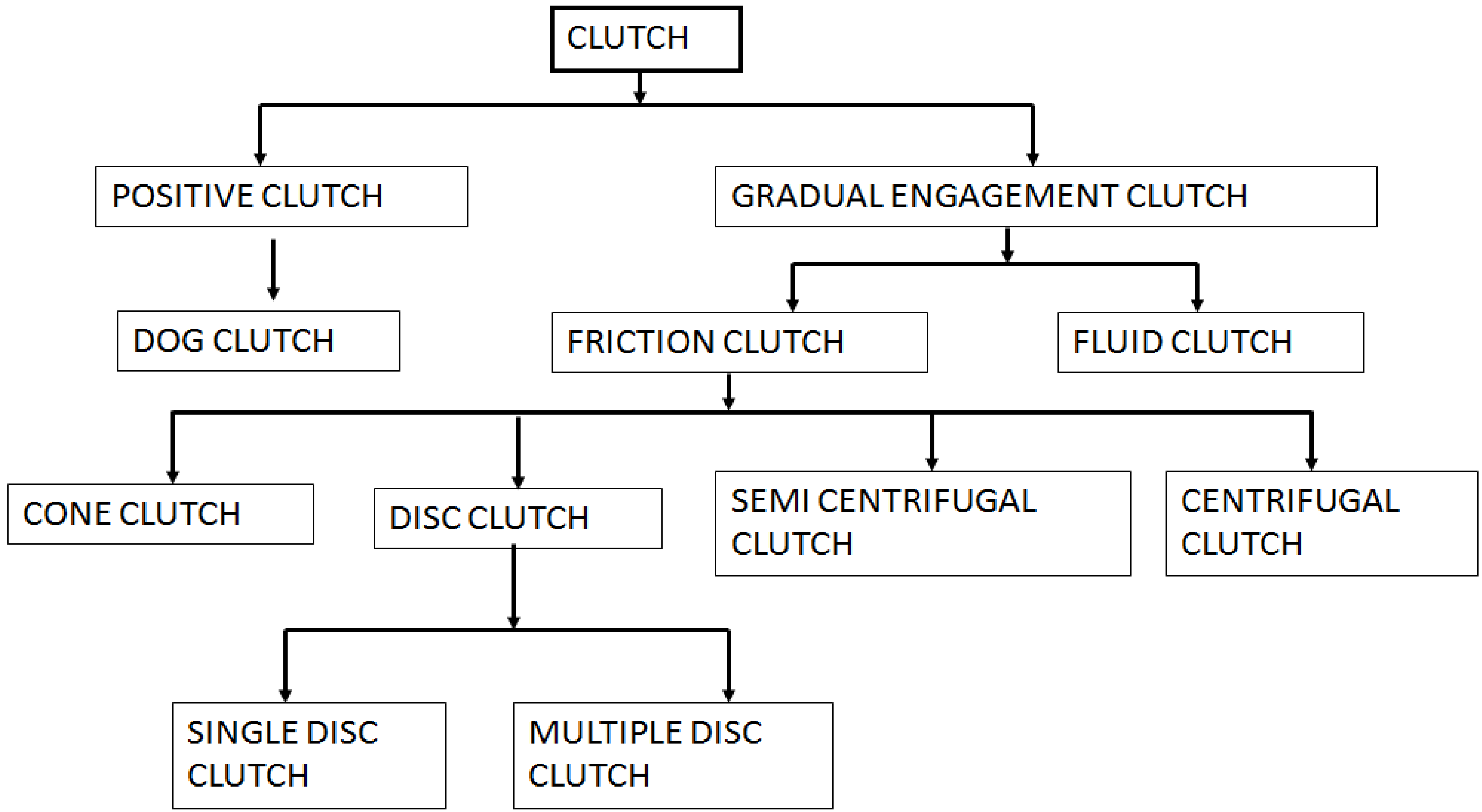
Requirements of Clutch

- Torque transmission: The clutch should be able to transmit the maximum torque of the engine under all condition. It is usually designed to transmit 125 to 150 per cent of the maximum engine torque
- Gradual engagement: The clutch should positively take the drive gradually without the occurrence of sudden jerks.
- Heat dissipation: During clutch application, large amounts of heat are generated. The rubbing surfaces should have sufficient area and mass to absorb the heat generated. The proper design of the clutch should ensure proper ventilation or cooling for adequate dissipation of the heat.
- Dynamic balancing: This is necessary particularly in the high speed clutches not be tiresome to the driver.

Requirements of Clutch

- Vibration damping : Suitable mechanism should be incorporated with in the clutch, to eliminate noise produced in the transmission.
- Size: The size of the clutch must be smallest possible so that it should occupy minimum amount of space.
- Inertia : The clutch rotating parts should have minimum inertia. Otherwise, when the clutch is released for gear changing, the clutch plate will keep on spinning, causing hard shifting and gear clashing in spite of synchronizer.
- Clutch free pedal play: To reduce effective damping load on the carbon thrust bearing and wear thereof, sufficient clutch free pedal play must be provided in the clutch.
- Ease of operation: For higher torque transmissions the operation of disengaging the clutch must

Types of clutch



Gradual Engagement Clutches

- FRICTION CLUTCHES: Enable the driven member to be disengaged and engaged gradually with the driving member.

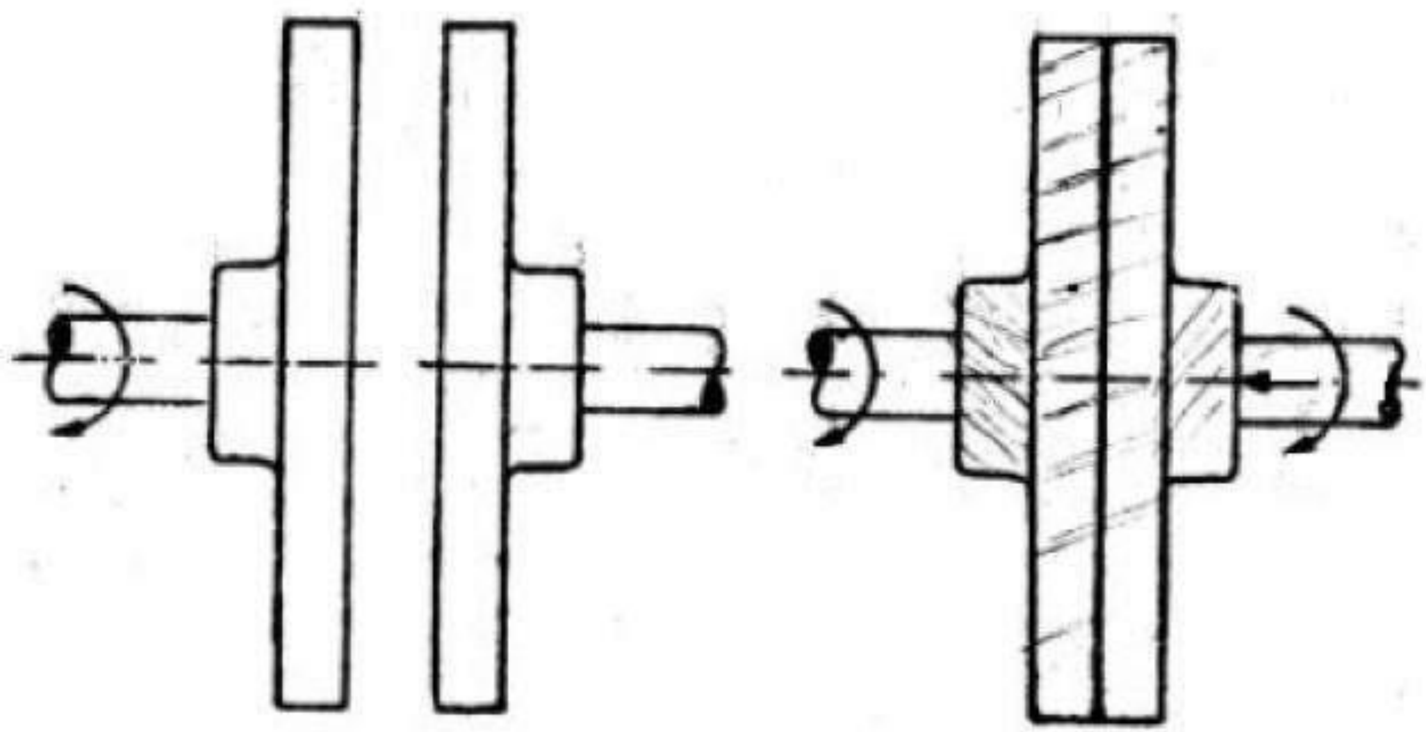
- Action depends on the friction force between the members.
- At start low frictional force and increases with the pressing force.
- Pressure exerted by means of coil springs.

- The Torque transmitted by a friction clutch depends upon the factors namely Coefficient of friction (u), Axial pressure (w) and Mean effective Radius of contact surfaces(R).

The Torque Transmitted (T) = μwR.

Basic Principle of Friction Type Clutch

- To understand the working principle of clutch, let's take two discs, first one driven by a power drill corresponds to the flywheel of a car, driven by the engine. If a second sanding disc is brought into contact with the first, friction makes it revolve too but more slowly. But when the second disc pressed against the first disc which is connect to the power drill, as the I pressure increases the two discs revolve as one. This is how a friction clutch works.



Types of friction clutches

a) Cone clutch

b) Single plate clutch

c) Mutilate clutch

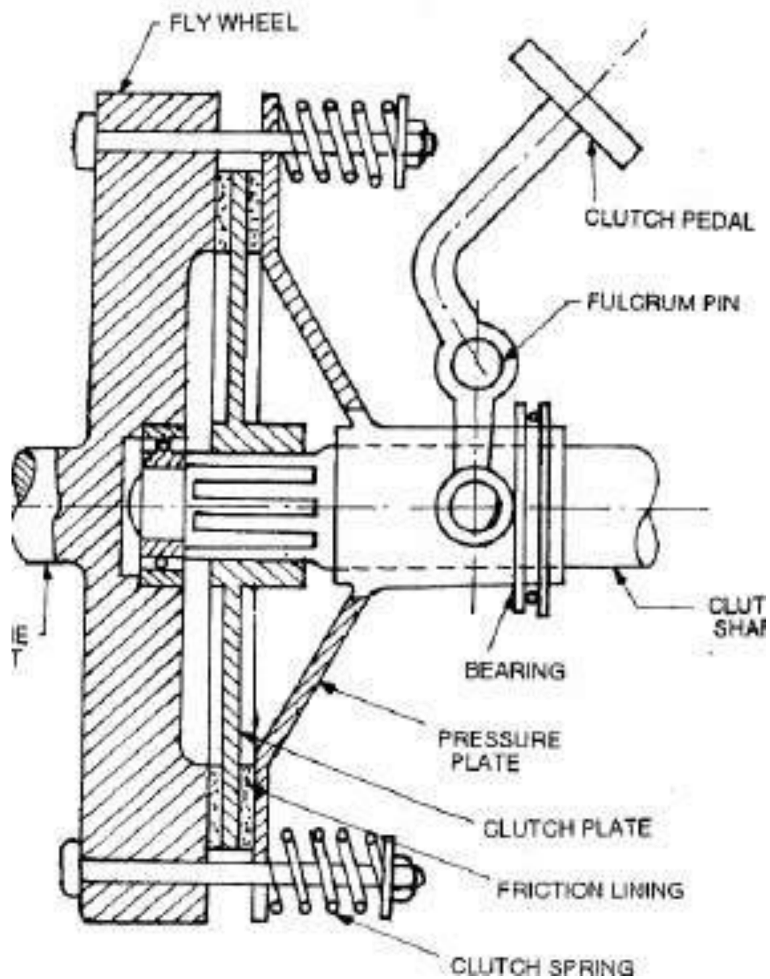
d) Semi centrifugal clutch

e) Centrifugal clutch.

Construction And Working of Single Plate Clutch

- It is the most common type of clutch used in motor vehicles.
- A single disc or plate clutch consists of a clutch plate whose both sides are faced with a frictional material. It is mounted on the hub which is free to move axially along he splines of the driven (clutch) shaft.
- the pressure plate is mounted inside the clutch body which is bolted to the flywheel.
- Both the pressure plate and the flywheel rotate with the engine crank shaft.
- The pressure plate pushes the clutch plate towards the flywheel by a set of strong springs which are arranged radially inside the body
- When the clutch is engaged, due to the friction between the flywheel, clutch plate and pressure plate, revolves the clutch shaft which is connected to the transmission system also revolves.
- When the clutch pedal is pressed, the pressure plate moves back against the force of the springs, and the clutch plate becomes free between the fly wheel and pressure plate.

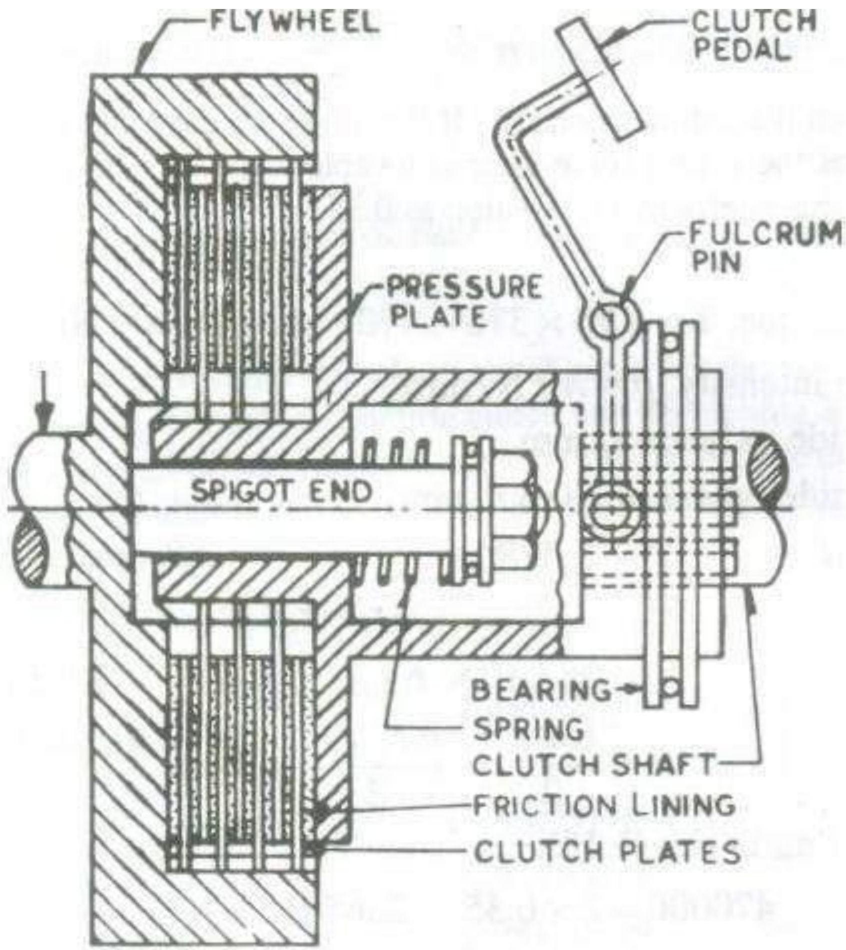
Construction and Working of Single Plate Clutch

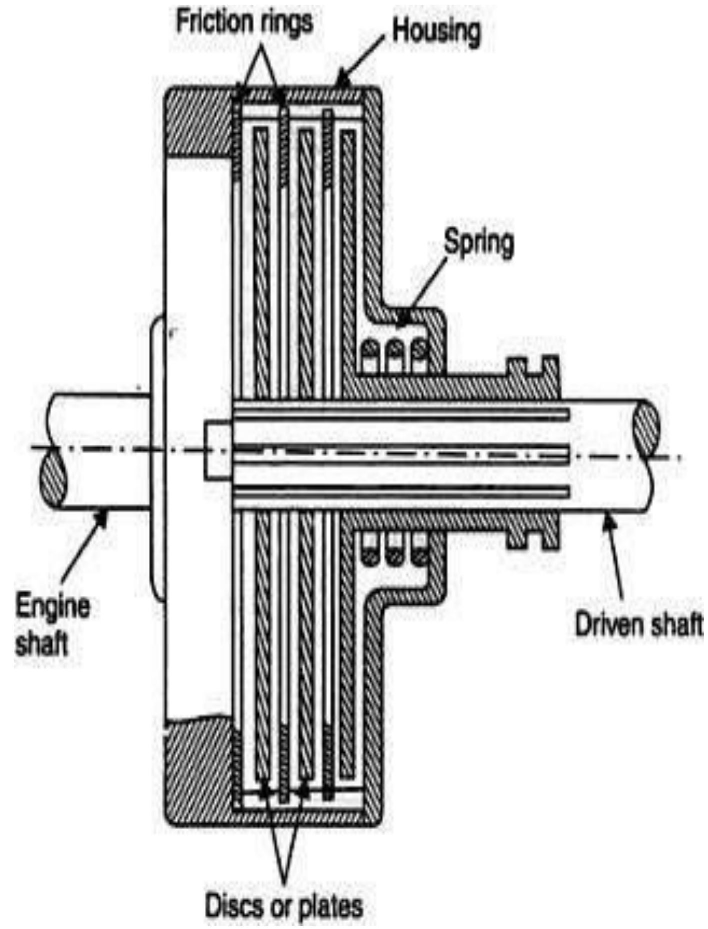


Construction and Working of Multiplate Clutch

- Multi plate clutch consists of a number of clutch plates.
- As the number of clutch plates increased, the friction surfaces also increased.
- the increased number of friction surfaces obviously increases the capacity of the clutch to transmit torque.
- one set of plates slides in grooves on the flywheel and the other set slides on spines on pressure plate hub.
- They are firmly pressed by strong coil springs and assembled in a drum.
- Each of the alternate plate slides in grooves on the flywheel and the other slides on spines on the pressure plate.
- These clutches are used in heavy commercial vehicles, racing cars and motor cycles for transmitting higher torque. Beside these clutches are used in scooters and motor cycles where space available is limited.
- Overall diameter is reduced for the same torque transmission as single plate clutch.

Construction and Working of Multiplate Clutch

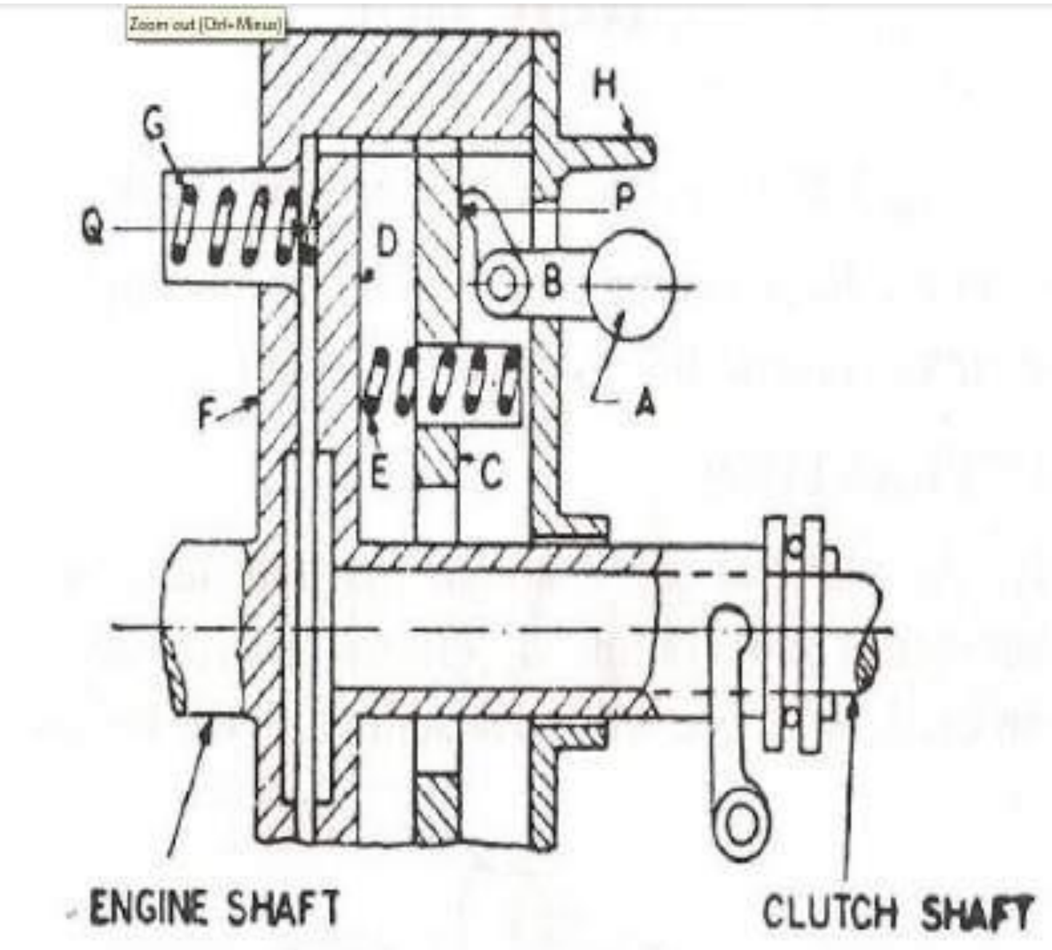




Centrifugal Clutch

- This type of clutch is operated automatically depending upon the engine speed. This means that the vehicle can be stopped in gear without stalling the engine. Similarly while starting, the driver can first select the gear, put the car into the gear and simply press the accelerator pedal. This makes driving operation very easy. This type of clutch is operated by the centrifugal force. This type of clutch is operated automatically depending upon the engine speed. This means that the vehicle can be stopped in gear without stalling the engine. Similarly while starting, the driver can first select the gear, put the car into the gear and simply press the accelerator pedal. This makes driving operation very easy. This type of clutch is operated by the centrifugal force. the bell crank lever 'B' which presses the plate 'C'. This force is transmitted to the plate 'D' by means of springs 'E'. the plate 'D', which contains frictional lining, is thus pressed against the flywheel 'F' there by engaging the clutch. Spring 'G' serves to keep the clutch disengaged at low speed (at about 500 r.p.m). The stop ‘H’ limits the amount of centrifugal force.

Centrifugal Clutch



Cone Clutch

- In this type the contact surfaces are in the form of cones as shown in the figure.
- In the engaged position, the male cone is fully inside the female cone so that the friction surfaces are in complete contact.
- This is done by means of springs which keep the male cone pressed all the time. When the clutch is engaged, the torque is transmitted from the engine via the fly wheel and the male cone to the splined gear box shaft.
- For disengaging the clutch the male cone is pulled out by means of the lever system operated through the clutch pedal thereby separating the contact surfaces.

➢ **Advantage**

- The only advantage of the cone clutch is that the normal force acting on the contact surfaces in this case is larger than the axial force, as compared to the simple single plate clutch in which the normal force acting on the contact surfaces is equal to the axial force.

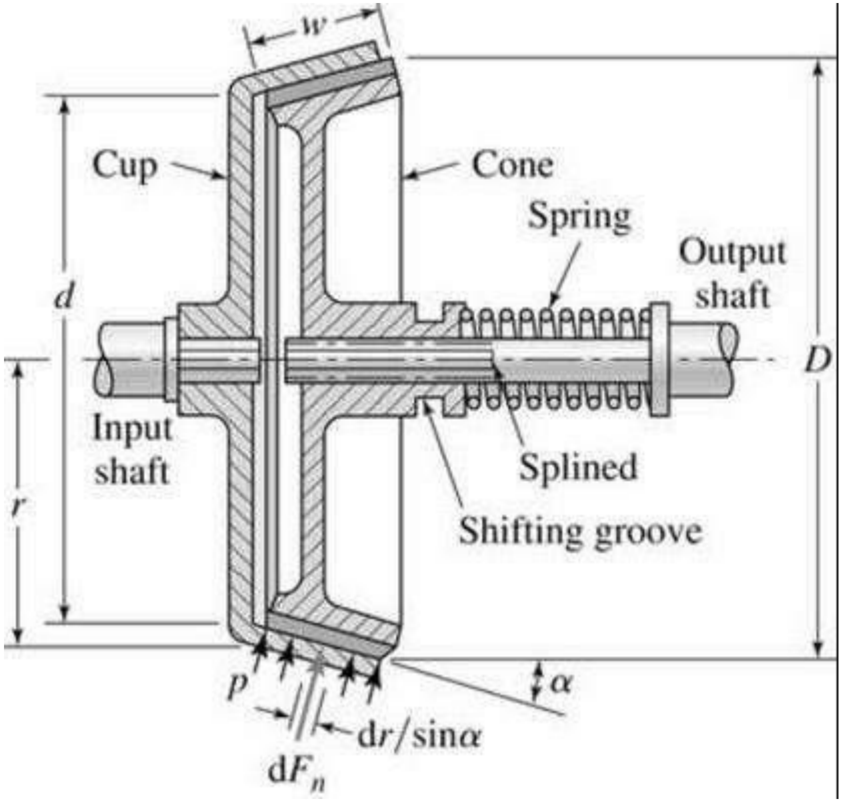
Cone Clutch

Disadvantages:

This type of clutch is practically obsolete because of certain inherent disadvantages:

➢ If the angle of cone is made smaller than about 20° the male cone tends to bind or join in the female cone and it becomes difficult to disengage the clutch.

