Practical No.1

AIM: To understand construction & working of various types of Boilers.

OBJECTIVES:

1. To understand working of steam boilers.
2. To differentiate between different types of boilers.
3.

OUTCOMES: To understand and appreciate significance of boilers in different fields of Engineering.

THEORY:A boiler is a closed vessel made of steel in which heat is transferred to water by combustion of fuel which vaporizes the water and is converted into steam at desired pressure and temperature. According to Indian boiler regulation (IBR), a boiler is a closed pressure vessel with capacity exceeding 22.75 liters used for generating steam under pressure. The steam produced by the boiler is used for power generation, process heating and space heating. Steam is generated at higher pressure when steam is used for power generation whereas it is generated at lower pressure when it is used for process heating and space heating.

BASIC COMPONENTS OF A BOILER

1. **Boiler shell:**It consists of one or more steel plates bent into cylindrical form and riveted or welded together. Various mountings are fitted on it.
2. **Grate:**It is the platform on which fuel is burnt. It consists of cast iron bars with spacing between them so that air for combustion can pass through them. Ash falls into ash pit constructed below the grate.
3. **Furnace:**It is a chamber above the grate and below the boiler shell where the fuel is burnt to produce hot gases. It is also called fire box.
4. **Setting:**It is made of brick. It provides support to the boiler and forms the wall of the furnace and combustion chamber. Its function is to confine heat to the boiler and forms passage for gases.
5. **Fire hole:**It is the opening from which coal is added to the furnace.
6. **Ash pit:**It is the area below the grate in which ash of burnt coal is collected.
7. **Smoke box:**The hot exhaust gases after giving the heat to the water, enter a chamber called smoke box. The gases from smoke box are released to atmosphere through the chimney. It is provided with door for cleaning the fire tubes and the smoke box.
8. **Man hole:**It is a hole provided in the boiler shell so that a workman can go inside the boiler for inspection, cleaning and maintenance. It is usually oval in shape and a door is provided to close it.
9. **Hand hole:**It is a hole provided in the boiler shell to give easy access for the purpose of cleaning the water tubes or some internal parts of the boiler. It is also provided with cover.
10. **Mud box:**It collects all the impurities present in water. It is provided at the lowest part of the boiler. Mud and other impurities are removed from mud box with the help of blow off cock.
11. **Anti-priming pipe (Steam collecting pipe):**The function of anti-priming pipe is to separate water particles from wet steam and collect dry steam from boiler.
12. **Boiler stays:**Its function is to prevent bulging of the plates due to pressure of the steam. Various types of stays are (a) direct stays, (b) diagonal or gusset stays and (c) girder stays.
13. **Heating surface:**Surface of the boiler which is exposed to hot gases on one side and to water on the other side is known as heating surface.

CLASSIFICATION OF BOILERS

Boilers are mainly classified as follows:

1. According to relative position of hot gases and water

(a) Fire tube boiler: Hot flue gases pass through the boiler tubes and water surrounds these tubes. Heat is conducted through the walls of the tubes from the hot gases to the surrounding water.

Example: Cochran, Lancashire, Locomotive boiler etc.

(b) Water tube boiler: Water flows through the tubes and hot flue gases surround them. Flue gases give up their heat to water to generate steam.

Example: Babcock and Wilcox, Stirling boiler etc.

2. According to location of furnace

(a) Internally fired: Furnace is located inside the boiler shell. Fire tube boilers are usually internally fired.

(b) Externally fired: Furnace is located outside the boiler shell. Water tube boilers are always externally fired.

3. According to the axis of the shell

(a) Vertical boiler: Axis of boiler shell is vertical. e.g. Simple vertical boiler, Cochran boiler.

(b) Horizontal boiler: Axis of boiler shell is horizontal. e.g. Lancashire boiler, locomotive boiler and Babcock and Wilcox boiler.

(c) Inclined boiler: The axis of the boiler shell is inclined.

4. According to method of water circulation

(a) Natural circulation boiler: In this boiler, circulation takes place naturally by difference in density of water. Circulation of water is by convection currents which are set up during heating of water.

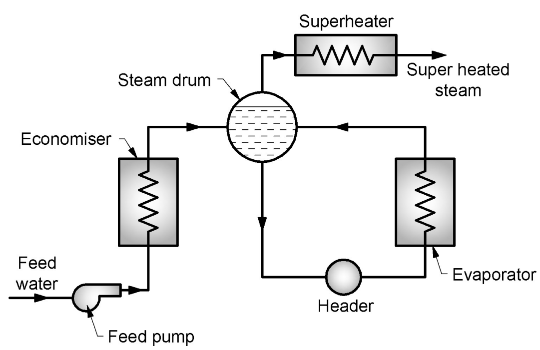


Fig. 1.1: Natural circulation boiler

As shown in Fig. 1.1 water from steam drum falls under gravity to header and then to evaporator where its temperature rises and density reduces. Steam so formed moves up due to low density. Normally low capacity boilers are natural circulation type boiler. eg. Lancashire, Babcock and Wilcox boiler.

(b) Forced circulation boiler: In this boiler, pump is used to circulate the water as shown in Fig. 1.2. High pressure and high capacity boiler use forced circulation e.g. Lamont, Benson, Velox boiler etc.

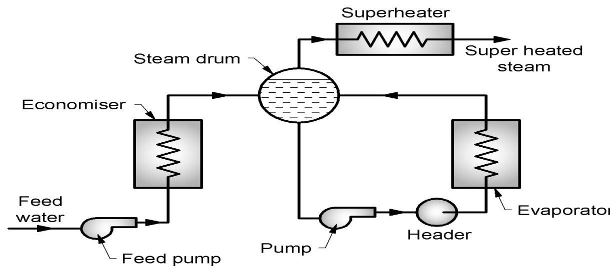


Fig. 1.2 Forced circulation boiler

5. **According to working pressure**

(a) Low pressure boiler: A boiler which generates steam below 80 bar is called low pressure boiler. e.g. Cochran, Lancashire and Babcock and Wilcox boiler etc.