➢ A small amount of wear on the cone surface results in a considerable amount of the axial movement of the male cone for which it will be difficult to allow

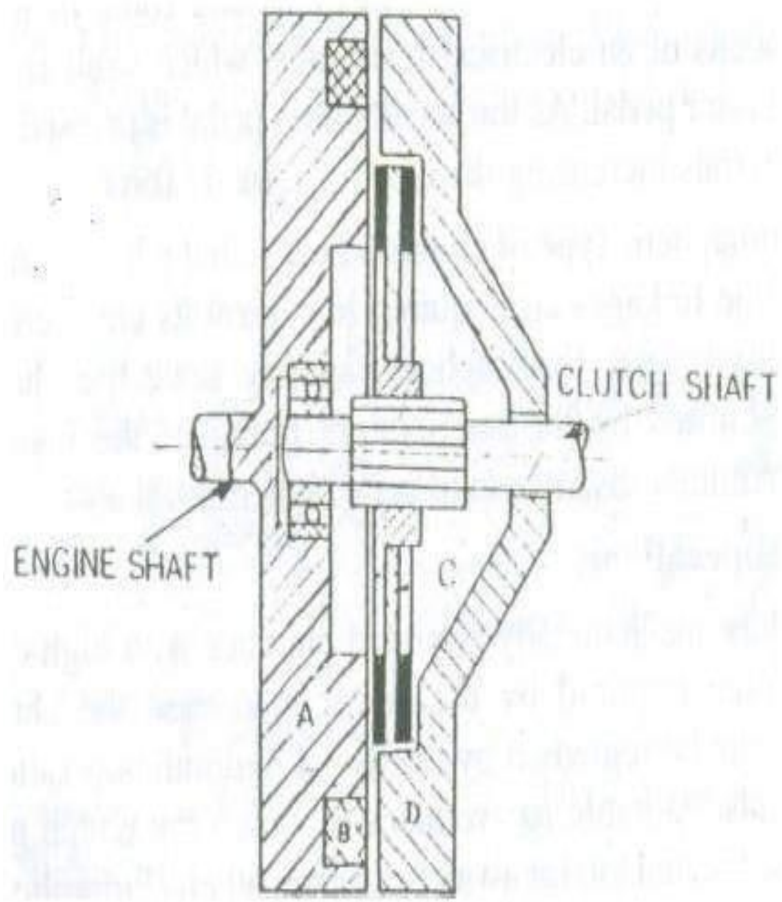


Electromagnetic Clutches

- This type of clutch has been employed on some Renault cars. The construction and working of this clutch may be understood by means of simplified Fig.
- ‘A’ is the engine flywheel incorporating the winding ‘B’. Clutch plate ‘C’ is lined with friction surfaces and is free to slide on splines on the clutch shaft.
- ‘D’ is the pressure plate. The winding ‘B’ is supplied with current from battery dynamo. When the winding ‘B’ is energized, it attracts the pressure plate ‘D’, thereby engaging the clutch.
- When supply to winding ‘B’ is cut off, the clutch is disengaged. There is a clutch release switch in the gear lever. This switch is operated as soon as the driver holds the gear lever to change the gear, cutting off current to the winding and thus causing clutch disengagement.
- Ordinarily the winding is connected to engine dynamo. At lower engine speeds, dynamo output is also low which makes the force in winding very small.

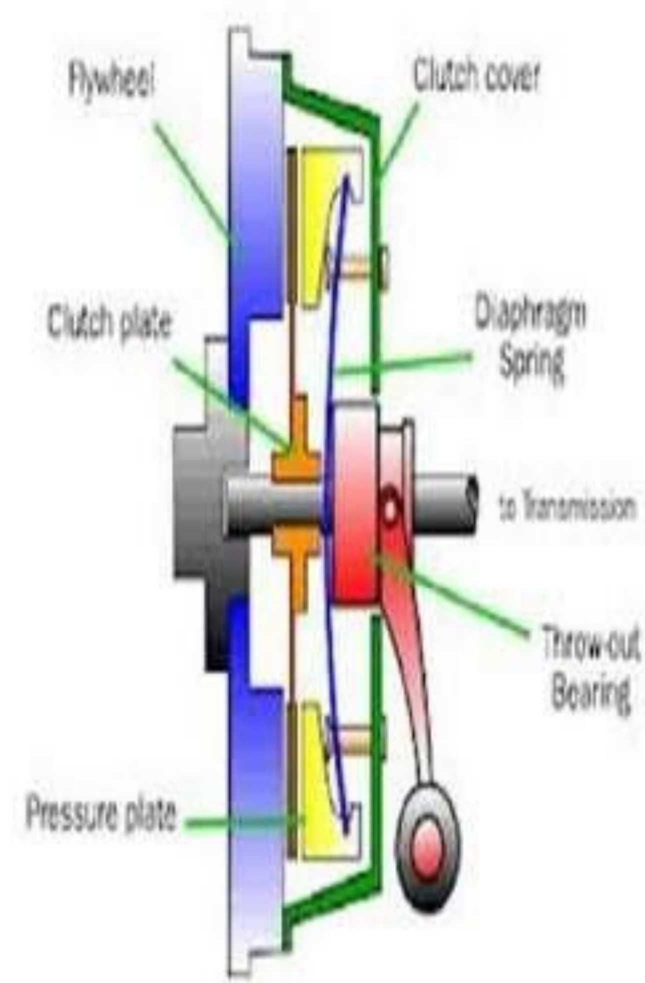
Electromagnetic Clutches

- Three springs are also provided in the clutch (not shown) to balance this reduced electromagnetic force at low speeds, thus disengaging .the clutch.
- During normal operation, the electromagnetic force of the winding is regulated by means of an electrical resistance, which itself is controlled by means of accelerator pedal. As the acceleration pedal is pressed the resistance is gradually cut, thus increasing the electromagnetic force.
- The electromagnetic type of clutch is best suited where remote operation is desired since no linkages are required to control its engagement.
- disadvantage is its higher initial cost.

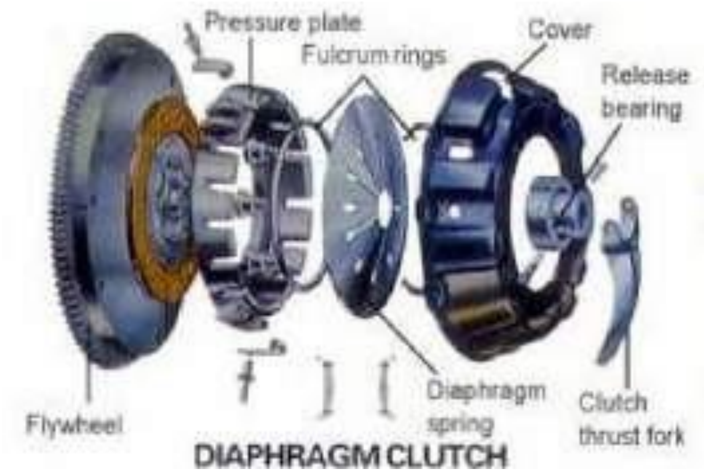


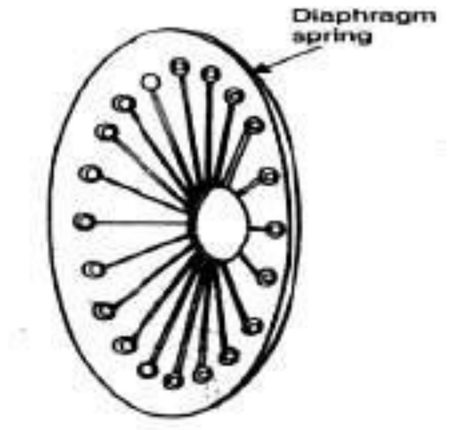
Diaphragm Spring Clutch

- Diaphragm spring pressure plate assemblies are widely used in most modern cars.
- The diaphragm spring is a single thin sheet of metal which yields when pressure is applied to it.
- When pressure is removed the metal springs back to its original shape.
- The centre portion of the diaphragm spring is slit into numerous fingers that act as release levers.
- During disengagement of the clutch the fingers are moved forward by the release bearing.
- The spring pivots over the fulcrum ring and its outer rim moves away from the flywheel.
- The retracting spring pulls the pressure plate away from the clutch plate thus disengaging the clutch.
- When engaged the release bearing and the fingers of the diaphragm spring move towards the transmission.
- As the diaphragm pivots over the pivot ring its outer rim forces the pressure plate against the clutch disc so that the clutch plate is engaged to the flywheel.



Diaphragm Spring Clutch





. Diaphragm spring used in diaphragm spring clutch.

ADVANTAGES OF DIAPHRAGM SPRING CLUTCH

1. It is more compact than other designs.
2. It is easier to balance rotationally and is less subjected to unwanted effects due to centrifugal force at high rotational speeds.
3. It gives uniformly distributed pressure on pressure plate.
4. It needs no release levers.
5. Minimum effort is sufficient to disengage the clutch.
6. It provides minimum number of moving components and hence minimum internal friction is experienced.
7. This is very commonly used in cars, light Lorries and mini trucks but is not much used in heavy vehicles

Lining Material

- Clutch linings are a type of friction material; a clutch is used to transfer the motion of one mechanical component to another by keeping two surfaces in contact. The clutch lining is what prevents these two surfaces from slipping.
- Today's clutch linings are usually made from fiberglass, kevlar or some type of metal. Throughout most of the 20th century however, clutch linings were made from asbestos.

➢ Common Clutch Facing Materials:

Organic friction materials are the most common types of clutch facing materials. Examples are :

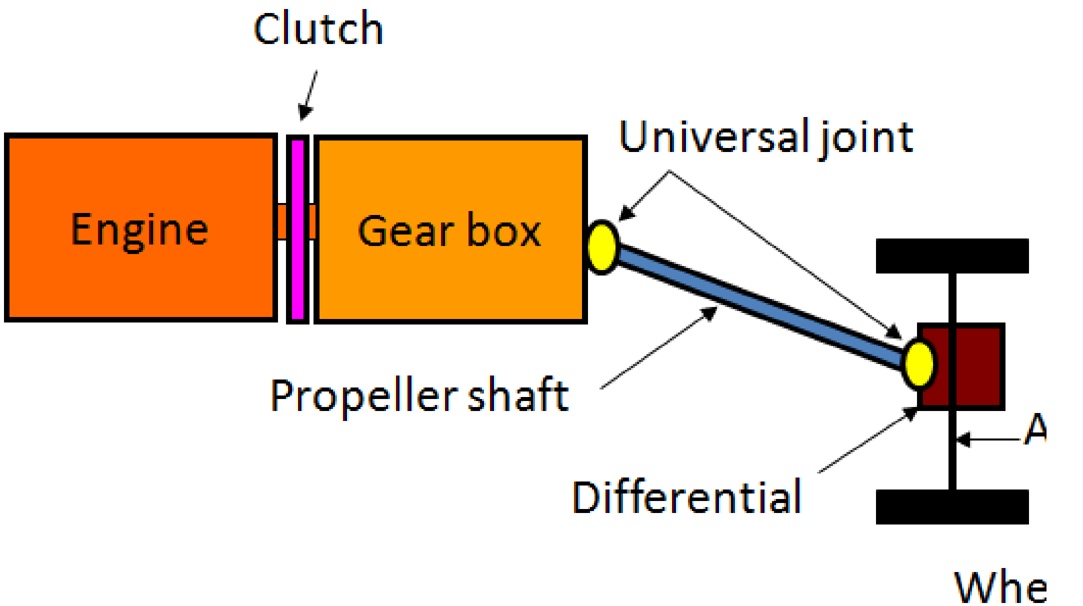
(a) Leather: Dry leather on iron has coefficient in friction of 0.27.
(b) Cork: Cork on dry steel or iron has coefficient of friction of 0.32.
(c) Fabric: Good quality fabric materials have coefficient of friction of about 0.4. But they cannot be used at high temperatures.
(d) Asbestos : Asbestos facing have coefficient of friction of about 0.2. However it has got anti-heat characteristics.
(e) Reybestos and Ferodo: These have a coefficient of friction of about 0.35 and are most suitable as friction facings. They are almost universally used for clutch facings

Clutch Control Systems

1. Pressure Plate
2. Release levers
3. Cover
4. Straps
5. Springs
6. Throwout Bearing

TRANSMISSION SYSTEM

- Clutch
- Gear box
- Universal joints
- Propeller shaft
- Differential gears
- Axial
- Wheel



POWER TRAIN

Necessity of Gear Box

- The gear box is necessary in the transmission system to maintain engine speed at the most economical value under all conditions of vehicle movement. An ideal gear box would provide an infinite range of gear ratios, so that the engine speed should be kept at or near that the maximum power is developed what ever the speed of the vehicle.

- The purpose of gear box is to provide high torque at the time of starting, hill climbing, accelerating and pulling a load. The vehicle will have to face the resistances like wind resistance, gradient resistance and rolling resistance. The tractive effort of the vehicle can be available at various speeds.

Function of Gear Box

- Torque ratio between engine and wheel to be varied for rapid acceleration and for climbing gradient.

- The transmission also provides a neutral position so that the engine & the road wheels are disconnected even with the clutch in the engaged position.

- A means to back the car by reversing the direction of rotation of the drive is also provided by the transmission.

Resistance to Motion of Vehicle

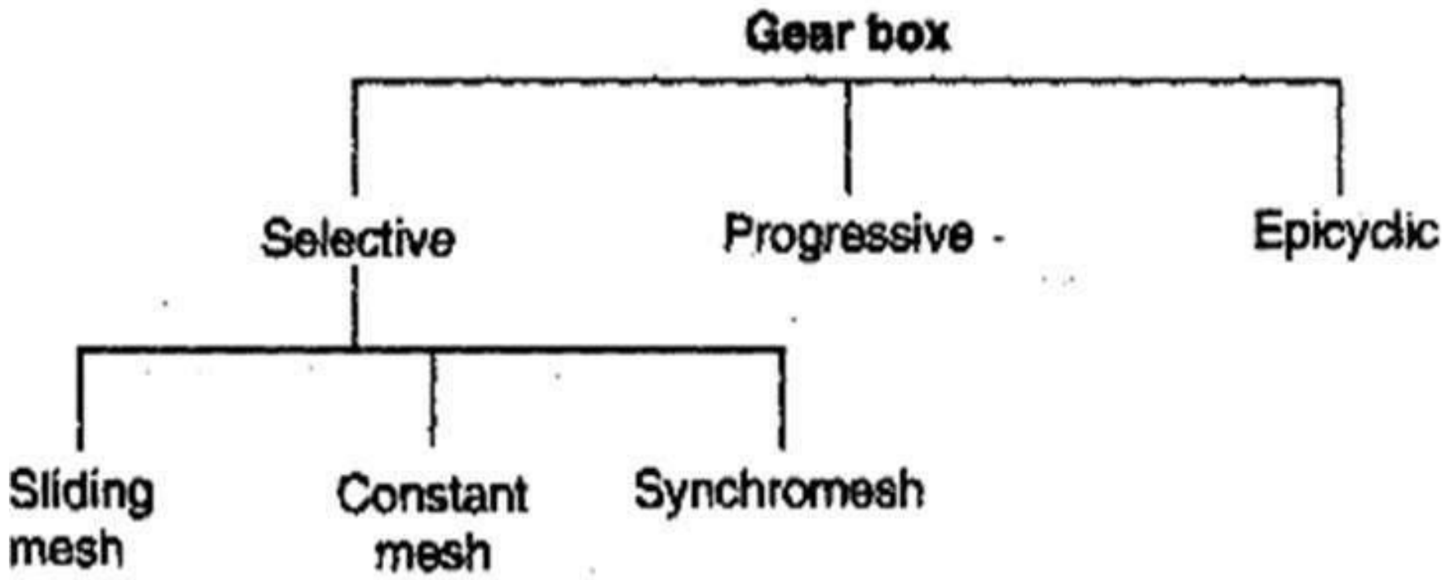
- Total resistance to the vehicle motion consists of:

(i) Resistance due to wind: this is taken to be proportional to the square of the vehicle speed.

(ii) Resistance due to gradient: this remains constant at all speeds. This is the component of the vehicle weight parallel to the plane of the road.

(iii) Miscellaneous: apart from the above two types various other factors also contribute towards the vehicles resistance. These are: type of the road, tyre friction etc.

Types of Gear Box



Selective Type Gear Box

- In this type of transmission, neutral position has to be obtained before selecting any forward or reverse position.

➢ Advantages:

- Simple in construction.
- Less maintenance
- Light & small
- Low production cost.

➢ Disadvantages:

- Noisy in operation
- Gear ratio not being continuous but being in steps (3 to 5 steps), making it necessary to shift gears each time when vehicle running condition change.

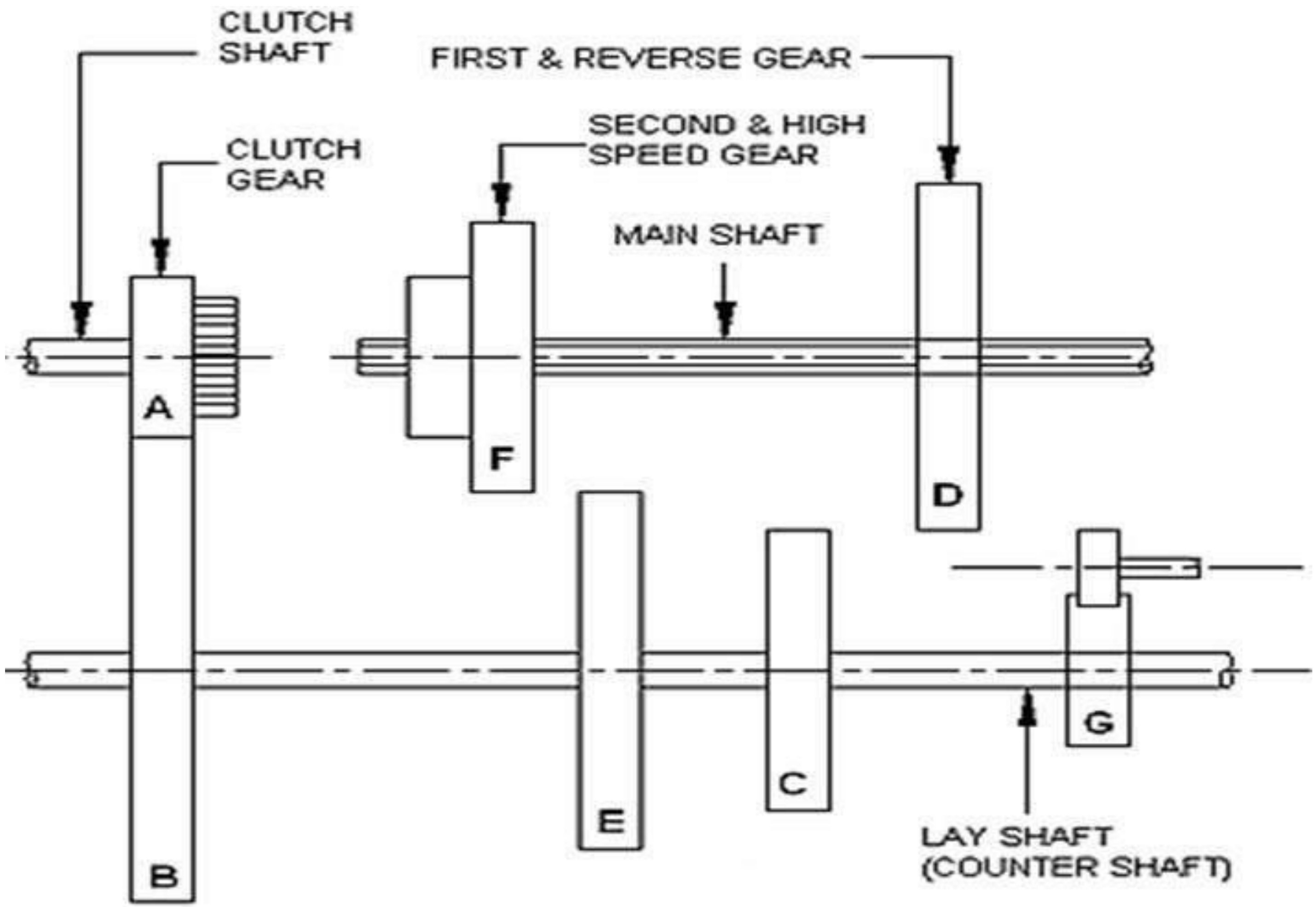
Sliding Mess Gear Box

- It is the simplest and oldest type of gear box.
- The clutch gear is rigidly fixed to the clutch shaft.
- The clutch gear always remains connected to the drive gear of countershaft.
- The other lay shaft gears are also rigidly fixed with it.
- Two gears are mounted on the main shaft and can be sliding by shifter yoke when shifter is operated.
- One gear is second speed gear and the other is the first and reverse speed gears. All gears used are spur gears.
- A reverse idler gear is mounted on another shaft and always remains connected to reverse gear of counter shaft.
- Spur gears are used in sliding mess gear box.

Sliding Mess Gear Box

- FIRST GEAR : By operating gearshift lever, the larger gear on main shaft is made to slide and mesh with first gear of countershaft. The main shaft turns in the same direction as clutch shaft in the ratio of 3:1.
- SECOND GEAR : By operating gear shaft lever, the smaller gear on the main shaft is made to slide and mesh with second gear of counter shaft. A gear reduction of approximately 2:1 is obtained.
- TOP GEAR : By operating gearshift lever, the combined second speed gear and top speed gear is forced a:dally against clutch shaft sear. External teeth on clutch gear mesh with internal teeth on top gear and the gear ratio is 1:1.
- REVERSE GEAR: By operating gearshift lever, the larger gear of main shaft is meshed with reverse idler gear. The reverse idler gear is always on the mesh with counter shaft reverse gear. Interposing the idler gear. between reverse and main shaft gear. the main shaft turns in a direction opposite to clutch shaft.
- NEUTRAL GEAR: When engine is running and the clutch is engaged. clutch shaft gear drives the drive gear of the lay shaft and thus lay shaft also rotates. But the main shaft remains stationary as no gears in main shaft are engaged with lay shaft gears.

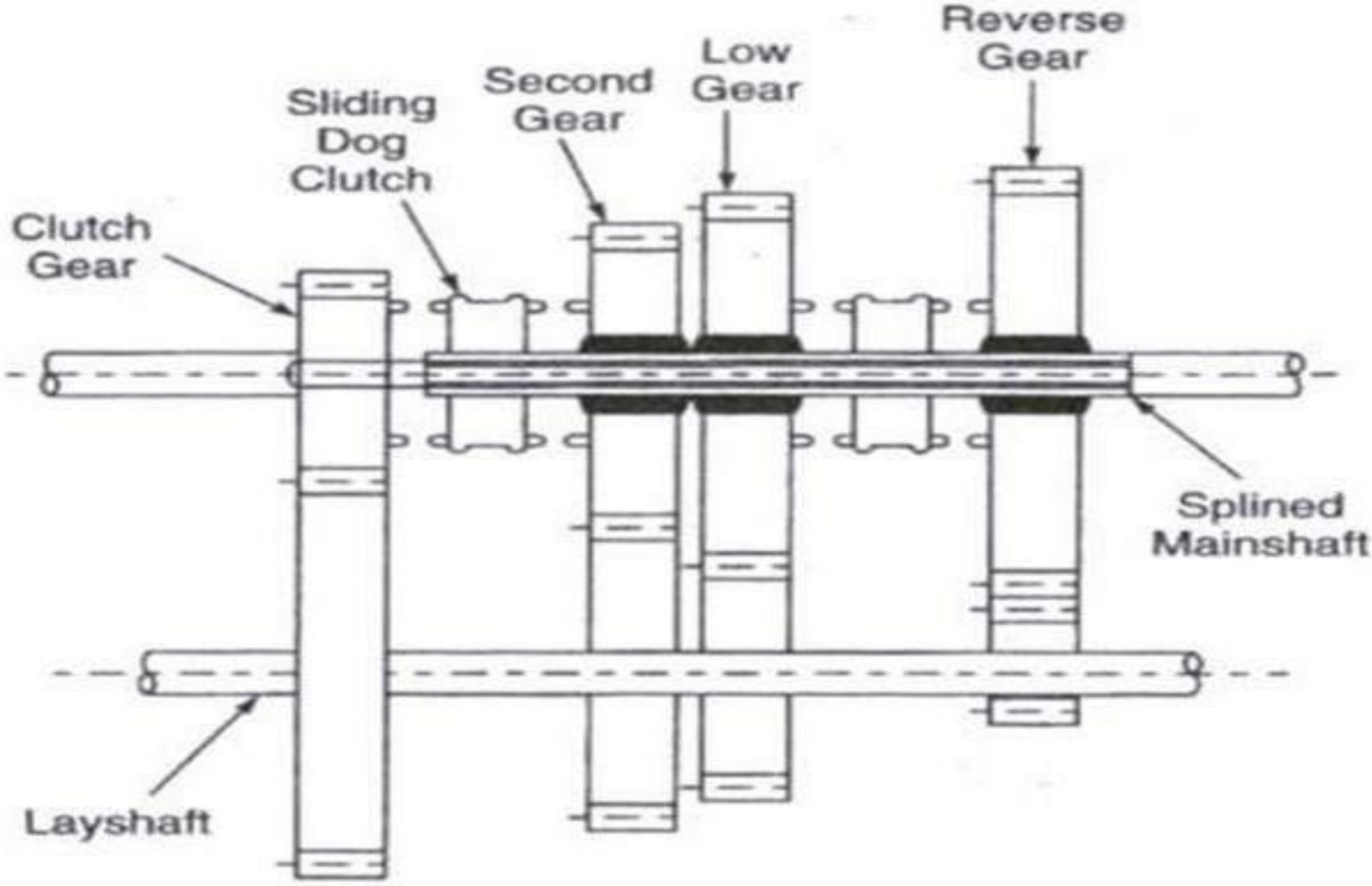
Sliding Mess Gear Box



Constant Mess Gear Box

- In this type of gear box, all the gears are in constant mesh with the corresponding gears on the lay shaft. The gears on the main shaft which is splined are free (Fig). The dog clutches are provided which are free to slide on the main shaft. The gears on the lay shaft are, however, fixed. When the left dog clutch is slid to the left by means of the selector mechanism, its teeth are engaged with those on the clutch gear and we get (the direct gear. The same dog clutch, however, when slid to right makes contact with the second gear and second gear is obtained. Similarly movement of the right dog clutch to the left results in low gear and towards right in reverse gear.
- Helical gears are used in this type of gear box.

Constant Mess Gear Box



Constant Mess Gear Box

- Advantage:
  - In constant mess type of gear box, because all the gears are in constant mesh, they are safe from being damaged & unpleasant grinding sound does not occur while engaging & disengaging.

Double Declutching

- In the constant mesh box, for the smooth engagement of the dog clutches it is necessary that the speed of main shaft gear and the sliding dog must be equal.
- Therefore to obtain lower gear, the speed of the clutch shaft, lay shaft and main shaft gear must be increased. This is done by double declutching.
- The procedure for double declutching is as given below:

➢ The clutch is disengaged and the gear is brought to neutral.

➢ Then the clutch is engaged and accelerator pedal pressed to increase the speed of the main shaft gears.

➢ After this the clutch is again disengaged and the gear moved to the required lower gear and the clutch is again engaged.

➢ As the clutch is disengaged twice in this process, it is called double declutching.

Synchromesh Gear Box

- This type of gear box is similar to the constant mesh type in that all the gears on the main shaft are in constant mesh with the corresponding gears on the lay shaft. The gears on the lay shaft are fixed to it while those on the main shaft are free to rotate on the same.
- Its working is also similar to the constant mesh type, but in the former there is one definite improvement over the latter. This is the provision of synchromesh device which avoids the necessity of double declutching. The parts which ultimately are to be engaged are first brought into frictional contact which equalizes their speed, after which these may be engaged smoothly.
- Synchromesh devices are fitted only on the high gears and on the low and reverse gears ordinary dog clutches are only provided. This is done to reduce the cost.

Synchromesh Gear Box

- An automatic arrangement for matching the speeds of engaging dogs is called synchromeshing. The gear box employing such an arrangement is termed as synchromesh gear box. The synchronizing between engaging dog & appropriate gear is achieved by a synchronizing assembly called synchronizer.
- The construction & working principle of a typical synchronizer is shown in fig 5.7. it consist of mainly three parts:

(i) A ring having internal teeth

(ii) Synchromesh cones, male C & female D

(iii) Toothed dogs A & B

- The ring is normally held in place by spring loaded balls. It rotates with the output shaft & also be slided along the splines cut on the shaft.
- Figure 5.7 a shows disengaged position. Neither the male synchronizer cone C mesh with its female one D, nor the male toothed dog A overrides the female toothed dog B.
- the input shaft, layshaft & gears are running free.

Synchromesh Gear Box

- Now when the selector is moved in the direction shown in fig 5.7 b, the synchronizer cone C & D comes in to contact & the friction between them either speed up or slows down the gear E w.r.t the out put shaft.
- A further movement to the selector causes to the dog A & B to override by overcoming spring loaded balls, & thus the gear E is locked to the output shaft, we call it a situation of gear engagement.

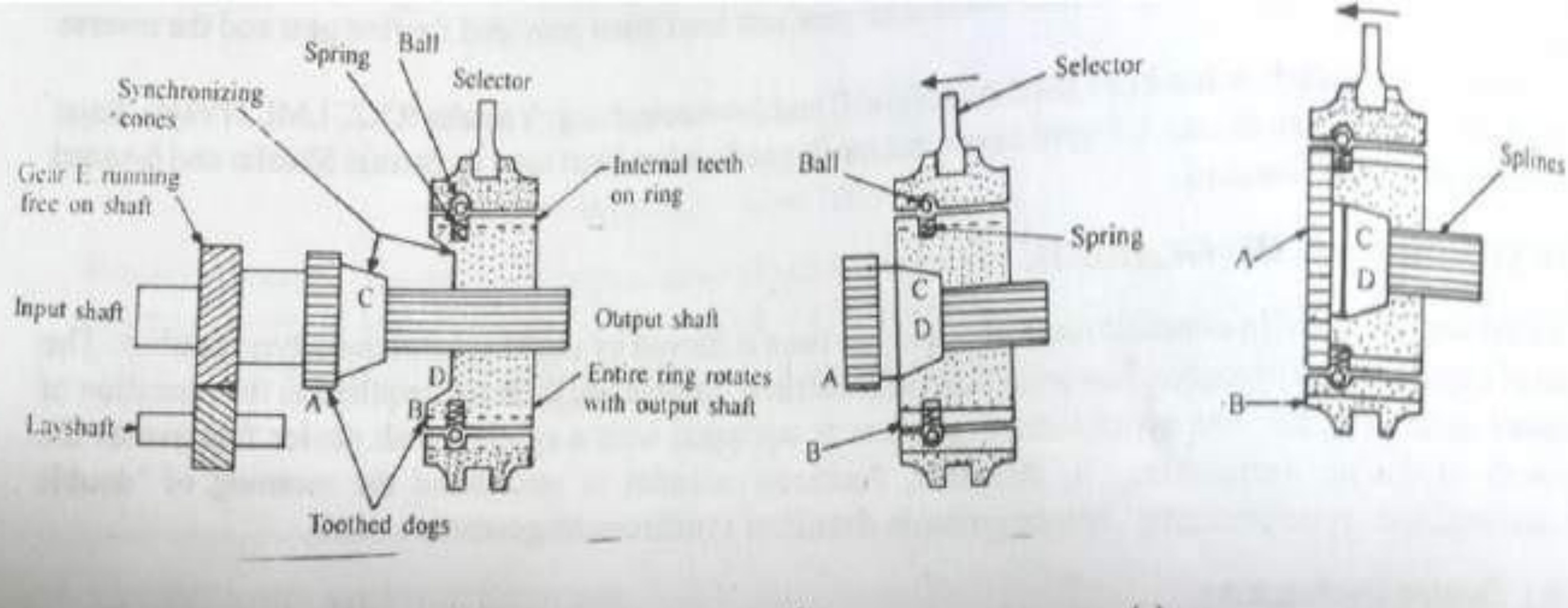


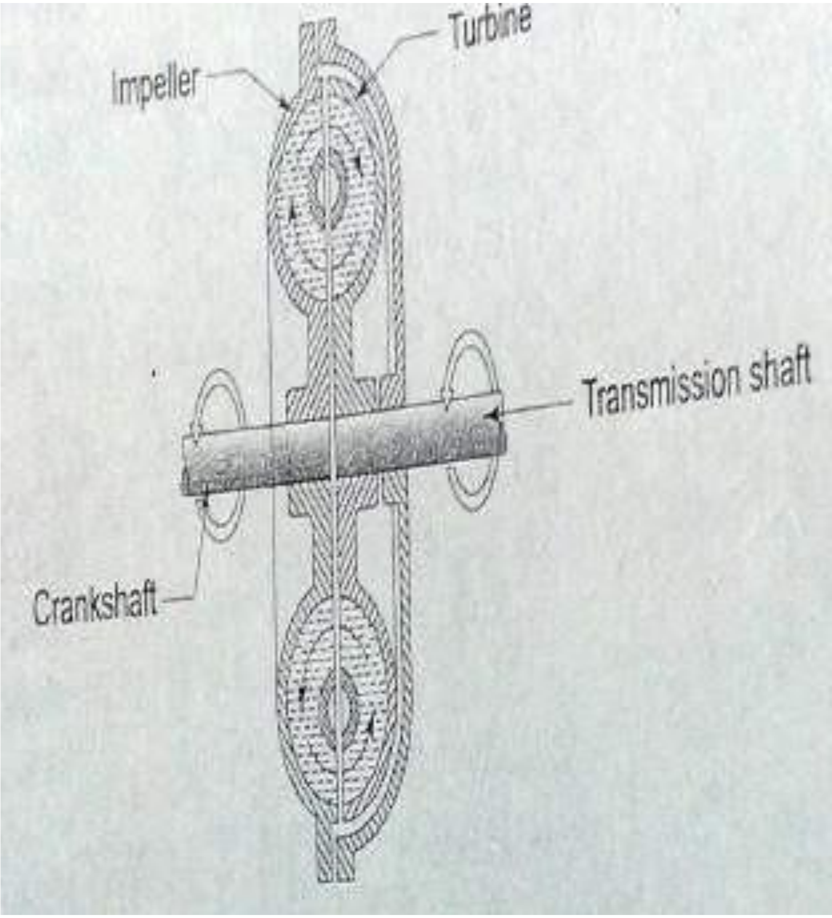
Fig. 5.7 Working of synchronizing assembly explains (*a*) disengaged cones and dogs, (*b*) engaged cones but disengaged dogs, and (*c*) engaged cones and dogs, on moving a selector.

Fluid flywheel

- Fluid flywheel or hydraulic coupling or fluid coupling as it is frequently called has been used in cars employing automatic transmission.
- It consist of two members, the driving and driven . The driving member is attached to the engine flywheel and the driven member to the transmission shaft. The two members do not have any direct contact with each other. The two rotors are always filled with fluid of suitable viscosity.

Fluid flywheel

- Working: there are two cups as shown in figure. One cup called impeller is fitted with the crankshaft. Another cup called turbine is fitted with the transmission shaft. There is oil in the coupling.
- When the crankshaft rotates the impeller also rotates. The centrifugal force acts on the oil between the vanes of the impeller due to which this oil is thrown into turbine. As a result of this, the turbine is forced to rotate. Thus the engine power is transmitted from the crankshaft to the transmission shaft.



Fluid flywheel

- Advantages:

(i) No wear on moving parts.
(ii) No adjustment is necessary.
(iii) Car can stop in gear and move off also by pressing accelerator pedal only.
(iv) Simple design.
(v) No maintenance necessary except oil level.
(vi) No skill required for operating it.

- Disadvantages:

(i) The fluid coupling is generally used with epicyclic gear box only. It cannot be used with the ordinary crash type gear box due to difficulty while changing gears.

Torque converter

Role of the torque converter:

- Multiplies torque generated by the engine.
- Serves as an automatic clutch which transmits engine torque to the transmission.
- Absorbs torsional vibration of the engine and drivetrain.
- Smoothes out engine rotation.
- Drives the oil pump of the hydraulic control system.

The torque converter is filled with automatic transmission fluid, and transmits the engine torque to the transmission. The torque converter can either multiply the torque generated by the engine or function as a fluid coupling.

Torque Converter Components

The torque converter's three major components are; the pump impeller, turbine runner and the stator. The pump impeller is frequently referred to as simply the impeller and the turbine runner is referred to as the turbine.

Pump Impeller

The impeller is integrated with the torque converter case, and many curved vanes that are radially mounted inside. A guide ring is installed on the inner edges of the vanes to provide a path for smooth fluid flow.

When the impeller is driven by the engine crankshaft, the fluid in the impeller rotates with it. When the impeller speed increases, centrifugal force causes the fluid to flow outward toward the turbine.

Turbine Runner

The turbine is located inside the converter case but is not connected to it. The input shaft of the transmission is attached by splines to the turbine hub when the converter is mounted to the transmission. Many cupped vanes are attached to the turbine. The curvature of the vanes is opposite from that of the impeller vanes. Therefore when the fluid is thrust from the impeller, it is caught in the cupped vanes of the turbine and torque is transferred to the transmission input shaft, turning it in the same direction as the engine crankshaft.

Stator

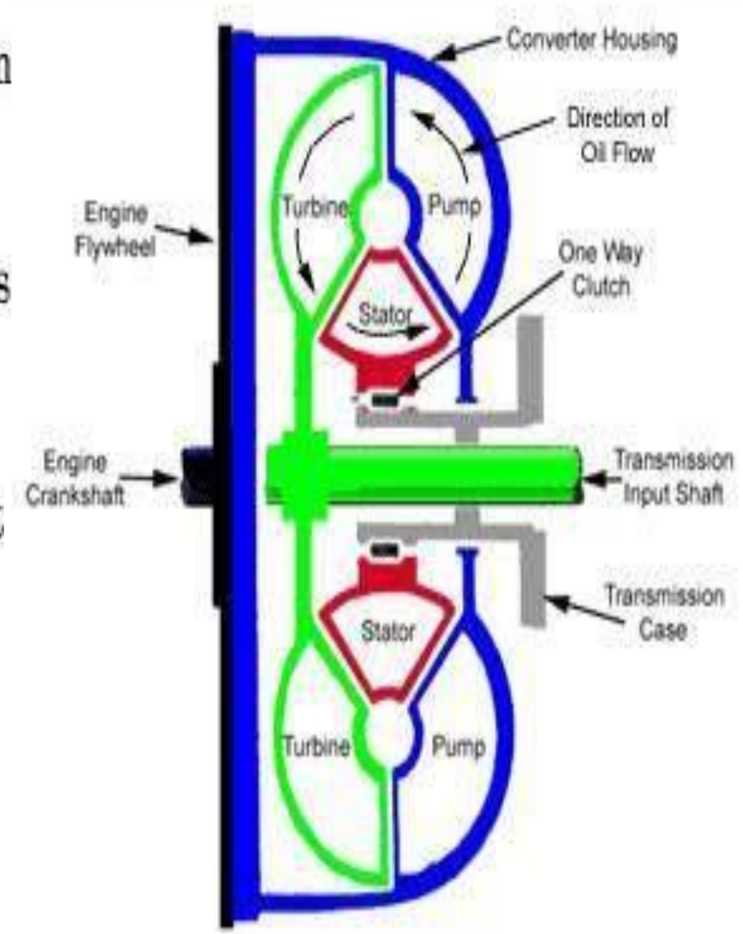
The stator is located between the impeller and the turbine. It is mounted on the stator reaction shaft which is fixed to the transmission case. The vanes of the stator catch the fluid as it leaves the turbine runner and redirects it so that it strikes the back of the vanes of the impeller, giving the impeller an added boost or torque. The benefit of this added torque can be as great as 30% to 50%.

The one-way clutch allows the stator to rotate in the same direction as the engine crankshaft. However, if the stator attempts to rotate in the opposite direction, the one-way clutch locks the stator to prevent it from rotating. Therefore the stator is rotated or locked depending on the direction from which the fluid strikes against the vanes.

Torque converter working operation

When the impeller is driven by the engine crankshaft, the fluid in the impeller rotates in the same direction. When the impeller speed increases, centrifugal force causes the fluid to flow outward from the center of the impeller and flows along the vane surfaces of the impeller. As the impeller speed rises further, the fluid is forced out away from the impeller toward the turbine. The fluid strikes the vanes of the turbine causing the turbine to begin rotating in the same direction as the impeller.

After the fluid dissipates its energy against the vanes of the turbine, it flows inward along the vanes of the turbine. When it reaches the interior of the turbine, the turbine's curved inner surface directs the fluid at the vanes of the stator, and the cycle begins again.

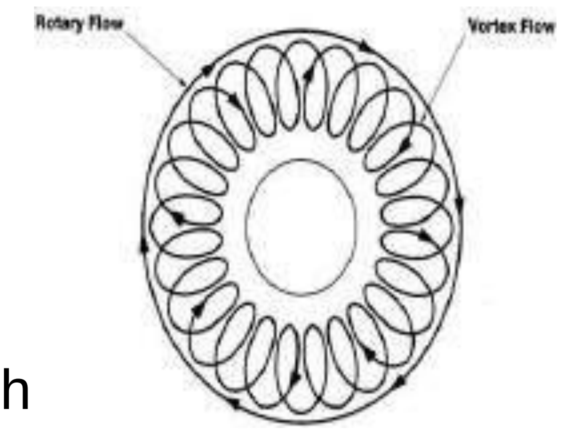


➢Torque converter fluid flow:

- Following types of flow developed during operation of converter:

a. Vortex flow occurs while vehicle is accelerating (impeller turning faster than turbine).

b. Rotary flow occurs while vehicle is crusing (impeller and turbine at all most same speed).



➢Phases of operation:

a. Torque multiplication:
- Relatively low impeller (engine) RPM’s
- Stator is locked into place by its one-way clutch
-Vortex fluid flow within the converter

b. Coupling phase:
- Occurs at normal driving conditions
- No torque multiplication
- Stator is freewheeling
- Turbine is spinning at approx 90% of impeller speed
- Rotary flow within the converter

Overdrives

In the top gear position, it is direct drive between the clutch shaft and the main shaft of the gear box. The gear ratio is 1 : 1 in this position. Through this transmission, there is neither gear reduction nor gear increase.

Sometimes, at high speeds, the main shaft of the gear box should necessarily turn faster than the clutch shaft. In this case the overdrive gear unit plays an important part.

The transmission is in overdrive, when the main shaft of the gear box is turning faster than the clutch shaft.

The overdrive is fitted to the rear of the gear box between the gear box and the propeller shaft. It is described below.

Construction

There are two shafts in the overdrive, namely the input and the output shaft. The main shaft of the gear box becomes the input shaft of the overdrive. The output shaft of the overdrive is connected to the propeller shaft.

There is an epicyclic train in which the sun gear is free to rotate on the input shaft. The carrier can move on splines on the input shaft. A free wheel clutch is also attached on these splines. The ring is connected to the output shaft.

Operation

When the sun gear is locked with the casing, it becomes stationary. In this situation, overdrive is engaged, thus increasing the speed of the output shaft.

When the sun gear is locked to the carrier, solid drive through the gear train is achieved. That is, normal direct drive is obtained. The same effect happens when the sun gear is locked to the ring.

Overdrives

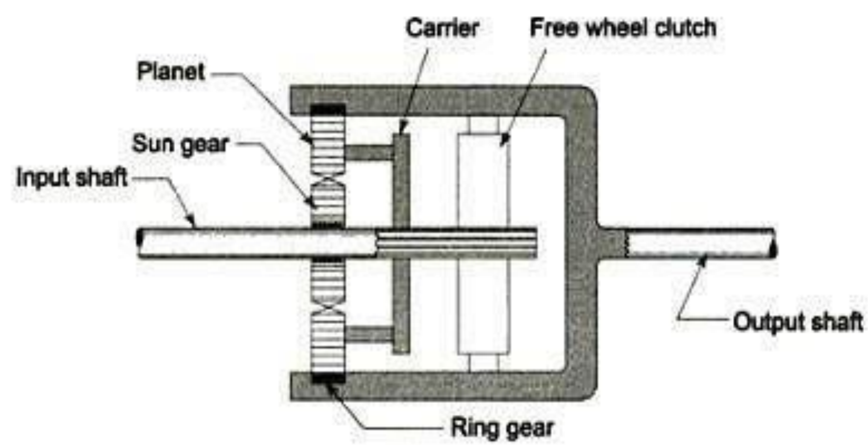
Advantages

The overdrive permits an engine at lower speed to maintain the car at high speed. When the car is moving at a steady speed, it does not require as much power to keep it moving.

As a result, the engine can run slower, produce power less than what is required, and still maintain the same car speed. Thus the fuel used by the car is saved and wear on the engine and accessories is reduced.

For example, when a car without the overdrive runs at 60 km per hour, assume that the engine crankshaft revolves at 1900 per minute. Suppose the same car runs with overdrive at 60 km per hour. Now the crankshaft of the engine will revolve only at 1300 per minute. This indicates that due to the overdrive, the revolution of the engine crankshaft is reduced from 1900 to 1300 per minute for the same speed. This saves a lot of fuel.

Another example is that of a typical overdrive gear box which can maintain a car at a speed of 89 km per hour while allowing the engine to turn at the equivalent of only 71 km per hour. Thus the consumption of fuel by the car is reduced.



Overdrive

- A **semi-automatic transmission** (SAT) (also known as a **clutchless manual transmission**, **automated manual transmission, flappy-paddle gearbox**, or **paddle-shift gearbox**) is an automobile transmission that does not change gears automatically, but rather facilitates manual gear changes by dispensing with the need to press a clutch pedal at the same time as changing gears. It uses electronic sensors, pneumatics, processors and actuators to execute gear shifts on the command of the driver or by a computer. This removes the need for a clutch pedal which the driver otherwise needs to depress before making a gear change, since the clutch itself is actuated by electronic equipment which can synchronise the timing and torque required to make quick, smooth gear shifts.

- A semi-automatic transmission is a very advanced system, which still uses a clutch to perform the gear shift instead of a torque converter. Unlike the manual transmission, the computer does all of the clutch disengaging, gear shifting, and clutch engaging. This not only makes the gear shifting faster than manual transmission, but also prevents the vehicle from stalling when the car is stationary.

- **The two most common semi-automatic transmissions are direct shift transmission (aka dual-clutch transmission) and electrohydraulic manual transmission (aka sequential transmission)**

Propeller shaft

- Function of propeller shaft:- This is a shaft which transmits the drive from the transmission system (gear box) to the rear axle through differential.

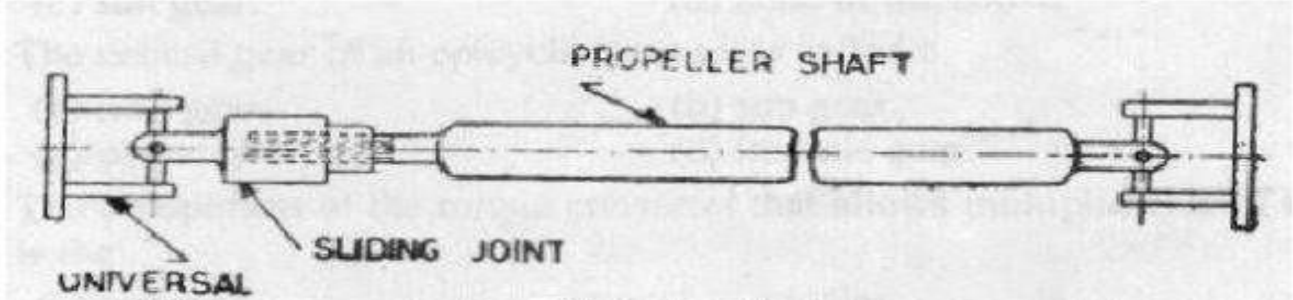
1. Transmit the power from gear box top final dive.
2. To compensate the change in length.
3. Transmit motion at an angle which is varying frequently.

- The rotary motion of the transmission main shaft is carried out through the propeller shaft to the differential, thus causing the rear wheels to rotate.
- Propeller shaft is used in front engine rare wheel drive vehicle to connect gear box & differential.
- Propeller shaft is manufactured in thin walled steel tube.

Propeller shaft

- The propeller shaft has following three components:

1. Shaft: it has to withstand mainly torsional loads. Therefore, it is usually made of tubular cross-section. At high speeds, whirling should be avoided. For this reason, this shaft has to be well balanced. Shafts are made of steel, aluminum or composite material
2. Universal joint: one or more universal joints are used to permit angle change.
3. Slip joint: depending upon the type of the drive, one slip joint may be employed in the shaft. This helps to adjust the length of the propeller shaft, according to the rear axel movements.



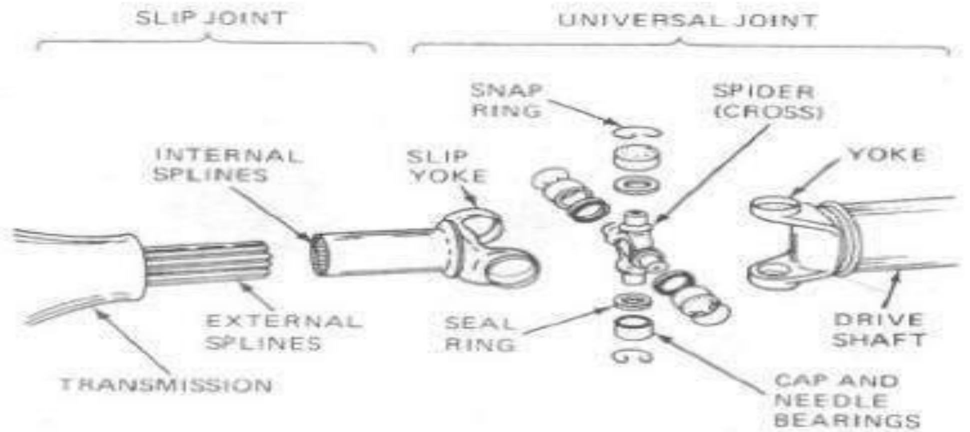
Propeller Shaft.

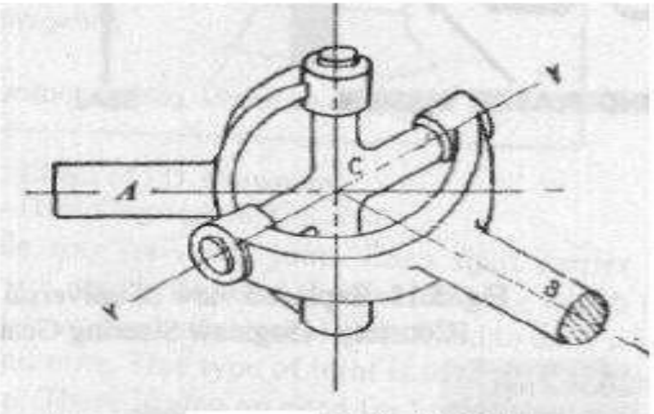
Universal joint

- The purpose of universal joints is to transmit power (torque) even at varied angles of the transmission system (propeller shaft).
- Power is transmitted from the gear box to the differential via the propeller shaft. Gear box is connected to one end of the propeller shaft by means of the universal joint. The differential is connected to the other end of the propeller shaft by means of another universal joint.
- The most common type of universal joint is Hook’s Joint.

Cross type or spider & two yoke (Hook's Joint)

- A single universal joint is shown in fig, there is a driving yoke on one side which is connected to the main shaft of the gear box & the driven yoke is connected to the propeller shaft. These two yokes are connected by means of a crossed spider. When the driving shaft rotates, the driven shaft also rotates. At the same time the universal joint permits angular motion. This propeller haft can rotate at any angle. Thus power is transmitted from the gear box to the propeller shaft at any particular angle.
- Universal joints have one common defect i.e. the speed of the driven shaft does not remain constant. Depending upon the angle of inclination of the shafts, driven shaft speed undergoes cyclic variation as shown in fig.

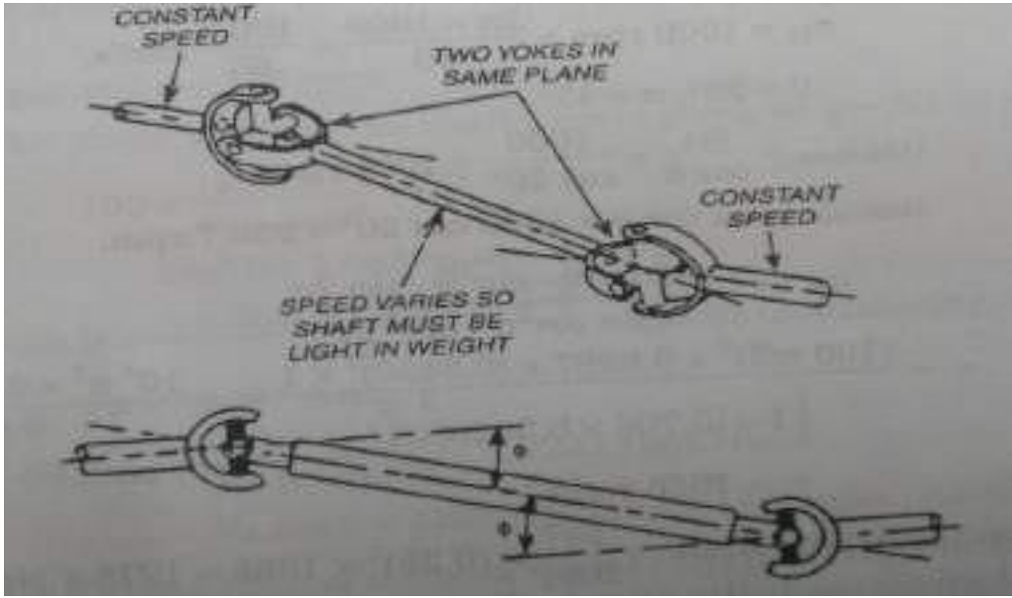




Hooke's Joint

Constant velocity universal joint

- This type of joints permit movement of both driving & driven shaft at constant velocity.
- One method to achieve a uniform driven shaft speed is by using two such joints as shown in fig.
- The intermediate shaft is so arrange that it makes equal angles with first and third shifts.
- The variation caused by one joint is then cancelled out by the second joint.
- however, this will be valid only when the angles on both joints are exactly equal, which is not always the case in practice.



Constant velocity joint

1. Constant velocity joints are used where the front axle are being driven, regulation of rotation and transmission of torque at large indication are vital.
2. In these vehicles the inclination between the shafts may assume a large varying (40°).
3. The speed of shaft connected by these joints is absolutely equal.

Final drive

- In most automobile vehicles the final driver is embodied in rear axle.
- But in various popular vehicles with front wheel drive and a few special purpose vehicles with four wheel drive, it becomes necessary to consider final drives as units dependent of their positions.

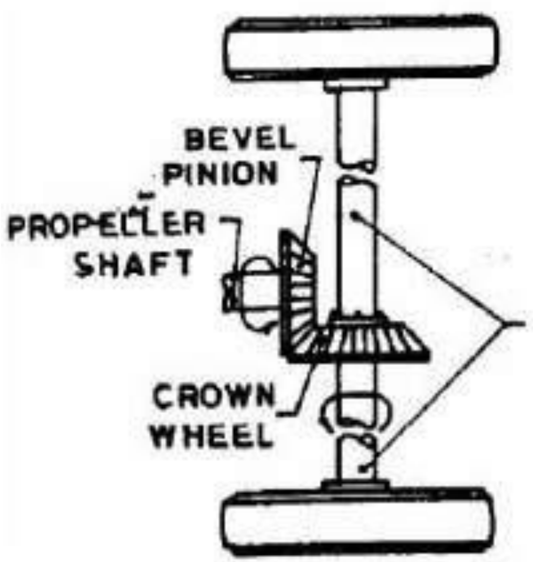
➢ FUNCTIONS OF FINAL DRIVE: In a motor vehicle the final drive has two purposes.

1) To provide a permanent speed reduction. For motor cars the reduction is usually about 4:1 and 10:1 in heavy vehicle.
2) To turn the drive through 90^{o} so that the torque may be transmitted from propeller shaft to the rear axle.

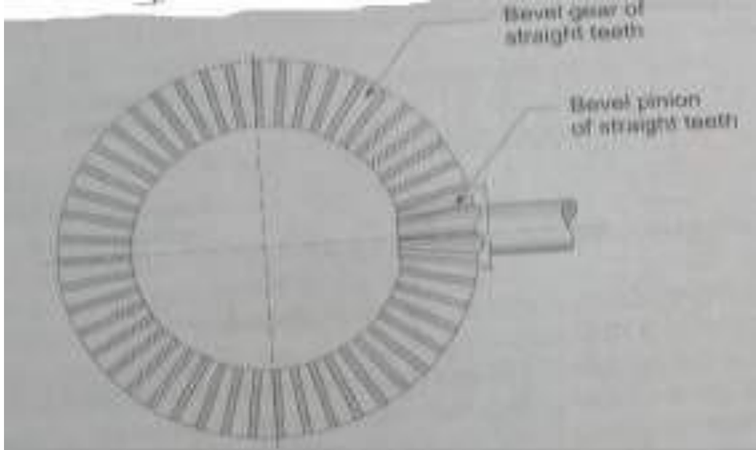
Construction of final drive

1) The final drive consist of a bevel pinion and crown wheel (ring gear)as shown in the figure.
2) The bevel pinion is mounted on the shaft
3) From the crown wheel the drive goes to the rear axle through the diffrential.
4) There are three types of the final drive gearing:

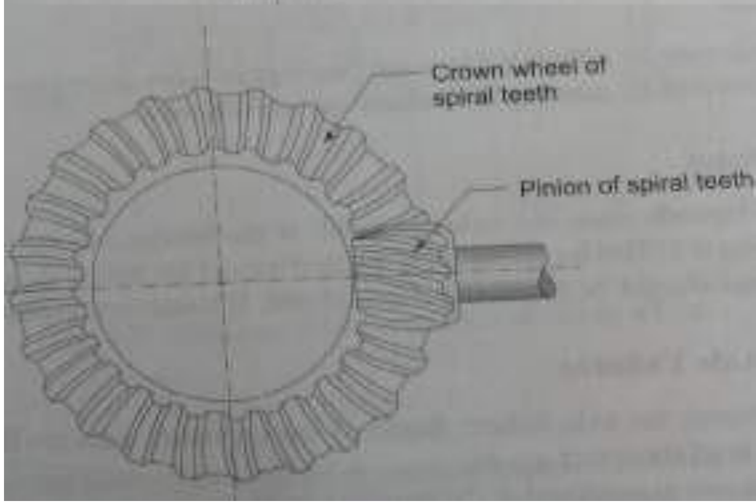
a. Straight Bevel gears
b. Sprial Bevel Gears
c. Hypoid Gears



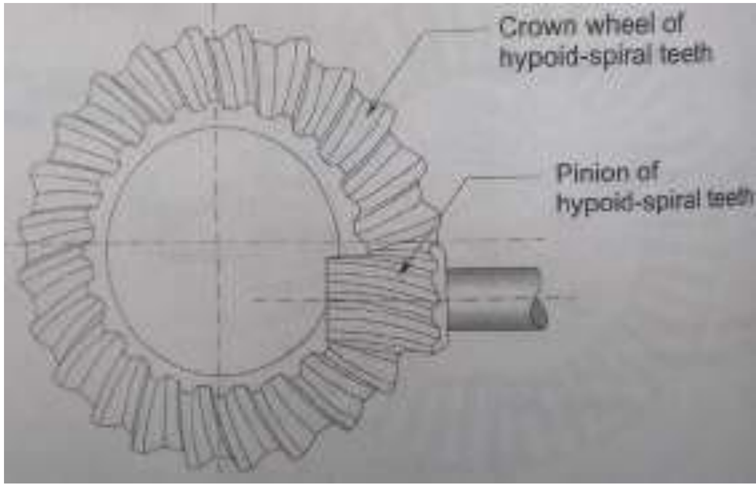
- Straight Bevel gears: this is the arrangement made in the older models. In this, the teeth of the crown wheel are straight. A bevel pinion of the propeller shaft is in mesh with the bevel gear of the crown wheel.



- Spiral bevel gear: in this the teeth of the crown wheel are in the form of a spiral gear. The pinion of the propeller shaft also has teeth in the same form. No sound is developed when these teeth mesh & the meshing is also very smooth. These are the advantages of this unit.



- Hypoid spiral gear: this is a form of bevel pinion & crown wheel drive. The axis of the pinion shaft is below the centre of the crown wheel. In this arrangement too the running is noiseless.



Construction of final drive

1) Final drive is the last stage in transferring power from engine to wheels.
2) It reduces the speed of the propeller shaft (drive shaft) to that of wheels.
3) It also turns the drive of the propeller shaft by an angle of 90^o to drive the wheels.
4) The propeller shaft has a small bevel pinion which meshes with crown wheel. The crown wheel gives rotary motion to rear axles.
5) The size of crown wheel in bigger than that of bevel pinion, therefore, the speed of rear axles (or crown wheel) in lower than the speed of pinion.
6) Final drive is of two types, i.e. chain type and gear type.
7) For final reduction in speed two types of gears can be used.
8) One of them may be use of bevel gears and another may be worm and worm wheel.
9) Worm and worm wheel combination provides large reduction without employing larger gears. It is strong also.

Differential

1) When a vehicle travels in a straight-line, the two rear wheels turn on road exactly at same speed & there is no relative movement between the rear wheels.
2) But when vehicle takes a turn, the outer wheel turns on a longer radius than inner wheel. The outer wheel turns faster than inner wheel i.e. there is relative movement between two rear wheels.
3) If the two rear wheels are rigidly fixed to a solid rear axle, the inner wheel will slip, which will cause rapid tire wear, steering difficulties & poor road holding.
4) Therefore there must Le some mechanism in the rear axle which should reduce the speed of inner wheels & increase the speed of outer wheels while taking turns.
5) It should be at the same time keep the speeds of all the wheels same when going straight ahead. Such a device which serves the above function is called as differential.

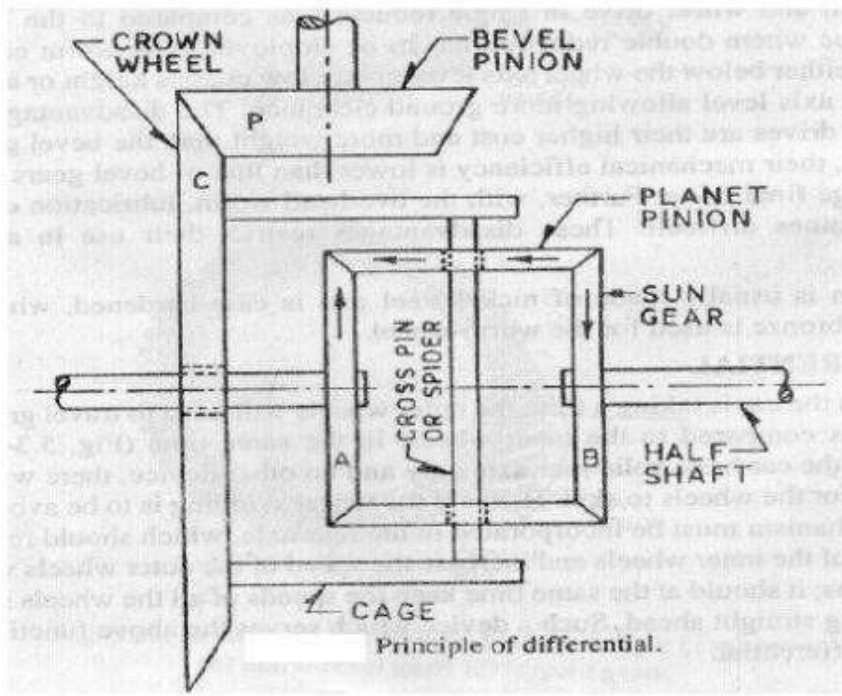
Differential

- To understand the principle on which differential works consider figure:

1. To the crown wheel of the final drive is attached a cage, which carries a cross-pin where two planet pinions are employed.
2. Two sun gears mesh with the two planet pinions. Axle half shafts are splined to each of these sun gears.
3. When the vehicle is going straight, the cage & inner gears rotate as a single unit & two half shafts revolve at same speed. In this situation, there is no relative movement among the various differential gears.
4. To understand what happens when the vehicle is taking turn, assume that the cage is stationary. Then turning any one sun gear will cause other to rotate in the opposite direction.
5. This means that if the left sun gear rotates "n" times in a particular time. the right gear will also rotate "n" in the same period. but of course in opposite direction.

Differential

6. Thus for example, consider a vehicle with wheel speed "N" r.p.m. going straight. When it takes turn towards, there will be resistance to the motion of right wheel & as a result differential action: if the right wheel rotates back at "n" rpm, then left wheel will rotate forwards at "n' rpm. This will give resultant speed of left wheel as (N+n) and that of right wheel as (N-n) rpm.



Principle of differential.

Non slip differential

- Conventional type differential described delivers same torque to each rear wheel. If any of the wheels slips due to any reason the wheel does not rotate and vehicle does not move.

- Non-slip or limited slip differential or self locking type differential overcomes this drawback:

1) A self locking differential consists of two clutches, one on each side, to lock the side gears and axles to the differential cage, when the differential action is not desired.
2) The mechanism consists of four differential pinion gears mounted on two cross shafts at right angles to each other.
3) When the differential cage is driven by the rear axle gears, the turning resistance causes the cross shafts to move up the ramps and push the shafts apart.
4) This action forces the pinions on each shaft to bear against the side gear rings in order to apply the clutch which locks both axle shafts and force them to turn at the same speed.

Differential Lock

1) The torque transmitted by the bevel gear differential to each of the rear wheels remains equal even when they are rotating at different speeds.
2) Due to this reason if one wheel in on a slippery surface, mend, lose dirt or sand the wheel on the solid ground will not be driven while the other spins around idly.
3) When the differential lock is applied, the differential action is stopped and the whole torque is then applied to the wheel which is gripping on the road.

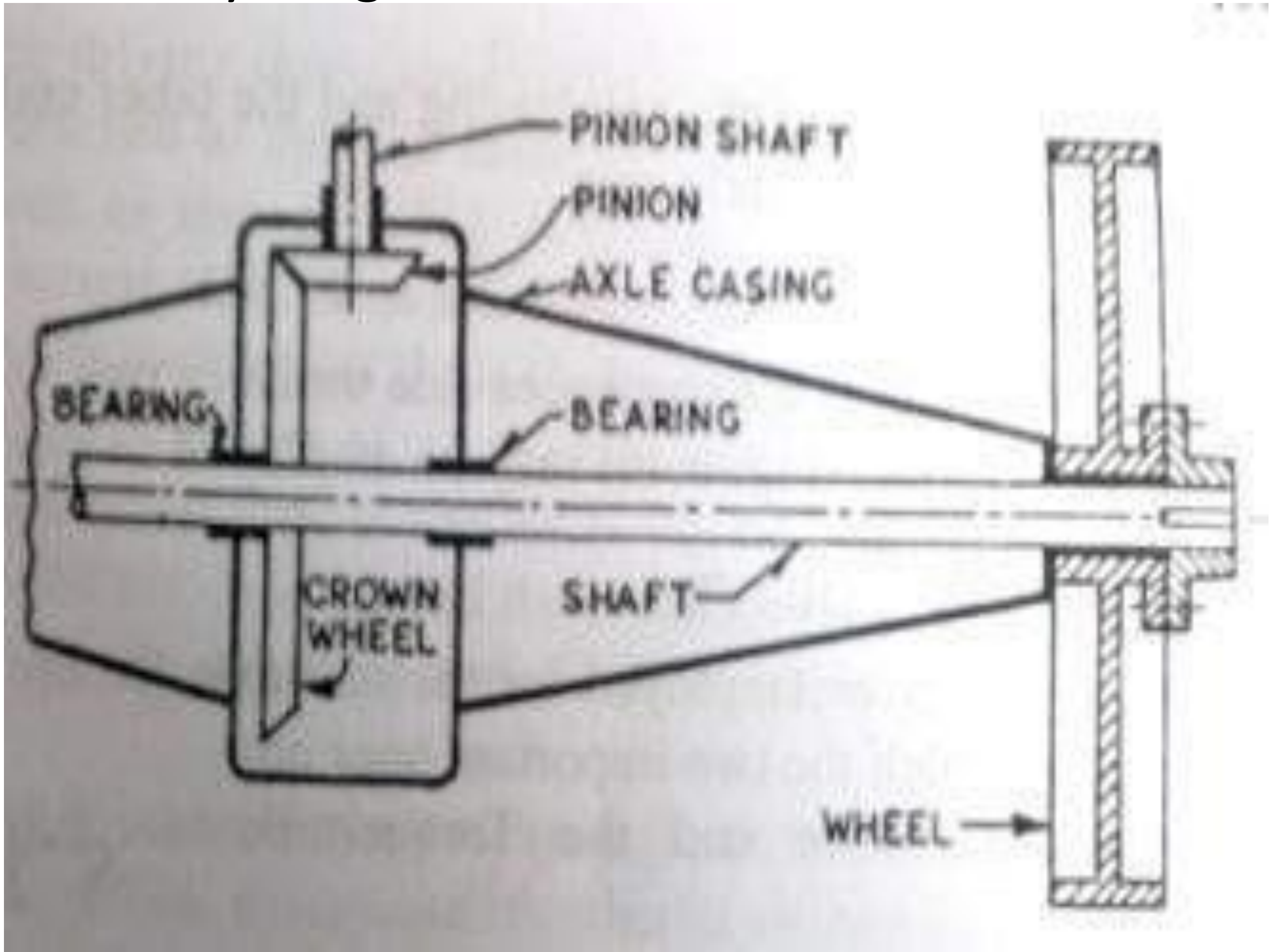
Rear axle

1. Rear axle transmits power from differential to the wheels so that vehicle may move.
2. Rear axle is not a single piece but it is in two parts which are connected by the differential.
3. Each part of rear axle is called the half shaft.
4. Outer end of the rear axle carries the wheel while inner end is connected to sun gear of the differential.
5. In vehicles which employ rear wheel drive, rear wheels are driving wheels. However, in front wheel drive vehicles, front wheels are driving wheels.
6. Rear axles and differential are completely enclosed in a housing to protect them from dust, dirt, water and any possible damage.

Rear Axel

Function of rear axel:

1. To transmit power from differential to wheels
2. To carry weight of automobile.



Rear wheel drive

- Commonly used rear wheel drive are:

1. Hotchkiss drive:
2. Torque tube drive:

Rear axel drive

1. Hostchkiss drive:

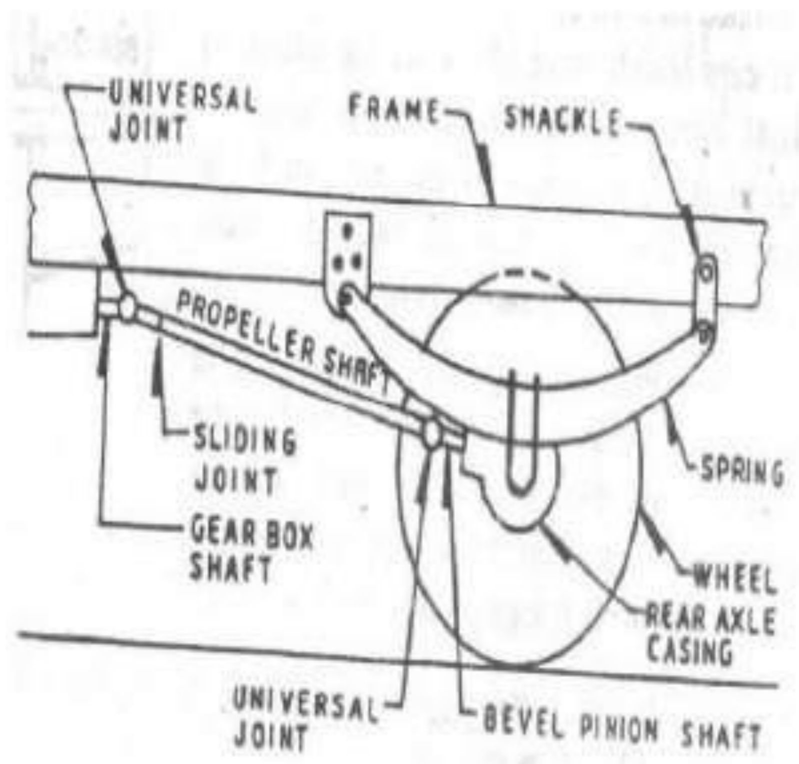
a) This is the simplest and most widely used type of rear axle drive.

b) In this case the springs besides taking weight of the body also take the torque reaction, driving thrust and side thrust.

c) The propeller shaft is provided with two universal joints also a sliding joint.

d) The springs is fixed rigidly in the middle to the rear axle.

e) The front end of the spring is fixed rigidly on the frame while the rear end is supported in the shackle.



Rear axel drive

2. Torque tube drive:

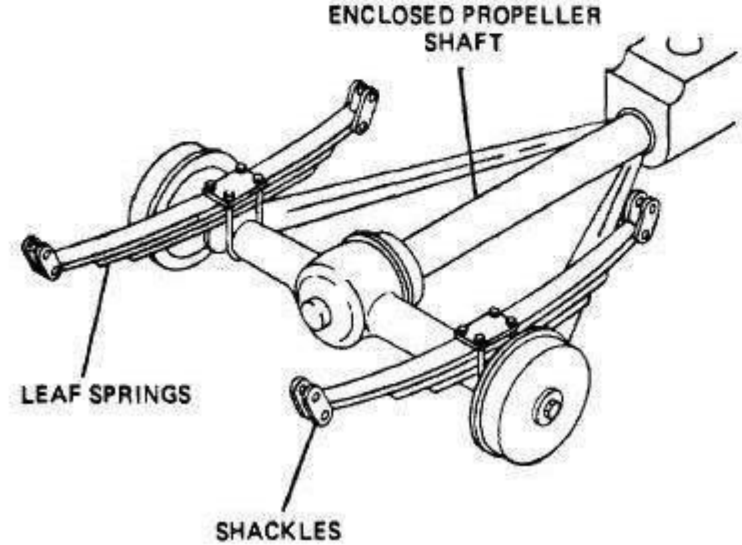
a. In this type ot drive the spring takes only the side thrust besides supporting the body weight.

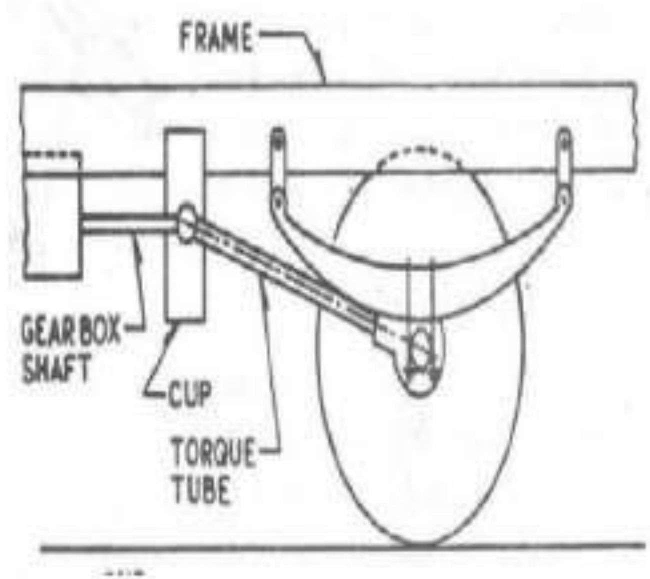
b. The torque reaction and driving thrust are taken by another member which is called torque tube.

c. One end of the torque tube is attached to the axle casing, another end which is in spherical shape fixed in the cup fixed to the frame.

d. The torque tube encloses the propeller shaft since the torque tube takes the torque reaction the centre line of the bevel pinion shaft will not shift.

e. So that no sliding joint is required and one universal joint is enough.





Rear axel shaft supporting

- **<u>Load on Rear live axle half shaft</u>**

  The various loads on rear live axle half shaft are

  a. Shaft force due to vehicle weight
  b. Bending moment on accountant of the offset of vehicle load applied through spring seats and road wheels.
  c. End thrust carried by side forces
  d. Bending moment caused by end thrust and its reaction offered by tyres
  e. Driving torque

Types of Rear Axle Support

Rear axles differ on the basis of method of supporting them and mounting of rear wheels.

On this basis, these axles can be classified into three types:

(a) Half floating axle /semi floating type

(b) Three-quarter floating axle

(c) Fully floating rear axle.

1. Semi floating type rear axel:

1) An axle in which the shaft has to take the entire load is called semi or non floating axle.

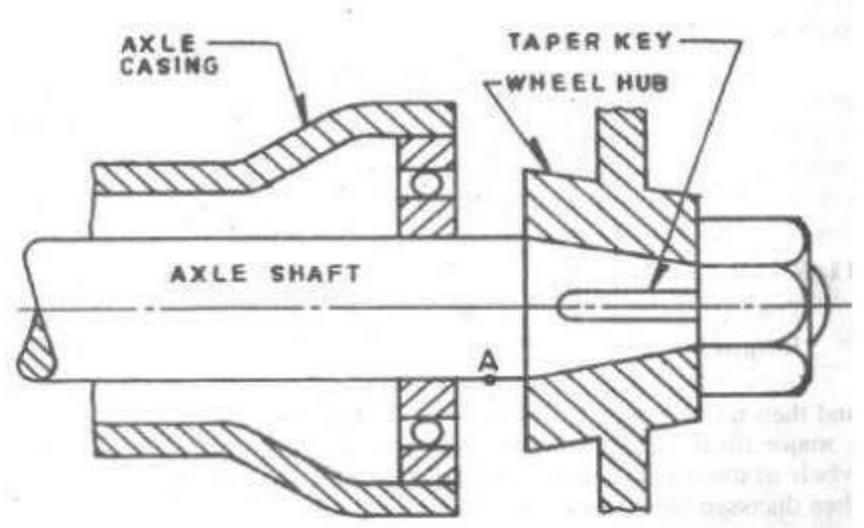
2) In this wheel hub is directly connected to the axle.

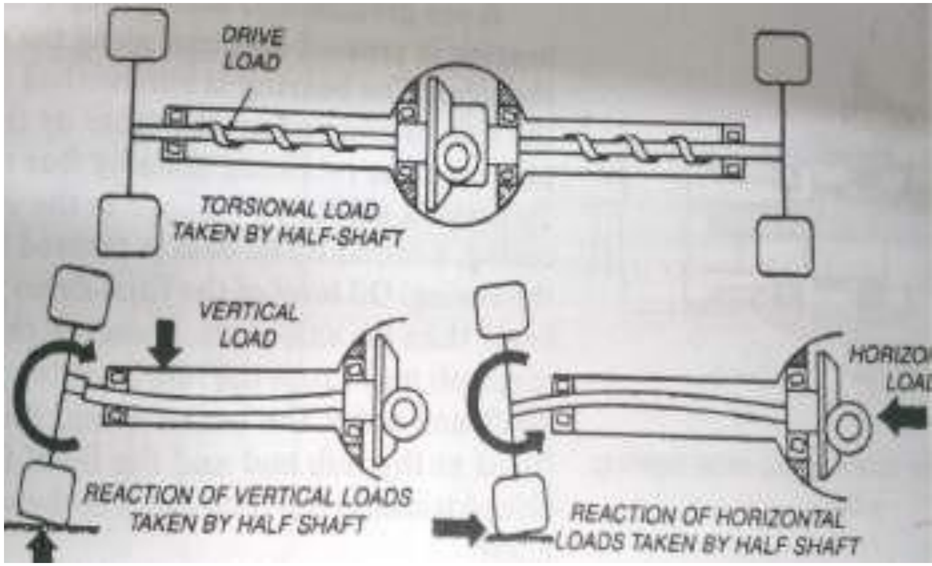
3) The inner end of the axle shaft is splined and is supported by the final drive unit where as outer end is supported by a single bearing inside the axle casing.

4) In this type all the loads are taken by the axle shaft.

5) The whole load acts on the shaft and shaft has a tendency to shear at the point A.

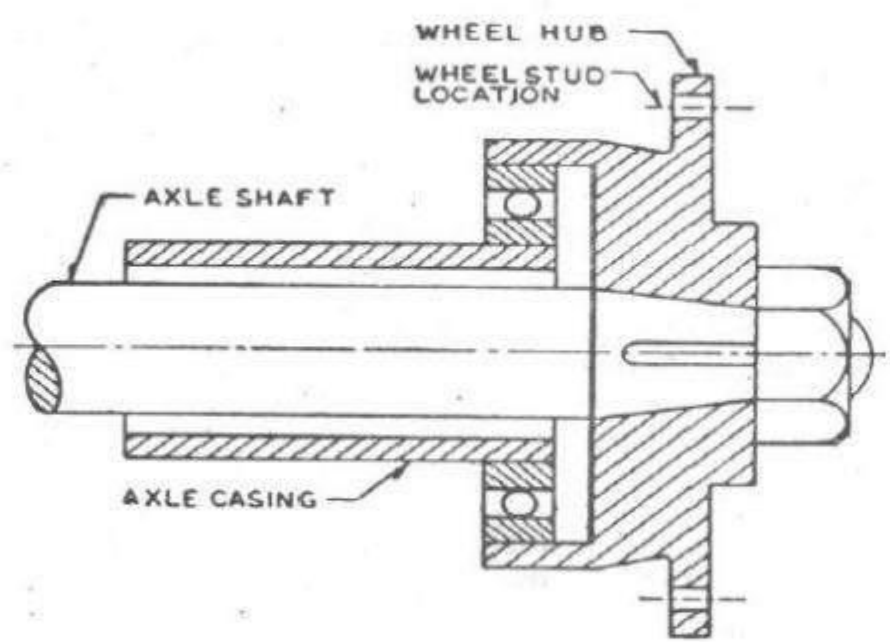
6) The semi floating axle is the simplest and cheapest but for a given torque they have to be of larger dia. for the same torque transmitted compared to the other type of rear axle supports.

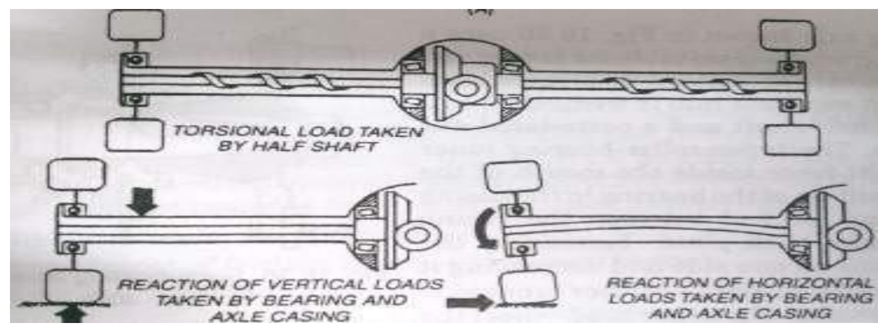




2. Three quarter floating axle:

1) This type of axle is a combination of full and semi floating bearing.
2) In this bearing is locating between the axle casing and hub axle shaft do not have to withstand any shearing or bending action due to the weight of the vehicle, which are taken up by the axle casing through the hub and bearing.
3) However it has to take the end loads and driving torque.





IGNITION SYSTEMS & FUEL INJECTION SYSTEMS

Ignition System:

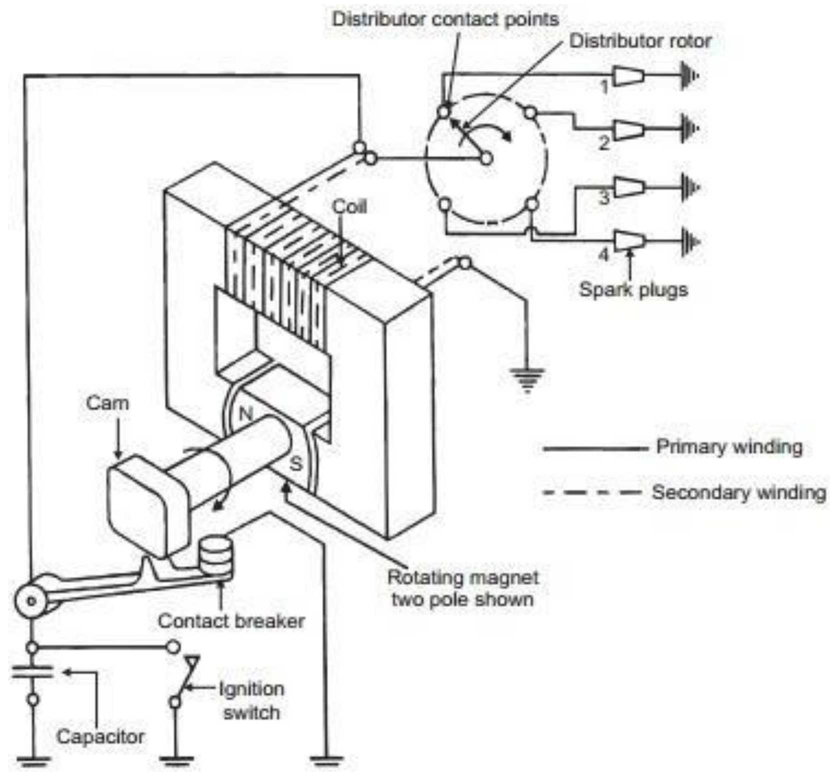
The ignition system is a system used to generate a very high voltage from the car battery and to send it to each sparkplug in turn thereby igniting the fuel-air mixture in the combustion chamber of the engine.

Types of Ignition System:

1. Magneto ignition systems
2. Battery coil ignition systems
3. Electronic ignition system

Magneto ignition systems:

This type of ignition system is mostly used in motorcycles, scooters and racing cars. The magneto Ignition system with main components is shown below:



Schematic of rotating magnet type magneto ignition systems

Magneto ignition system is a special type of ignition system with its own electric generator to provide the required necessary energy for the vehicle system. It is mounted on the engine and replaces all components of the coil ignition system except the spark plug. A magneto when rotated by the engine is capable of producing a very high voltage and doesn’t need a battery as source of external energy.

The main components of an ignition coil are

Distributor, Condenser, Contact Breaker (CB) points, Ignition Coil.

There are two important types of magneto ignition system. They are 1) Rotating armature type and 2) Rotating Magnet type.

In the first type, the armature consisting of the primary and secondary windings rotate in between the poles of a stationary magnet. In the second type the magnet revolves and windings are kept stationary is shown in the above figure. A third type of magneto called the polar inductor type magneto, where both the magnet and the windings remain stationary but the voltage is generated by reversing the flux field with the help of soft iron polar projections called inductors.

Condensor:

The function of the capacitor is to reduce arcing at the contact breaker (CB) points. Also when the CB opens the magnetic field in the primary winding begins to collapse. When the magnetic field is collapsing capacitor gets fully charged and then it starts discharging and helps in building up of voltage in secondary winding.

Contact Breaker:

It is to be noted that the Contact breaker cam and distributor rotor are mounted on the same shaft.

Distributor:

Ignition Coil:

The main advantage of the high tension magneto ignition system is the production of a very high voltage.Because of the poor starting characteristics of the magneto system invariably the battery ignition system is preferred to the magneto system in automobile engines. However, in two wheelers magneto ignition system is preferred due to light weight and less maintenance.

Battery coil ignition systems:

It is used in passenger cars and light trucks. A Battery Ignition system for four cylinder engine where the battery supplies the electrical energy. An ignition switch is used to control the battery current for starting or stopping the engine. The ignition coil transforms the battery low tension current to high tension current required to produce a spark by jumping in a spark plug. The distributor delivers the spark to the proper cylinder and incorporates the mechanical breaker, which opens and closes the primary circuit at exact times.

The various units are connected by electrical wiring. The spark plugs provide the spark in engine cylinder.

The figure shows battery ignition system for a 4-cylinder petrol engine. It mainly consists of a 6 or 12 volt battery, ammeter, ignition switch, auto-transformer (step up transformer), contact breaker, capacitor, distributor rotor, distributor contact points, spark plugs, etc.

The ignition system is divided into 2-circuits namely the Primary Circuit and Secondary Circuit.

(i) Primary Circuit : It consists of 6 or 12 V battery, ammeter, ignition switch, primary winding it has 200-300 turns of 20 SWG (Sharps Wire Gauge) gauge wire, contact breaker, capacitor. 53

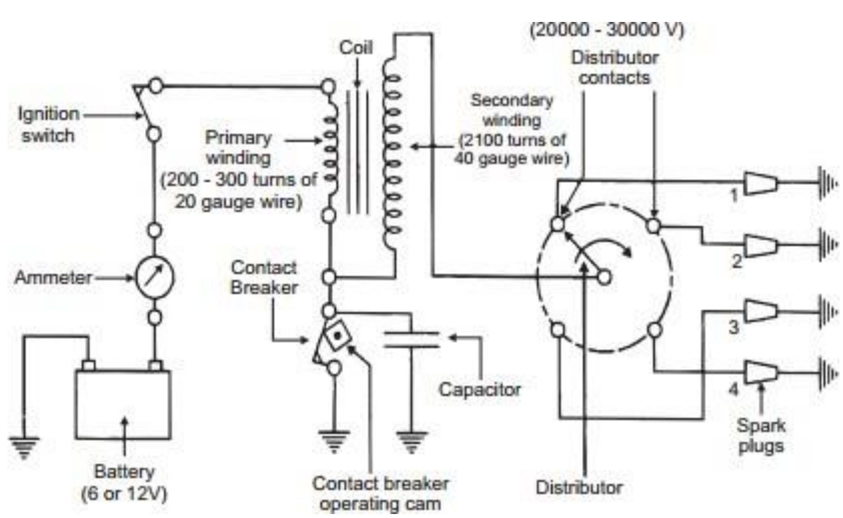
(ii) Secondary Circuit: It consists of secondary winding. Secondary Ignition Systems winding consists of about 21000 turns of 40 (S WG) gauge wire. Bottom end of which is connected to bottom end of primary and top end of secondary winding is connected to centre of distributor rotor. Distributor rotors rotate and make contacts with contact points and are connected to spark plugs which are fitted in cylinder heads.

Working:

When the ignition switch is closed and engine in cranked, as soon as the contact breaker closes, a low voltage current will flow through the primary winding. When the contact breaker opens the contact, the magnetic field begins to collapse. Because of this collapsing magnetic field, current will be induced in the secondary winding. And because of more turns of secondary, the voltage goes upto 20000-35000 volts.

This high voltage current is brought to centre of the distributor rotor. Distributor rotor rotates and supplies this high voltage current to proper stark plug depending upon the engine firing order. When the high voltage current jumps the spark plug gap, it produces the spark and the charge is ignited-combustion starts-products of combustion expand and produce power.

When compared to the magneto ignition system, the battery ignition system is more expensive but at the same time it is very highly reliable as it aids in reliable sparking..



Schematic Diagram of battery ignition systems

Electronic ignition system:

The requirement for higher mileage, reduced emissions and greater reliability has paved the way for development of the electronic ignition systems.

The main advantages of the electronic ignition system are

It provides better emission control.

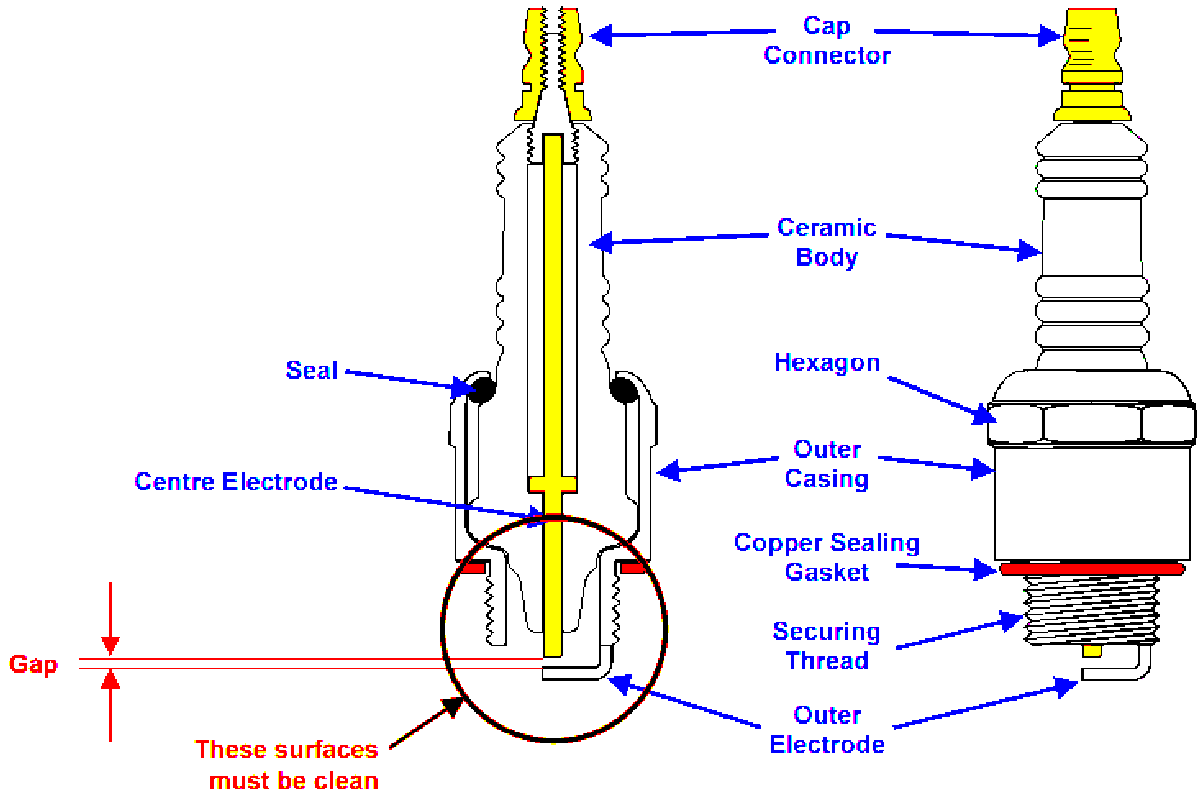
It provides a reasonable fuel economy. It provides better engine performance.

Spark plug:

The spark plug consists of a porcelain insulator in which there is an insulated electrode supported by a metal shell with a grounded electrode. They have a simple purpose of supplying a fixed gap in the cylinder across which the high voltage surges from the coil must jump after passing through the distributor. The spark plugs use ignition coil high voltage to ignite the fuel mixture. Somewhere between 4,000 and 10,000 volts are required to make current jump the gap at the plug electrodes. This is much lower than the output potential of the coil.

Spark plug gap is the distance between the center and side electrodes. Normal gap specifications range between .030 to .060 inch. Smaller spark plugs gaps are used on older vehicles equipped with contact point ignition systems.

Spark plugs are either resistor or non-resistor types . A resistor spark plug has internal resistance (approximately 10,000 ohms) designed to reduce the static in radios. Most new vehicles require resistortype plugs. Non-resistor spark plug has a solid metal rod forming the center electrode. This type of spark plugs is NOT commonly used except for racing and off-road vehicles.



Spark Plug Heat Range and Reach:

The heat range of the spark plug determines how hot the plug will get. The length and diameter of the insulator tip and the ability of the spark plug to transfer heat into the cooling system determine spark plug heat range.

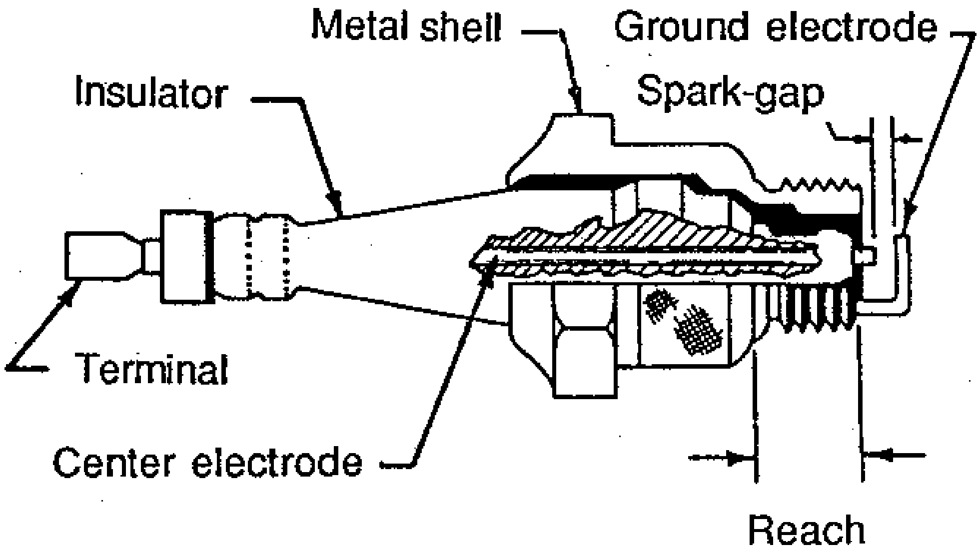
A hot spark plug has a long insulator tip that prevents heat transfer into the waterjackets. It will also bum off any oil deposits. This provides a self-cleaning action.

A cold spark plug has a shorter insulator tip and operates at a cooler temperature. The cooler tip helps prevent overheating and preignition. A cold spark plug is used in engines operated at high speeds.

Vehicle manufacturers recommend a specific spark plug heat range for their engines. The heat range is coded and given as a number on the spark plug insulator. The larger the number on the plug, the hotter the spark plug tip will operate. For example, a 54 plug would be hotter than a 44 or 34 plug.

The only time you should change from spark plug heat range specifications is when abnormal engine or operating conditions are encountered. For instance, if the plug runs too cool, sooty carbon will deposit on the insulator around the center electrode. This deposit could soon build up enough to short out the plug. Then high voltage surges would leak across the carbon instead of producing a spark across the spark plug gap. Using a hotter plug will bum this carbon deposit away or prevent it from forming.

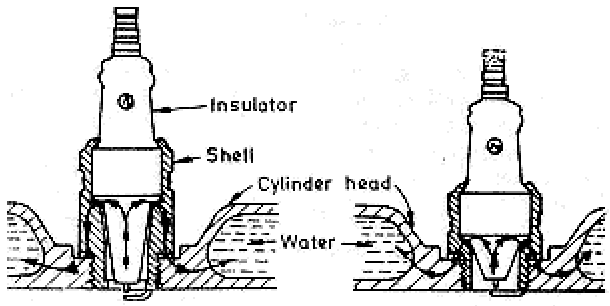
Spark plug reach is the distance between the end of the spark plug threads and the seat or sealing surface of the plug. Plug reach determines how far the plug reaches through the cylinder head. If spark plug reach is too long, the spark plug will protrude too far into the combustion chamber and the piston at TDC may strike the electrode. However, if the reach is too short, the plug electrode may not extend far enough into the cylinder head and combustion efficiency will be reduced. A spark plug must reach into the combustion chamber far enough so that the spark gap will be properly positioned in the combustion chamber without interfering with the turbulence of the air-fuel mixture or reducing combustion action.



Sectional view of a (A) non-resistor and (B) resistor spark plug.

Construction of Spark Plug:

Types of spark plugs:



Introduction to carburetor systems:

Carburetor is a device used for providing proper air/fuel mixture ratio. The carburetor works on Bernoulli's principle i.e. The faster the air moves, the lower is its static pressure, and the higher is its dynamic pressure. The throttle or accelerator linkage indirectly controls the flow of fuel by actuating the carburetor mechanisms which meters the flow of air being pulled into the engine. The speed of this flow, and therefore its pressure, determines the amount of fuel drawn into the airstream.

The latest type of carburetor system is the electronic feedback design, which provides better combustion by improved control of the air/fuel mixture. A three-way converter not only oxidizes HC and CO but also chemically reduces oxides of nitrogen (NOX).If the air/fuel mixture is too lean, NOX is not converted efficiently. If the mixture is too rich, HC and CO does not oxidize efficiently. Monitoring the air/fuel ratio is the job of the exhaust gas oxygen sensor.

An oxygen sensor senses the amount of oxygen present in the exhaust stream. A lean mixture produces a high level of oxygen in the exhaust. The oxygen sensor, placed in the exhaust before the catalytic converter, produces a voltage signal that varies with the amount of oxygen the sensor detects in the exhaust. If the oxygen level is high (a lean mixture), the voltage output is low. If the oxygen level is low (a rich mixture), the voltage output is high.The electrical output of the oxygen sensor is monitored by an electronic control unit (ECU). This microprocessor is programmed to interpret the input signals from the sensor and in turn generate output signals to a mixture control device that meters more or less fuel into the air charge as it is needed to maintain the 14.7 to 1 ratio.

Whenever these components are working to control the air/fuel ratio, the carburetor is said to be operating in closed loop. The oxygen sensor is constantly monitoring the oxygen in the exhaust, and the control module is constantly making adjustments to the air/fuel mixture based on the fluctuations in the sensor's voltage output. However, there are certain conditions under which the control module ignores the signals from the oxygen sensor and does not regulate the ratio of fuel to air. During these times, the carburetor is functioning in conventional manner and is said to be operating in open loop. (The control cycle has been broken.)

The carburetor operates in open loop until the oxygen sensor reaches a certain temperature (approximately 600F). The carburetor also goes into open loop when a richer-than-normal air/fuel mixture is required, such as during warm-up and heavy throttle application.

Several other sensors are needed to alert the electronic sensor provides input relating to engine temperature. A vacuum sensor and a throttle position sensor indicate wide open throttle.

Early feedback systems used a vacuum switch to control metering devices on the carburetor. Closed loop signals from the electronic control module are sent to a vacuum solenoid regulator, which in turn controls vacuum to a piston and diaphragm assembly in the carburetor. The vacuum diaphragm and a spring above the diaphragm work together to lift and lower a tapered fuel metering rod that moves in and out of an auxiliary fuel jet in the bottom of the fuel bowl. The position of the metering rod in the jet controls the amount of fuel allowed to flow into the main fuel well.

A less common method to control the air/fuel mixture is with a back suction system feedback. The back suction system consists of an electric stepper motor, a metering pintle valve, an internal vent restrictor, and a metering orifice. The stepper motor regulates the pintle movement in the metering orifice, thereby varying the area of the opening communicating control vacuum to the fuel bowl. The larger this area, the leaner the air/fuel mixture. Some of the control vacuum is bled off through the internal vent restrictor. The internal vent restrictor also serves to vent the fuel bowl when the back suction control pintle is in the closed position.

COOLING SYSTEM

A system, which controls the engine temperature, is known as a cooling system.

NECESSITY OF COOLING SYSTEM

The cooling system is provided in the IC engine for the following reasons:

- The temperature of the burning gases in the engine cylinder reaches up to 1500 to 2000°C, which is above the melting point of the material of the cylinder body and head of the engine. (Platinum, a metal which has one of the highest melting points, melts at 1750 °C, iron at 1530°C and aluminium at 657°C.) Therefore, if the heat is not dissipated, it would result in the failure of the cylinder material.
- Due to very high temperatures, the film of the lubricating oil will get oxidized, thus producing carbon deposits on the surface. This will result in piston seizure.
- Due to overheating, large temperature differences may lead to a distortion of the engine components due to the thermal stresses set up. This makes it necessary for, the temperature variation to be kept to a minimum.
- Higher temperatures also lower the volumetric efficiency of the engine.

REQUIREMENTS OF EFFICIENT COOLING SYSTEM

The two main requirements of an efficient cooling system are:

1. It must be capable of removing only about 30% of the heat generated in the combustion chamber. Too much removal of heat lowers the thermal efficiency of the engine.
2. It should remove heat at a fast rate when the engine is hot. During the starting of the engine, the cooling should be very slow so that the different working parts reach their operating temperatures in a short time.

TYPES OF COOLING SYSTEM

There are two types of cooling systems:

(i) Air cooling system and
(ii) Water-cooling system.

AIR COOLING SYSTEM

In this type of cooling system, the heat, which is conducted to the outer parts of the engine, is radiated and conducted away by the stream of air, which is obtained from the atmosphere. In order to have efficient cooling by means of air, providing fins around the cylinder and cylinder head increases the contact area. The fins are metallic ridges, which are formed during the casting of the cylinder and cylinder head
The amount of heat carried off by the air-cooling depends upon the following factors:

(i) The total area of the fin surfaces,
(ii) The velocity and amount of the cooling air and
(iii) The temperature of the fins and of the cooling air.

Air-cooling is mostly tractors of less horsepower, motorcycles, scooters, small cars and small aircraft engines where the forward motion of the machine gives good velocity to cool the engine. Air-cooling is also provided in some small industrial engines. In this system, individual cylinders are generally employed to provide ample cooling area by providing fins. A blower is used to provide air.

Advantages of Air Cooled Engines

Air cooled engines have the following advantages:

1. Its design of air-cooled engine is simple.
2. It is lighterin weight than water-cooled engines due to the absence of water jackets, radiator, circulating pump and the weight of the cooling water.
3. It is cheaper to manufacture.
4. It needs less care and maintenance.
5. This system of cooling is particularly advantageous where there are extreme climatic conditions in the arctic or where there is scarcity of water as in deserts.
6. No risk of damage from frost, such as cracking of cylinder jackets or radiator water tubes.

WATER COOLING SYSTEM

It serves two purposes in the working of an engine:

a) It takes away the excessive heat generated in the engine and saves it from over heating.
b) It keeps the engine at working temperature for efficient and economical working. This cooling system has four types of systems:

    (i) Direct or non-return system,
    (ii) Thermo-Syphone system,
    (iii) Hopper system and
    (iv) Pump/forced circulation system.

Though the present tractor has a forced circulation system, it is still worthwhile to get acquainted with the other three systems.

Non-Return Water Cooling System

This is suitable for large installations and where plenty of water is available. The water from a storage tank is directly supplied to the engine cylinder. The hot water is not cooled for reuse but simply discharges. The low H.P. engine, coupled with the irrigation pump is an example.

Thermo-Syphone Water Cooling System

This system works on the principle that hot water being lighter rises up and the cold water being heavier goes down. In this system the radiator is placed at a higher level than the engine for the easy flow of water towards the engine. Heat is conducted to the water jackets from where it is taken away due to convection by the circulating water. As the water jacket becomes hot, it rises to the top of the radiator. Cold water from the radiator takes the place of the rising hot water and in this way a circulation of water is set up m the system. This helps in keeping the engine at working temperature.

Disadvantages of Thermo-Syphone System

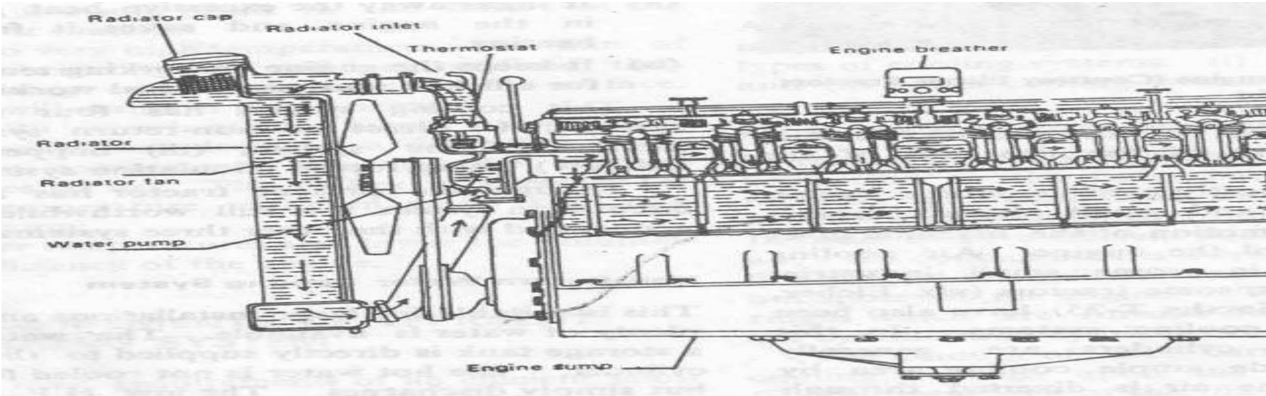
1 Rate of circulation is too slow.
2. Circulation commences only when there is a marked difference in temperature.
3. Circulation stops as the level of water falls below the top of the delivery pipe of the radiator. For these reasons this system has become obsolete and is no more in use.

Hopper Water Cooling System

This also works on the same principle as the thermo-syphone system. In this there is a hopper on a jacket containing water, which surrounds the engine cylinder. In this system, as soon as water starts boiling, it is replaced by cold water. An engine fitted with this system cannot run for several hours without it being refilled with water.

Force Circulation Water Cooling System

This system is similar in construction to the thermo-syphone system except that it makes use of a centrifugal pump to circulate the water throughout the water jackets and radiator



The water flows from the lower portion of the radiator to the water jacket of the engine through the centrifugal pump. After the circulation water comes back to the radiator, it loses its heat by the process of radiation. This system is employed in cars, trucks, tractors, etc.

Parts of Liquid Cooling System

The main parts in the water-cooling system are: (i) water pump, (ii) fan, (iii) radiator and pressure cap, (iv) fan belt (v) water jacket, (vi) thermostat valve, (vii) temperature gauge and (viii) hose pipes.

Water Pump

This is a centrifugal type pump. It is centrally mounted at the front of the cylinder block and is usually driven by means of a belt. This type of pump consists of the following parts: (i) body or casing, (ii) impeller (rotor), (iii) shaft, (iv) bearings, or bush, (v) water pump seal and (vi) pulley.

The bottom of the radiator is connected to the suction side of the pump. The power is transmitted to the pump spindle from a pulley mounted at the end of the crankshaft.

Seals of various designs are incorporated in the pump to prevent loss of coolant from the system.

Fan

The fan is generally mounted on the water pump pulley, although on some engines it is attached directly to the crankshaft. It serves two purposes in the cooling system of a engine.

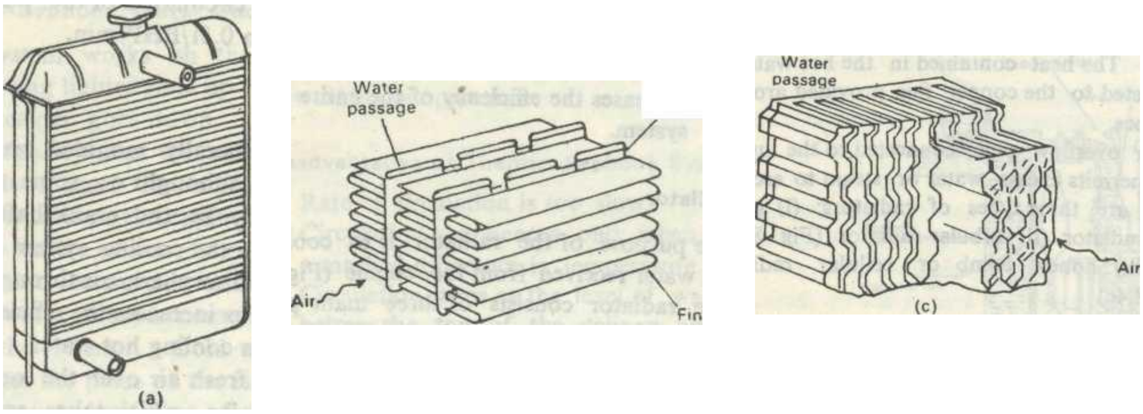
(a) It draws atmospheric air through the radiator and thus increases the efficiency of the radiator in cooling hot water.

(b) It throws fresh air over the outer surface of the engine, which takes away the heat conducted by the engine parts and thus increases the efficiency of the entire cooling system.

Radiator

The purpose of the radiator is to cool down the water received from the engine. The radiator consists of three main parts: (i) upper tank, (ii) lower tank and (iii) tubes.

Hot water from the upper tank, which comes from the engine, flows downwards through the tubes. The heat contained in the hot water is conducted to the copper fins provided around the tubes.
An overflow pipe, connected to the upper[1] tank, permits excess water or steam to escape. There are three types of radiators: (i) gilled tube radiator, (ii) tubular radiator (Fig. b)
and (iii) honey comb or cellular radiator (Fig. c)



Type of radiators

Gilled tube radiator:

This is perhaps the oldest type of radiator, although it is still in use. In this, water flows inside the tubes. Each tube has a large number of annular rings or fins pressed firmly over its outside surface.

Tubular radiator: The only difference between a gilled tubes radiator and a tubular one is that in this case there are no separate fins for individual tubes. The radiator vertical tubes pass through thin fine copper sheets which run horizontally.

Honey comb or cellular radiator: The cellular radiator consists of a large number of individual air cells which are surrounded by water. In this, the clogging of any passage affects only a small parts of the cooling surface. However, in the tubular radiator, if one tube becomes clogged, the cooling effect of the entire tube is lost.

Thermostat Valve

It is a kind of check valve which opens and closes with the effect of temperature. It is fitted in the water outlet of the engine. During the warm-up period, the thermostat is closed and the water pump circulates the water only throughout the cylinder block and cylinder head. When the normal operating temperature is reached, the thermostat valve opens and allows hot water to flow towards the radiator

Standard thermostats are designed to start opening at 70 to 75°C and they fully open at 82°C. High temperature thermostats, with permanent anti-freeze solutions (Prestine, Zerex, etc.), start opening at 80 to 90°C

and fully open at 92°C.

Types of thermostat

There are three types of thermostats: (i) bellow type, (ii) bimetallic type and (iii) pellet type.

Bellow type valve: Flexible bellows are filled with alcohol or ether. When the bellows is heated, the liquid vaporises, creating enough pressure to expand the bellows. When the unit is cooled, the gas condenses. The pressure reduces and the bellows collapse to close the valve.

Bimetallic type valve: This consists of a bimetallic strip. The unequal expansion of two metallic strips causes the valve to open and allows the water to flow in the radiator.

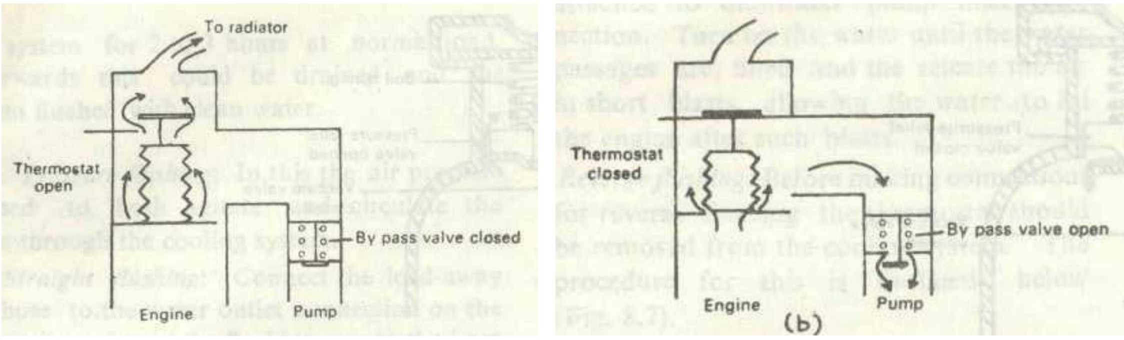
Pellet type valve: A copper impregnated wax pellet expands when heated and contracts when cooled. The pellet is connected to the valve through a piston, such that on expansion of the pellet, it opens the valve. A coil spring closes the valve when the pellet contracts.

PRESSURE COOLING SYSTEM

In the case of the ordinary water-cooling system where the cooling water is subjected to atmospheric pressure, the water boils at 212°F. But when water is boiled in a closed radiator under high pressure, the boiling temperature of water increases. The higher water temperature gives more efficient engine performance and affords additional protection under high altitude and tropical conditions for long hard driving periods. Therefore, a pressure-type radiator cap is used with the forced circulation cooling system (Fig. 8.6a). The cap is fitted on the radiator neck with an air tight seal. The pressure-release valve is set to open at a pressure between 4 and 13 psi. With this increase in pressure, the boiling temperature of water increases to 243°F (at 4 psi boiling tap 225°F and 13 psi boiling temperature 243°F). Any increase in pressure is released by the pressure release valve to the atmosphere. On cooling, the vapours will condense and a partial vacuum will be created which will result in the collapse of the hoses and tubes. To overcome this problem the pressure release valve is associated with a vacuum valve which opens the radiator to the atmosphere.

ANTI-FREEZE SOLUTIONS

In order to prevent the water in the cooling system from freezing, some chemical solutions which are known as anti-freeze solutions are mixed with water. In cold areas, if the engine is kept without this solution for some time, the water may freeze and expand leading to fractures in the cylinder block, cylinder head, pipes and/or radiators.
The boiling point of the anti-freeze solution should be as high as that of water. An ideal mixture should easily dissolve in water, be reasonably cheap and should not deposit any foreign matter in the jacket pipes and radiator.



No single anti-freeze solution satisfies all these requirements. The materials commonly used are wood

alcohol, denatured alcohol, glycerine, ethylene, glycol, propylene glycol, mixtures of alcohol and glycerine and various mixtures of other chemicals.

SERVICING & CLEANING OF COOLING SYSTEM

For smooth and trouble-free service, the cooling system should be cleaned at periodic intervals to prevent the accumulation of excessive rust and scale. The commercial cleaning compounds available must be carefully used in accordance with the manufacturers' instructions.
A general cleaning procedure is outlined below. If a considerable amount of scale and rust has accumulated, it may not be possible that cleaning alone will remove it. In that case, the radiator and engine water jackets must be flushed out with special air pressure guns.

Cooling System Cleaning Procedure

It involves the following steps.

1. Drain the system by opening the drain cocks. Prepare a solution of washing soda and water, with a ratio of 1 kg soda to 10 litres of water. Fill up this solution in the radiator and engine block and run the engine on idle load for 8 to 10 hours. Drain this solution and flush the system

with clean water.

2. In case the scale formulation is bard and cannot be completely removed with washing soda, another cleaning agent can be prepared with 40 parts of water, 5 parts of commercial hydrochloric acid and 1 part of formaldehyde. This solution is allowed to remain in the system for 2 to 3 hours at normal load. Afterwards this could be drained and the system flushed with clean water.
3. *Pressure flushing:* In this the air pressure is used to both agitate and circulate the water through the cooling system.

(a) *Straight flushing:* Connect the lead-away hose to the water outlet connection on the engine. Insert the flushing gun in the hose attached to the water pump inlet connection. Turn on the water until the water passages are filled and the release the air in short blasts, allowing the water to fill the engine after such blasts.

(b) *Reverse flushing:* Before making connections for reverse flushing the thermostat should be removed from the cooling system. The procedure for this is outlined below:

(i) *Radiator:* Disconnect the top hose of the radiator from the engine and attach a lead-away hose to the radiator. Disconnect the bottom of the radiator from water pump and attach the flushing gun. Connect water and air hoses to the gun. Turn on the water and fill the radiator to the top. Release the air in short blasts and allows the water to fill the radiator between each blast. Continue the operation until the water from the lead-away hose is clear, (ii) *Engine:* Connect the lead-away hose to the inlet of the water pump and the flushing gun to the water outlet of the pump on the cylinder head. Follow the same procedure.

LUBRICATION SYSTEM

IC. engine is made of many moving parts. Due to continuous movement of two metallic surfaces over each other, there is wearing moving parts, generation of heat and loss of power in the engine lubrication of moving parts is essential to prevent all these harmful effects.

PURPOSE OF LUBRICATION

Lubrication produces the following effects: (a) Reducing friction effect (b) Cooling effect (c) Sealing effect and (d) Cleaning effect.

(a) Reducing frictional effect: The primary purpose of the lubrication is to reduce friction and wear between two rubbing surfaces. Two rubbing surfaces always produce friction. The continuous friction produce heat which causes wearing of parts and loss of power. In order to avoid friction, the contact of two sliding surfaces must be reduced as far a possible. This can be done by proper lubrication only. Lubrication forms an oil film between two moving surfaces. Lubrication also reduces noise produced by the movement of two metal surfaces over each other.

(b) Cooling effect: The heat, generated by piston, cylinder, and bearings is removed by lubrication to a great extent. Lubrication creates cooling effect on the engine parts.

(c) Sealing effect: The lubricant enters into the gap between the cylinder liner, piston and piston rings. Thus, it prevents leakage of gases from the engine cylinder.

(d) Cleaning effect: Lubrication keeps the engine clean by removing dirt or carbon from inside of the engine along with the oil.

Lubrication theory: There are two theories in existence regarding the application of lubricants on a surface: (i) Fluid film theory and (ii) Boundary layer theory.

(i) **Fluid film theory:** According to this theory, the lubricant is, supposed to act like mass of globules, rolling in between two surfaces. It produces a rolling effect, which reduces friction.

(ii) **Boundary layer theory:** According to this theory, the lubricant is soaked in rubbing surfaces and forms oily surface over it. Thus the sliding surfaces are kept apart from each other, thereby reducing friction.

TYPES OF LUBRICANTS

Lubricants are obtained from animal fat, vegetables and minerals Lubricants made of animal fat, does not stand much heat. It becomes waxy and gummy which is not very suitable for machines.

Vegetable lubricants are obtained from seeds, fruits and plants. Cottonseed oil, olive oil, linseed oil and castor oil are used as lubricant in small Simple machines.

Mineral lubricants are most popular for engines and machines. It is obtained from crude petroleum found in nature. Petroleum lubricants are less expensive and suitable for internal combustion engines. A good lubricant should have the following qualities:

1. It should have sufficient viscosity to keep the rubbing surfaces apart
2. It should remain stable under changing temperatures.
3. It should keep lubricated pans clean.
4. It should not corrode metallic surfaces.

ENGINE LUBRICATING SYSTEM

The lubricating system of an engine is an arrangement of mechanism and devices which maintains supply of lubricating oil to the rubbing surface of an engine at correct pressure and temperature.

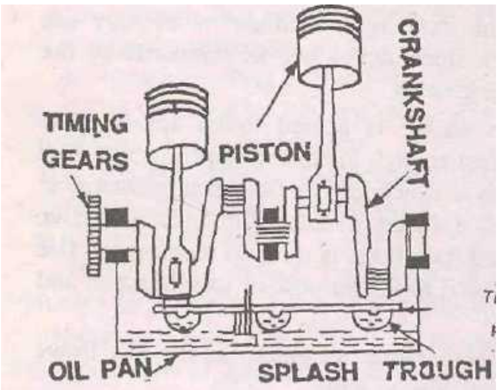
The parts which require lubrication are: (i) cylinder walls and piston (ii) piston pin (iii) crankshaft and connecting rod bearings (iv) camshaft bearings (v) valves and valve operating mechanism (vi) cooling fan (vii) water pump and (viii) ignition mechanism.

There are three common systems of lubrication used on stationary engines, tractor engines and automobiles:

(i) Splash system (ii) Forced feed system and (iii) Combination of splash and forced feed system.

SPLASH SYSTEM

In this system, there is an oil trough, provided below the connecting rod. Oil is maintained at a uniform level in the oil trough. This is obtained by maintaining a continuous flow of oil from the oil sump or reservoir into a splash pan, which has a depression or a trough like arrangement under each connecting rod. This pan receives its oil supply from the oil sump either by means of a gear pump or by gravity. A dipper is provided at the lower end of the connecting rod. This dipper dips into to oil trough and splashes oil out of the pan. The splashing action of oil maintains a fog or mist of oil that drenches the inner parts of the engine such as bearings, cylinder walls, pistons, piston pins, timing gears etc.

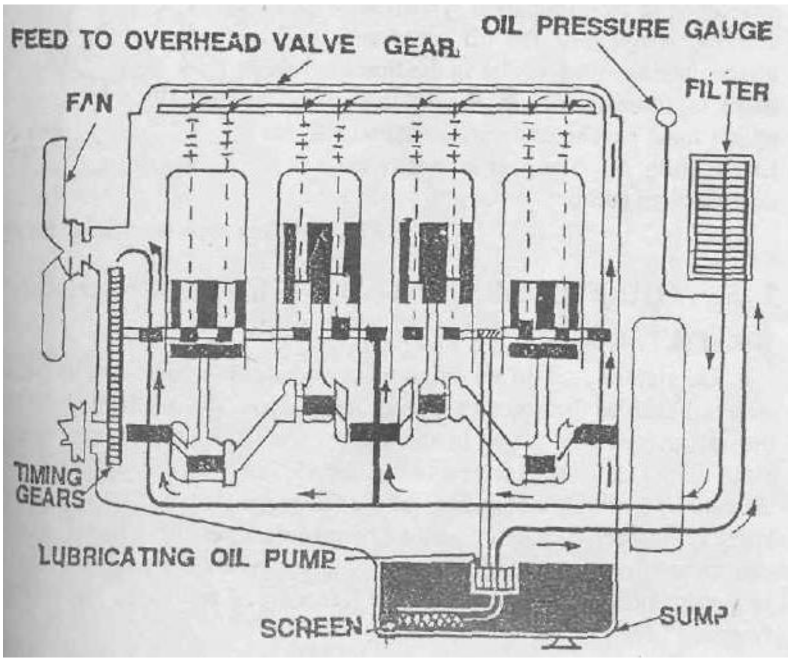


Splash lubrication system

This system is usually used on single cylinder engine with closes crankcase. For effective functioning of the engine, proper level of oil maintained in the oil pan.
Lubrication depends largely upon the size of oil holes and clearances. This system is very effective if the oil is clean and undiluted. Its disadvantages are that lubrication is not very uniform and when the rings are worn, the oil passes the piston into combustion chamber, causing carbon deposition, blue smoke and spoiling the plugs. There is every possibility that oil may become very thin through crankcase dilution. The worn metal, dust and carbon may be collected in the oil chamber and be carried to different parts of the engine, causing wear and tear.

FORCED FEED SYSTEM

In this system, the oil is pumped directly lo the crankshaft, connecting rod, piston pin, timing gears and camshaft of the engine through suitable paths of oil. Usually the oil first enters the main gallery, which may be a pipe or a channel in the crankcase casting. From this pipe, it goes to each of the main bearings through holes. From main bearings, it goes to big end bearings of connecting rod through drilled holes in the crankshaft. From there, it goes to lubricate the walls, pistons and rings. There is separate oil gallery to lubricate timing gears. Lubricating oil pump is a positive displacement pump, usually gear type or vane' type. The oil also goes to valve stem and rocker arm shaft under pressure through an oil gallery.

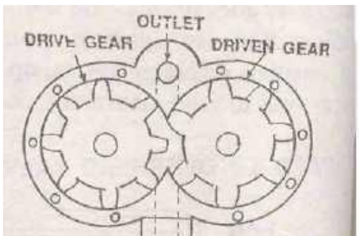


Forced feed lubrication system

The excess oil comes back from the cylinder head to the crankcase. The pump discharges oil into oil pipes, oil galleries or ducts, leading different parts of the engine. This system is commonly used on high speed multi-cylinder engine in tractors, trucks and automobiles.

COMBINATION OF SPLASH AND FORCED FEED SYSTEM In this system, the engine component, which are subjected to very heavy load are lubricated under forced pressure, such as main bearing connecting rod bearing and camshaft bearing. The rest of the parts like cylinder liners, cams, tappets etc are lubricated by splashed oil.

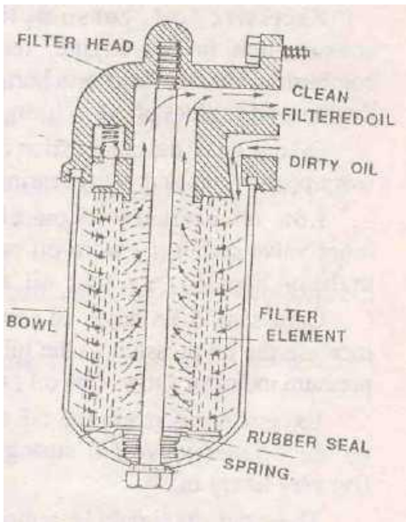
Oil pump: Oil pump is usually a gear type pump, used to force oil into the oil pipe. The pump is driven by the camshaft of t engine. The lower end of the pump extends down into the crankcase which is covered with a screen to check foreign particles. A portion of the oil forced to the oil filter and the remaining oil goes to lubricate various par of the engine. An oil pressure gauge fitted in the



line, indicates the oil pressure in the lubricating system. About 3 kg/sq cm (45 psi) pressure is developed in the lubrication system of a tractor engine, [f the oil pressure gauge indicates no pressure in the line, there is some defect in the system which must be checked immediately. Lubricating oil pump is a positive displacement pump.

OIL FILTER: Lubricating oil in an engine becomes contaminated with various materials such as dirt, metal particles and carbon. Oil filler removes the dirty elements of the oil in an effective way. It is a type of

strainer using cloth, paper, felt, wire screen or similar elements. Some oil filter can be cleaned by washing, but in general old filters are replaced by new filters at specified interval of time prescribed by manufacturers. Wearing of parts, oil consumption and operating cost of an engine can be considerably reduced by proper maintenance of oil filters. Oil filters are of two types: (i) Full-flow filter and (ii) By-pass filler.



(i) Full flow filter: In this filter the entire quantity of oil is forced to circulate through it before it enters the engine. A spring loaded valve is usually fitted in the filter as a protection device against oil starvation in case of filter getting clogged. Filter element consists of felt, cloth, paper and plastic. All these elements are replaceable and should be changed after the recommended period.

(ii) By pass filter: In this type of filter, the supply lines are from the pump and are connected to permit only a part of the oil. Through the filter the balance oil reaches directly to the engine parts. Over a period of operation, all the oil in the crankcase passes through the filter.

Oil pressure gauge: Oil pressure gauge is used to indicate the oil pressure in the oil lines. It serves to warn the operator of any irregularity in the system.

Crankcase breather: The engine crankcase is always fitted with some kind of breather, connecting the space above the oil level with the outside atmosphere. The purpose of the breather is to prevent building up pressure in the crankcase.

Relief valve: Relief valve is provided to control the quantity of oil circulation and to maintain correct pressure in the lubricating system.

TROUBLES IN LUBRICATION SYSTEM

There are a few common troubles in lubrication system such as: (1) Excessive oil consumption (2) Low oil pressure and (3) Excessive oil pressure-

Excessive oil consumption: When there is excessive oil consumption in the engine, the reasons arc : (a) more oil goes to combustion chamber and gets burnt (b) some leakage occurs in some part of - the line and (c) loss of oil in form of vapour through ventilating system. Oil can enter the combustion chamber through rings and cylinder walls, worn piston rings and worn bearings.

Low oil pressure: Low oil pressure can result due to: (i) weak relief valve spring (ii) worn oil pump (iii) cracked oil line (iv) obstruction in the oil lines (v) very thin oil and (vi) worn out bearings.

Care should be taken to remove these defects as far as possible to increase the oil pressure in the lubricating system. Sometimes defective oil pressure indicator shows low oil pressure. This should be checked.

Excessive oil pressure: Excessive oil pressure may result due to : (i) stuck relief valve (ii) strong valve spring (iii) clogged oil line and (iv) very heavy oil.

These defects should be removed to reduce the excessive oil pressure in the lubricating system. Sometimes defective oil pressure indicator records high oil pressure. Care should be taken to check this defect.

CARE AND MAINTENANCE OF LUBRICATION SYSTEM

The following are few suggestions for good lubrication system:

- A good design of oil circulation system should be chosen.
- Correct grade of lubricant ensures long and trouble free service.
- Oil should be maintained at desired level in the oil chamber.
- Oil should be cleaned regularly and after specified period of use, old filters should be replaced by new filters.
- Connections, pipings, valves and pressure gauge should be checked regularly.
- Oil should be changed regularly after specified interval of time. Before putting the new oil, the crankcase should be cleaned and flushed well with a flushing oil.
- Precautions should be taken to keep the oil free from dust and water.

Hybrid Electrical Vehicles

Introduction

A hybrid electric vehicle (HEV) has two types of energy storage units, electricity and fuel. Electricity means that a battery (sometimes assisted by ultracaps) is used to store the energy, and that an electromotor (from now on called *motor*) will be used as traction motor.
Fuel means that a tank is required, and that an Internal Combustion Engine (ICE, from now on called *engine*) is used to generate mechanical power, *or* that a fuel cell will be used to convert fuel to electrical energy. In the latter case, traction will be performed by the electromotor only. In the first case, the vehicle will have both an engine and a motor.

- Depending on the drive train structure (how motor and engine are connected), we can distinguish between parallel, series or combined HEVs. This will be explained in paragraph 1.
- Depending on the share of the electromotor to the traction power, we can distinguish between mild or micro hybrid (start-stop systems), power assist hybrid, full hybrid and plug-in hybrid. This will be explained in paragraph 2.
- Depending on the nature of the non-electric energy source, we can distinguish between combustion (ICE), fuel cell, hydraulic or pneumatic power, and human power. In the first case, the ICE is a spark ignition engines (gasoline) or compression ignition direct injection (diesel) engine. In the first two cases, the energy conversion unit may be powered by gasoline, methanol, compressed natural gas, hydrogen, or other alternative fuels.

Motors are the "work horses" of Hybrid Electric Vehicle drive systems. The electric traction motor drives the wheels of the vehicle. Unlike a traditional vehicle, where the engine must "ramp up" before full torque can be provided, an electric motor provides full torque at low speeds. The motor also has low noise and high efficiency. Other characteristics include excellent "off the line" acceleration, good drive control, good fault tolerance and flexibility in relation to voltage fluctuations.
The front-running motor technologies for HEV applications include PMSM (permanent magnet synchronous motor), BLDC (brushless DC motor), SRM (switched reluctance motor) and AC induction motor.
A main advantage of an electromotor is the possibility to function as generator. In all HEV systems, mechanical braking energy is regenerated.
The max. operational braking torque is less than the maximum

traction torque; there is always a mechanical braking system integrated in a car.

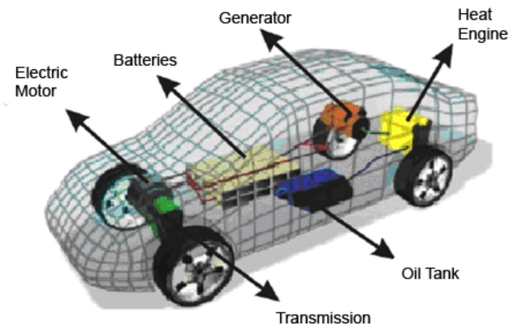
The battery pack in a HEV has a much higher voltage than the SIL automotive 12 Volts battery, in order to reduce the currents and the I^2R losses.

Accessories such as power steering and air conditioning are powered by electric motors instead of being attached to the combustion engine. This allows efficiency gains as the accessories can run at a constant speed or can be switched off, regardless of how fast the combustion engine is running.
Especially in long haul trucks, electrical power steering saves a lot of energy.

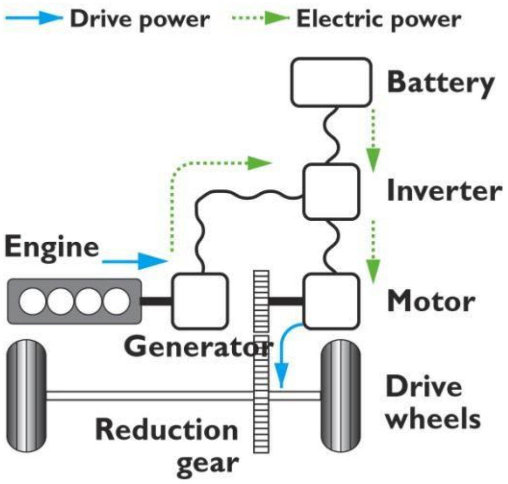
1. Types by drivetrain structure

Series hybrid

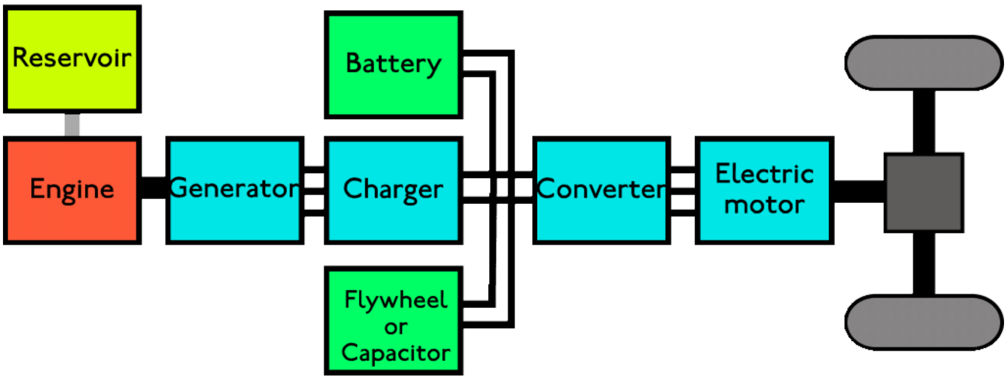
In a series hybrid system, the combustion engine drives an electric generator (usually a three-phase alternator plus rectifier) instead of directly driving the wheels. The electric motor is the only means of providing power to the wheels. The generator both charges a battery and powers an electric motor that moves the vehicle. When large amounts of power are required, the motor draws electricity from both the batteries and the generator.



Series hybrid configurations already exist a long time: diesel-electric locomotives, hydraulic earth moving machines, diesel-electric power groups, loaders.



Structure of a series hybrid vehicle (below with flywheel or ultracaps as peak power unit)

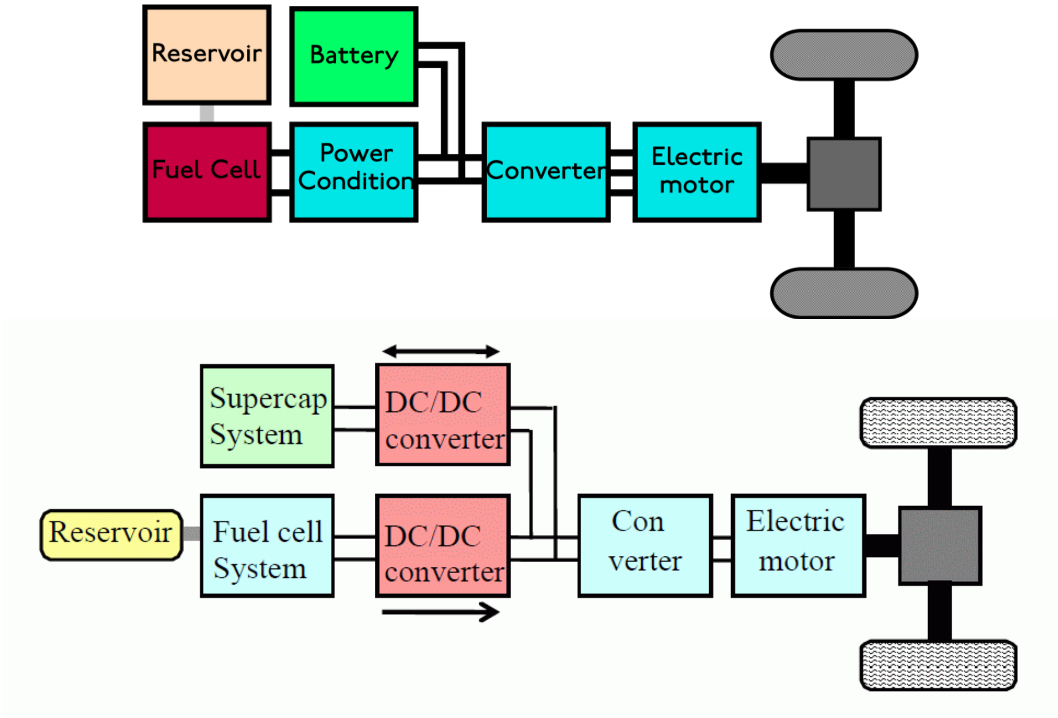


Series hybrids can be assisted by ultracaps (or a flywheel: KERS=Kinetic Energy Recuperation System), which can improve the efficiency by minimizing the losses in the battery. They deliver peak energy during acceleration and take regenerative energy during braking. Therefore, the ulracaps are kept charged at low speed and almost empty at top speed. Deep cycling of the battery is reduced, the stress factor of the battery is lowered.

A complex transmission between motor and wheel is not needed, as electric motors are efficient over a wide speed range. If the motors are attached to the vehicle body, flexible couplings are required.

Some vehicle designs have separate electric motors for each wheel. Motor integration into the wheels has the disadvantage that the unsprung mass increases, decreasing ride performance. Advantages of individual wheel motors include simplified traction control (no conventional mechanical transmission elements such as gearbox, transmission shafts, differential), all wheel drive, and allowing lower floors, which is useful for buses. Some 8x8 all-wheel drive military vehicles use individual wheel motors.

A fuel cell hybrid electric always has a series configuration: the engine-generator combination is replaced by a fuel cell.



Structures of a fuel cell hybrid electric vehicle

Weaknesses of series hybrid vehicles:

- The ICE, the generator and the electric motor are dimensioned to handle the full power of the vehicle. Therefore, the total weight, cost and size of the powertrain can be excessive.
- The power from the combustion engine has to run through both the generator and electric motor. During long-distance highway driving, the total efficiency is inferior to a conventional transmission, due to the several energy conversions.

Advantages of series hybrid vehicles:

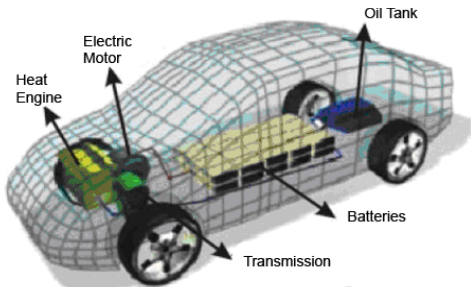
- There is no mechanical link between the combustion engine and the wheels. The engine-generator group can be located everywhere.
- There are no conventional mechanical transmission elements (gearbox, transmission shafts).
Separate electric wheel motors can be implemented easily.
- The combustion engine can operate in a narrow rpm range (its most efficient range), even as the car changes speed.

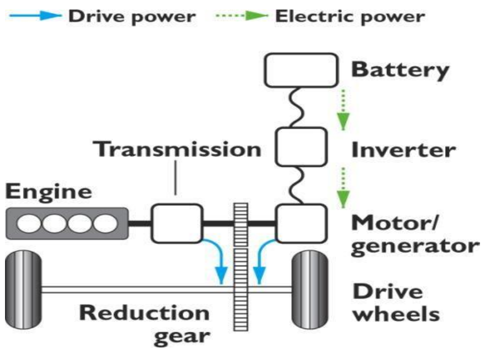
- Series hybrids are relatively the most efficient during stop-and-go city driving.

Example of SHEV: Renault Kangoo.

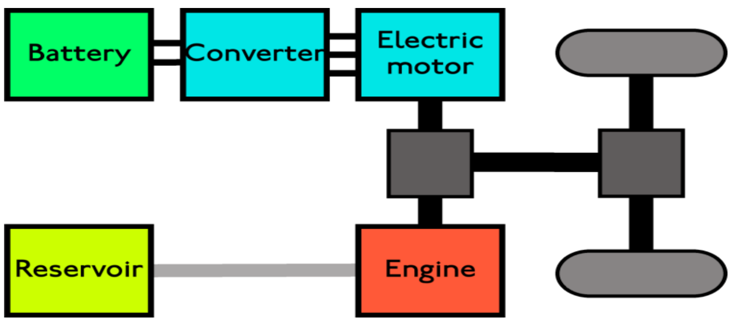
Parallel hybrid

Parallel hybrid systems have both an internal combustion engine (ICE) and an electric motor in parallel connected to a mechanical transmission.



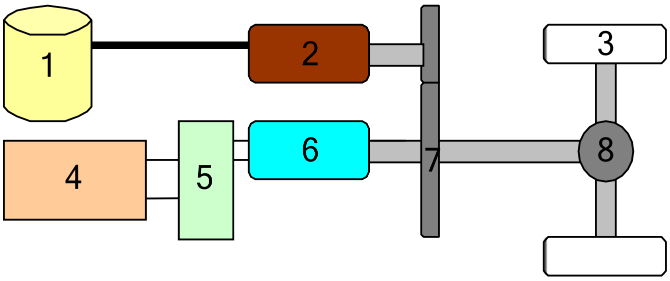


Structure of a parallel hybrid electric vehicle



Most designs combine a large electrical generator and a motor into one unit, often located between the combustion engine and the transmission, replacing both the conventional starter motor and the alternator (see figures above). The battery can be recharged during regenerative breaking, and during cruising (when the ICE power is higher than the required power for propulsion). As there is a fixed mechanical link between the wheels and the motor (no clutch), the battery cannot be charged when the car isn't moving.

When the vehicle is using electrical traction power only, or during brake while regenerating energy, the ICE is not running (it is disconnected by a clutch) or is not powered (it rotates in an idling manner).



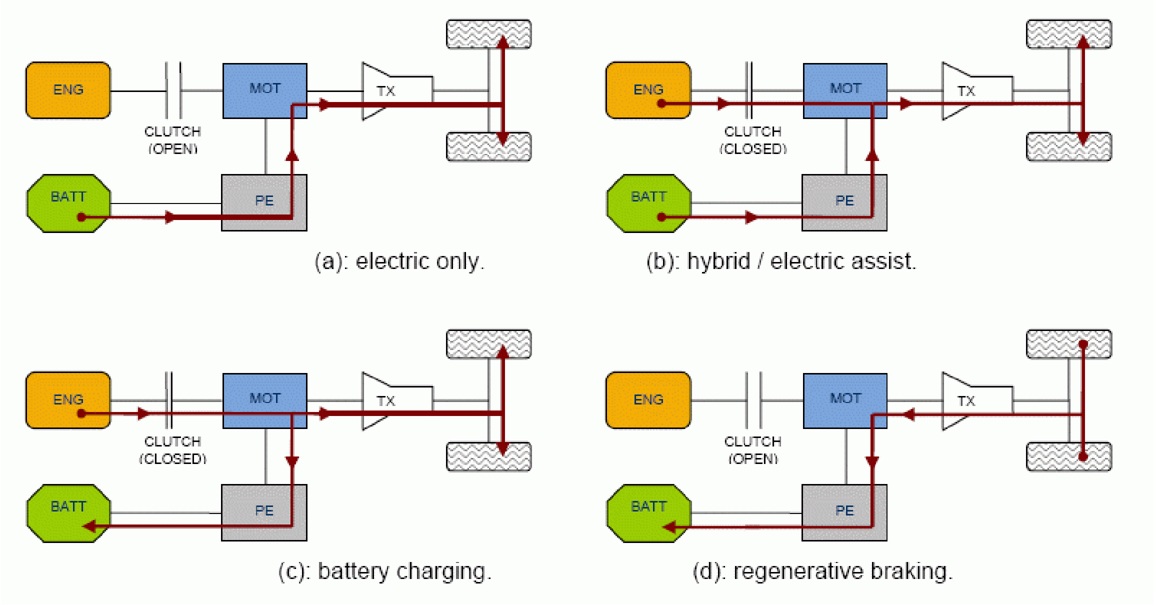
1: Fuel tank
2: Engine
3: Wheels
4: Battery
5: Converter
6: Electric Motor
7: Reduction gear
8: Differential

$$\omega_8 = \omega_6 = \omega_2 / x2$$

$$T8 = \frac{T_6}{\eta_6} + \frac{x_2 \cdot T_2}{\eta_2}$$

Operation modes:

The parallel configuration supports diverse operating modes:



Some typical modes for a parallel hybrid configuration PE = Power electronics
TX = Transmission

(a) electric power only: Up to speeds of usually 40 km/h, the electric motor works with only the energy of the batteries, which are not recharged by the ICE. This is the usual way of operating around the city, as well as in reverse gear, since during reverse gear the speed is limited.

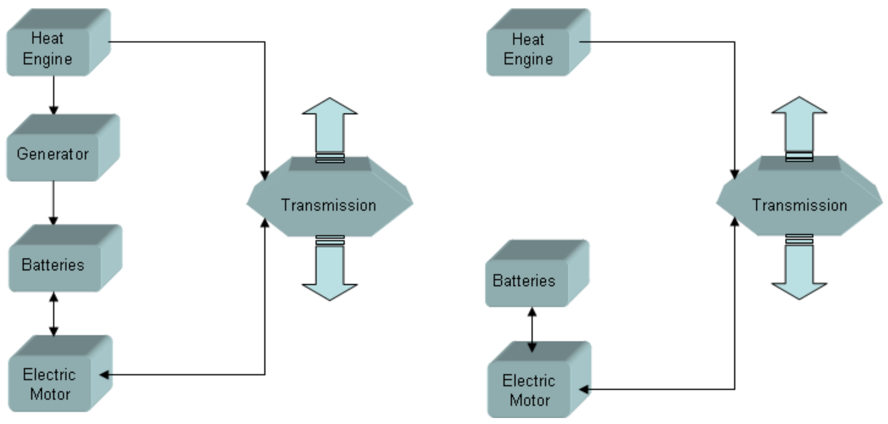
(b) ICE power only: At speeds superior to 40 km/h, only the heat engine operates. This is the normal operating way at the road.

(b) ICE + electric power: if more energy is needed (during acceleration or at high speed), the electric motor starts working in parallel to the heat engine, achieving greater power

(c) ICE + battery charging: if less power is required, excess of energy is used to charge the batteries. Operating the engine at higher torque than necessary, it runs at a higher efficiency.

(d) regenerative breaking: While braking or decelerating, the electric motor takes profit of the kinetic energy of the he moving vehicle to act as a generator.

Sometimes, an extra generator is used: then the batteries can be recharged when the vehicle is not driving, the ICE operates disconnected from the transmission. But this system gives an increased weight and price to the HEV.



A parallel HEV can have an extra generator for the battery (left) Without generator, the motor will charge the battery (right)

Weaknesses of parallel hybrid vehicles:

- Rather complicated system.
- The ICE doesn't operate in a narrow or constant RPM range, thus efficiency drops at low rotation speed.
- As the ICE is not decoupled from the wheels, the battery cannot be charged at standstill.

Advantages of parallel hybrid vehicles:

- Total efficiency is higher during cruising and long-distance highway driving.
- Large flexibility to switch between electric and ICE power
- Compared to series hybrids, the electromotor can be designed less powerful than the ICE, as it is assisting traction. Only one electrical motor/generator is required.

Example of PHEV:

Honda Civic. Honda's IMA (Integrated Motor Assist) uses a rather traditional ICE with continuously variable transmission, where the flywheel is replaced with an electric motor.

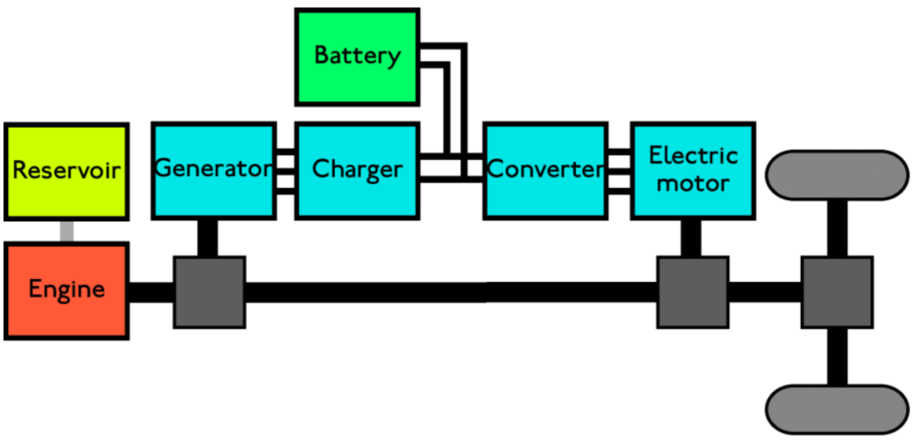
Influence of scale: a Volvo 26 ton truck (12 ton own weight, 14 ton max load) equipped with 200 kg of batteries can drive on pure electric power for 2 minutes only! Because of space constraints, it is not possible to build in more batteries.

BMW 7Series ActiveHybrid.

Combined hybrid

Combined hybrid systems have features of both series and parallel hybrids. There is a *double connection between the engine and the drive axle: mechanical and electrical*. This split power path allows interconnecting mechanical and electrical power, at some cost in complexity.

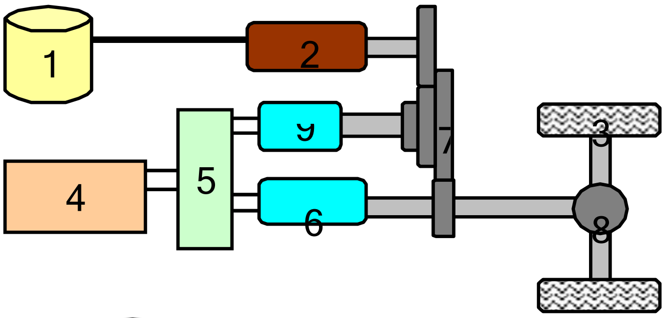
Power-split devices are incorporated in the powertrain. The power to the wheels can be either mechanical or electrical or both. This is also the case in parallel hybrids. But the main principle behind the combined system is the *decoupling of the power supplied by the engine from the power demanded by the driver*.



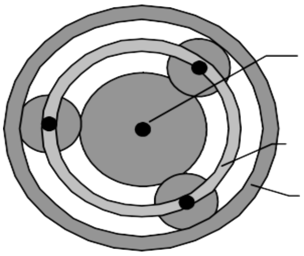
Simplified structure of a combined hybrid electric vehicle

In a conventional vehicle, a larger engine is used to provide acceleration from standstill than one needed for steady speed cruising. This is because a combustion engine's torque is minimal at lower RPMs, as the engine is its own air pump. On the other hand, an electric motor exhibits maximum torque at stall and is well suited to complement the engine's torque deficiency at low RPMs. In a combined hybrid, a smaller, less flexible, and highly efficient engine can be used. It is often a variation of the conventional Otto cycle, such as the Miller or Atkinson cycle. This contributes significantly to the higher overall efficiency of the vehicle, with regenerative braking playing a much smaller role.

At lower speeds, this system operates as a series HEV, while at high speeds, where the series powertrain is less efficient, the engine takes over. This system is more expensive than a pure parallel system as it needs an extra generator, a mechanical split power system and more computing power to control the dual system.



1: Fuel tank
2: Engine
3: Wheels
4: Battery
5: Convertors
6: MG2
7: Power Split device
8: Differential
9: MG1



S: sun

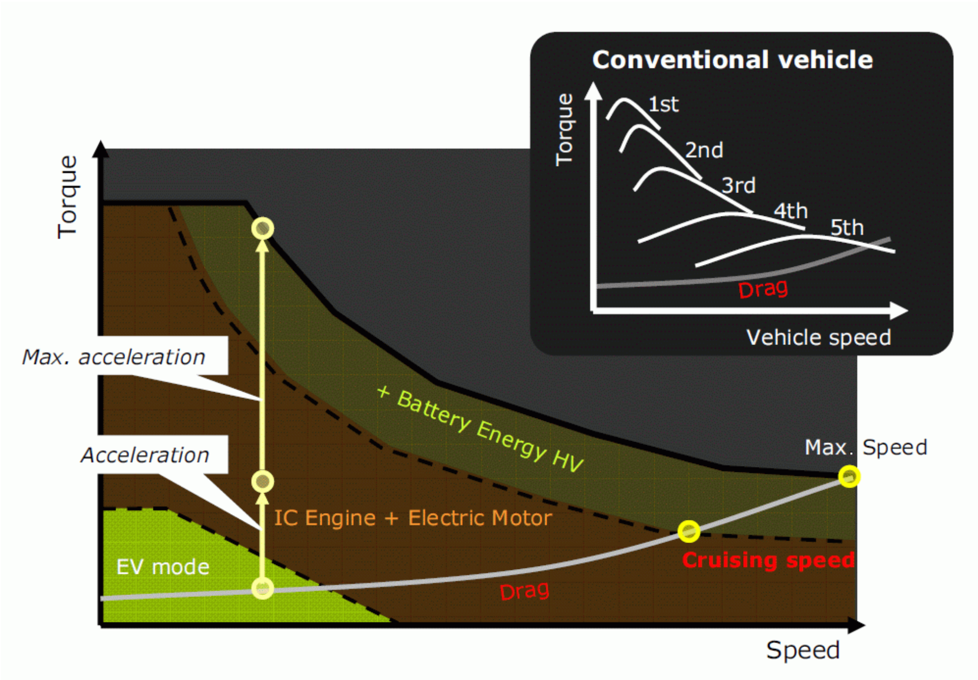
C: carrier

R: ring

$$(1+\rho)\cdot\omega_C = \omega_S + \rho\cdot\omega_R$$

$$\rho = z_R / z_S$$

Combined HEV with planetary unitas used in the Toyota Prius



Combined hybrid drive modes

<u>Weaknesses of combined hybrid vehicles:</u>

- Very complicated system, more expensive than parallel hybrid.
- The efficiency of the power train transmission is dependent on the amount of power being transmitted over the electrical path, as multiple conversions, each with their own efficiency, lead to a lower efficiency of that path (~70%) compared with the purely mechanical path (98%).

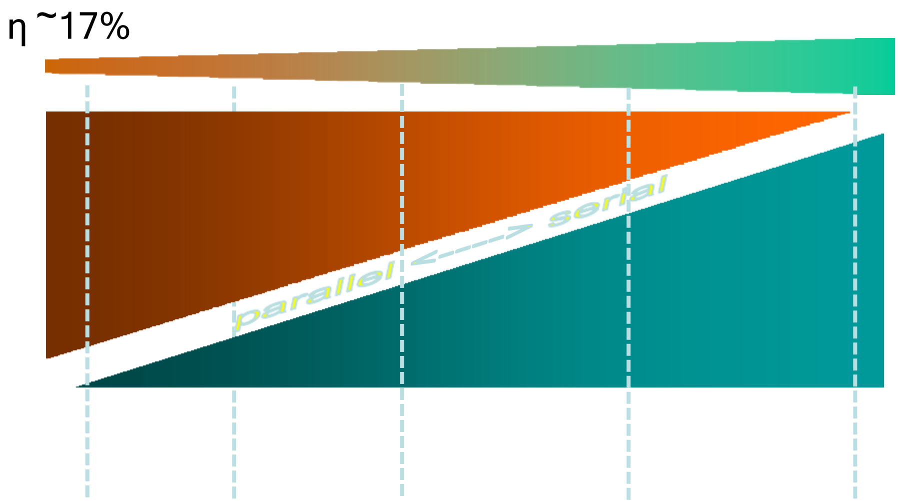
<u>Advantages of combined hybrid vehicles:</u>

- Maximum flexibility to switch between electric and ICE power
- Decoupling of the power supplied by the engine from the power demanded by the driver allows for a smaller, lighter, and more efficient ICE design.

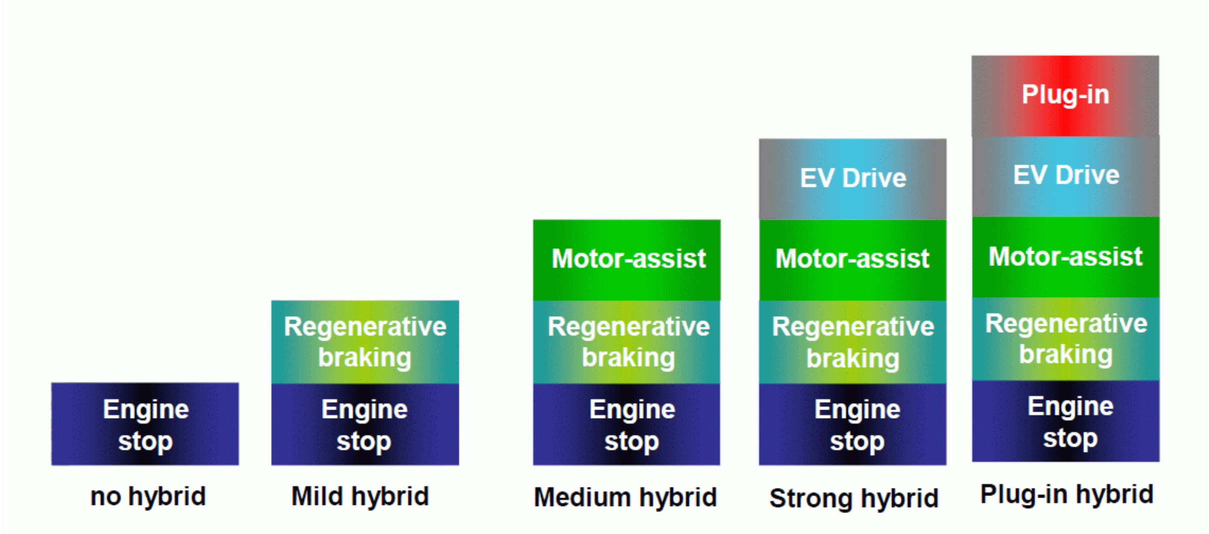
<u>Example of CHEV:</u> Toyota Prius, Auris, Lexus CT200h, Lexus RX400h.

2. Types by degree of hybridization

Parallel and combined hybrids can be categorized depending upon how balanced the different portions are at providing motive power. In some cases, the combustion engine is the dominant portion; the electric motor turns on only when a boost is needed. Others can run with just the electric system operating.



Con-ventional Vehicle	Micro-HEV	Medium/ mild-HEV	Full-HEV	Plug-In HEV	Electric Vehicle
	e.g. BMW 1er „Stop& Start“	e.g. Citroen C4 HDi	e.g. Toyota Prius, Auris	e.g. Volvo C30 Concept	



Overview of Hybrid-powertrain concepts

Strong hybrid (= full hybrid)

A full hybrid EV can run on just the engine, just the batteries, or a combination of both. A large, high-capacity battery pack is needed for battery-only operation.

<u>Examples:</u>

The Toyota Prius, Auris and Lexus are full hybrids, as these cars can be moved forward on battery power alone. The Toyota brand name for this technology is Hybrid Synergy Drive. A computer oversees operation of the entire system, determining if engine or motor, or both should be running. The ICE will be shut off when the electric motor is sufficient to provide the power.

Medium hybrid (= motor assist hybrid)

Motor assist hybrids use the engine for primary power, with a torque-boosting electric motor connected in *parallel* to a largely conventional powertrain. EV mode is only possible for a very limited period of time, and this is not a standard mode. Compared to full hybrids, the amount of electrical power needed is smaller, thus the size of the battery system can be reduced. The electric motor, mounted between the engine and transmission, is essentially a very large starter motor, which operates not only when the engine needs to be turned over, but also when the driver "steps on the gas" and requires extra power. The electric motor may also be used to re-start the combustion engine, deriving the same benefits from shutting down the main engine at idle, while the enhanced battery system is used to power accessories. The electric motor is a generator during regenerative breaking.

<u>Examples:</u>

Honda's hybrids including the Civic and the Insight use this design, leveraging their reputation for design of small, efficient gasoline engines; their system is dubbed Integrated Motor Assist (IMA). Starting with the 2006 Civic Hybrid, the IMA system now can propel the vehicle solely on electric power during medium speed cruising.

A variation on this type of hybrid is the Saturn VUE Green Line hybrid system that uses a smaller electric motor (mounted to the side of the engine), and battery pack than the Honda IMA, but functions similarly.

Another variation on this type is Mazda's e-4WD system, offered on the Mazda Demio sold in Japan. This front-wheel drive vehicle has an electric motor which can drive the rear wheels when extra traction is needed. The system is entirely disengaged in all other driving conditions, so it does not enhance performance or economy.

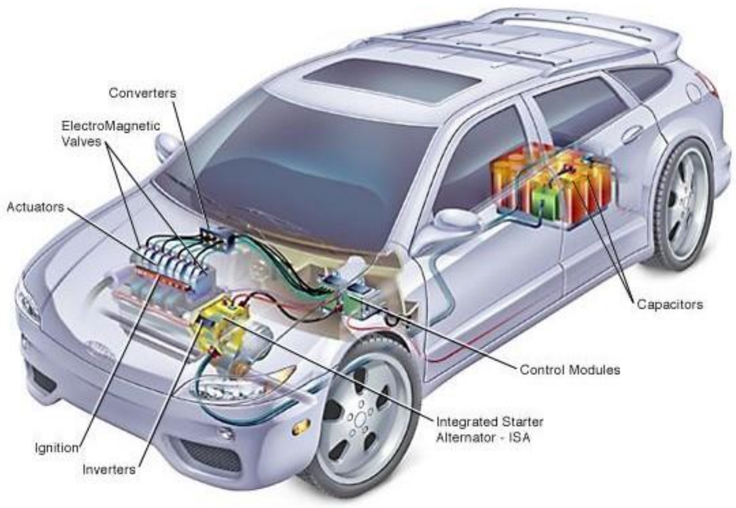
Mild hybrid / micro hybrid (= start/stop systems with energy recuperation)

Mild hybrids are essentially conventional vehicles with oversized starter motors, allowing the engine to be turned off whenever the car is coasting, braking, or stopped, yet restart quickly and cleanly.
During restart, the larger motor is used to spin up the engine to operating rpm speeds before injecting any fuel. That concept is not unique to hybrids; Subaru pioneered this feature in the early 1980s, and the Volkswagen Lupo 3L is one example of a conventional vehicle that shuts off its engine when at a stop.

As in other hybrid designs, the motor is used for regenerative braking to recapture energy. But there is no motor-assist, and no EV mode at all. Therefore, many people do not consider these to be hybrids, since there is no electric motor to drive the vehicle, and these vehicles do not achieve the fuel economy of real hybrid models.

Some provision must be made for accessories such as air conditioning which are normally driven by the engine. Those accessories can continue to run on electrical power while the engine is off.

Furthermore, the lubrication systems of internal combustion engines are inherently least effective immediately after the engine starts; since it is upon startup that the majority of engine wear occurs, the frequent starting and stopping of such systems reduce the lifespan of the engine considerably. Also, start and stop cycles may reduce the engine's ability to operate at its optimum temperature, thus reducing the engine's efficiency.



Powertrain of a mild HEV

Examples:

BMW succeeded in combining regenerative braking with the mild hybrid "start-stop" system in their current 1-series model.

Citroën proposes a start-stop system on its C2 and C3 models. The concept-car C5 Airscape has an improved version of that, adding regenerative breaking and traction assistance functionalities, and supercapacitors for energy buffering.

Plug-in hybrid (= grid connected hybrid = vehicle to grid V2G)

All the previous hybrid architectures could be grouped within a classification of *charge sustaining*: the energy storage system in these vehicles is designed to remain within a fairly confined region of state of charge (SOC). The hybrid propulsion algorithm is designed so that on average, the SOC of energy storage system will more or less return to its initial condition after a drive cycle.

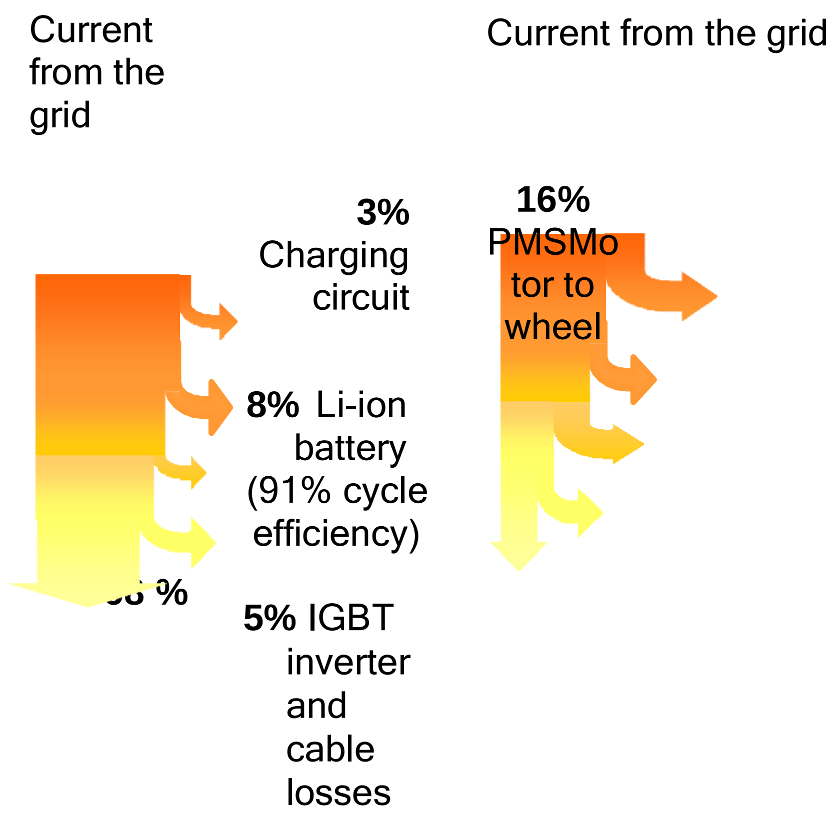
A plug-in hybrid electric vehicle (PHEV) is a *full hybrid*, able to run in electric-only mode, with larger batteries and the ability to recharge from the electric power grid. Their main benefit is that they can be gasoline-independent for daily commuting, but also have the extended range of a hybrid for long trips.

Grid connected hybrids can be designed as *charge depleting*: part of the "fuel" consumed during a drive is delivered by the utility, by preference at night. Fuel efficiency is then calculated based on actual fuel consumed by the ICE and its gasoline equivalent of the kWh of energy delivered by the utility during recharge. The "well-to-wheel" efficiency and emissions of PHEVs compared to gasoline hybrids depends on the energy sources used for the grid utility (coal, oil, natural gas, hydroelectric power, solar power, wind power, nuclear power).

In a serial Plug-In hybrid, the ICE only serves for supplying the electrical power via a coupled generator in case of longer driving distances. Plug in hybrids can be made multi-fuel, with the electric power supplemented by diesel, biodiesel, or hydrogen.

The Electric Power Research Institute's research indicates a lower total cost of ownership for PHEVs due to reduced service costs and gradually improving batteries.

Some scientists believe that PHEVs will soon become standard in the automobile industry. Plug-in vehicles which use batteries to store electric energy *outperform* cars which use hydrogen as carrier for the energy taken from the grid. The following figures indicate the efficiencies of a hydrogen fuel cell HEV and a battery powered EV.



Traction power efficiency of a plugged EV.
Left a battery powered plug in EV (Mitsubishi Lancer Evolution MIEV)) Right a Fuel Cell EV (Mercedes NECAR 3)

For typical driving cycles, the achieved efficiencies are lower. The battery powered EV achieves efficiencies in the range of 50 to 60%. The hydrogen powered EV has a total efficiency of about 13% only at those drive cycles.

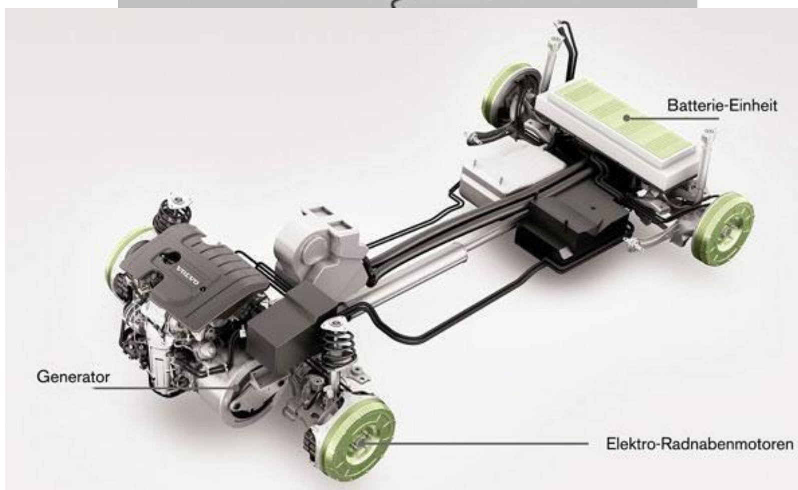
<u>Examples:</u>

Mercedes BlueZERO E-CELL PLUS (concept car): series HEV. Opel Ampera: series

HEV.

Plug-in-Hybrid Opel Ampera

The Plug-in-Hybrid Volvo C30 (concept car) is a series HEV. It has a 1,6 liter gasoline/bio-ethanol ICE. A synchronous generator charges the Li-polymer battery (ca. 100 km autonomy) when the battery SoC is lower than 30%. There are four electric wheel-motors.



Plug-in-Hybrid Volvo C30

3. Types by nature of the power source

Electric-internal combustion engine hybrid

There are many ways to create an electric-internal combustion hybrid. The variety of electric-ICE designs can be differentiated by how the electric and combustion portions of the powertrain connect (series, parallel or combined), at what times each portion is in operation, and what percent of the power is provided by each hybrid component. Many designs shut off the internal combustion engine when it is not needed in order to save energy, see 2.3.

Fuel cell hybrid

Fuel cell vehicles have a series hybrid configuration. They are often fitted with a battery or supercapacitor to deliver peak acceleration power and to reduce the size and power constraints on the fuel cell (and thus its cost). See 1.1.

Human power and environmental power hybrids

Many land and water vehicles use human power combined with a further power source. Common are parallel hybrids, e.g. a boat being rowed and also having a sail set, or motorized bicycles. Also some series hybrids exist. Such vehicles can be tribrid vehicles, combining at the same time three power sources e.g. from on-board solar cells, from grid-charged batteries, and from pedals.

The following examples don't use electrical power, but can be considered as hybrids as well:

Pneumatic hybrid

Compressed air can also power a hybrid car with a gasoline compressor to provide the power. Moteur Developpement International in France produces such air cars. A team led by Tsu-Chin Tsao, a UCLA mechanical and aerospace engineering professor, is collaborating with engineers from Ford to get Pneumatic hybrid technology up and running. The system is similar to that of a hybrid-electric vehicle in that braking energy is harnessed and stored to assist the engine as needed during acceleration.

Hydraulic hybrid

A hydraulic hybrid vehicle uses hydraulic and mechanical components instead of electrical ones. A variable displacement pump replaces the motor/generator, and a hydraulic accumulator (which stores energy as highly compressed nitrogen gas) replaces the batteries. The hydraulic accumulator, which is essentially a pressure tank, is potentially cheaper and more durable than batteries. Hydraulic hybrid technology was originally developed by Volvo Flygmotor and was used experimentally in buses from the early 1980s and is still an active area.

Initial concept involved a giant flywheel (see Gyrobus) for storage connected to a hydrostatic transmission, but it was later changed to a simpler system using a hydraulic accumulator connected to a hydraulic pump/motor. It is also being actively developed by Eaton and several other companies, primarily in heavy vehicles like buses, trucks and military vehicles. An example is the Ford F-350 Mighty Tonka concept truck shown in 2002. It features an Eaton system that can accelerate the truck up to highway speeds.