(b) High pressure boiler: A boiler which generates steam above 80 bar is called high pressure boiler. e.g. Lamont, Benson, Velox boiler etc.

6. **According to use or application**

(a) Stationary boilers: These boilers are stationary and cannot be moved from one place to another place. e.g. Boilers used for power generation and industrial boilers used for process heating.

(b) Mobile boilers: These boilers are portable and can be moved from one place to another place. eg. Locomotive boilers.

7. **According to number of tubes**

(a) Single tube boiler: In this type of boiler, there is only one fire or water tube. e.g. Simple vertical boiler, Cornish boiler.

(b) Multi-tube boiler: In this type of boiler, there are two or more number of fire or water tubes. e.g. Lancashire, Babcock and Wilcox boiler.

8. **According to nature of draught used**

(a) Natural draught boiler: Chimney is used to produce the draught.

(b) Forced draught boiler: Fan is used to produce the draught.

(c) Steam jet draught boiler: Steam of the boiler is used to produce the draught.

COCHRAN BOILER:

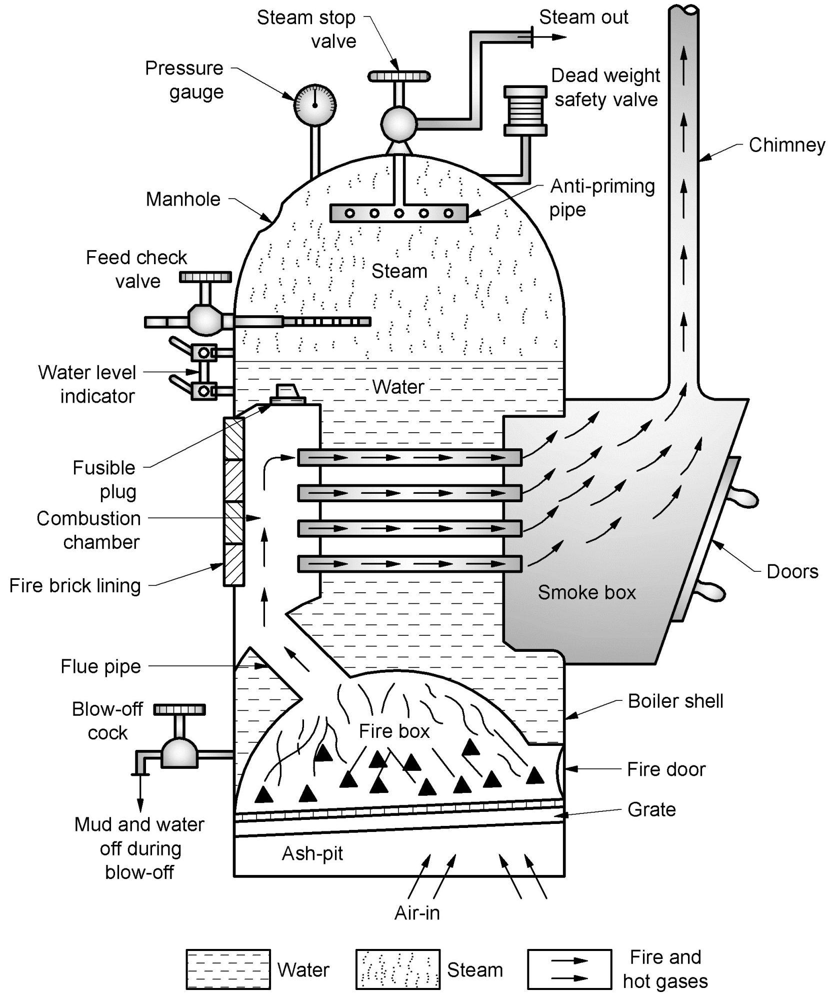


Fig. 1.3 Cochran Boiler

It is a vertical, multi tabular fire tube boiler used for small capacity steam generation. It is made in different sizes of evaporative capacities ranging from 150-3000 kg/hr and working pressure up to 20 bar. It is modification of simple vertical boiler where heating surface is increased by increasing the number of fire tubes.

Construction

(1) It consists of a cylindrical shell with its crown having hemispherical shape as shown in Fig. 1.3. The furnace is also hemispherical in shape. The hemispherical crown of the boiler shell gives maximum space and strength to withstand the pressure of steam inside the boiler.

(2) The hemispherical shape of the furnace can withstand intense heat and permits maximum absorption of radiant heat. The grate is placed at the bottom of the furnace and the ash pit is located below the grate.

(3) The coal is fed to the grate through the fire door and ash formed is collected in the ash pit located just below the grate. The furnace is connected to the combustion chamber by a flue pipe. The back of the combustion chamber is lined with fire bricks.

(4) About 160 to 170 fire tubes (generally 6.25 cm in diameter) are placed horizontally and these connect the combustion chamber and the smoke box.

(5) A man hole is provided at the top of the shell for cleaning. Number of hand holes are also provided around the outer shell for cleaning purpose. Smoke box is provided with doors for cleaning of the interior of fire tubes.

(6) Various mountings like pressure gauge, water level indicator, safety valve, fusible plug, blow off cock, steam stop valve and feed check valve are provided for proper functioning of the boiler.

Working

(1) The water is supplied to the boiler through the feed check valve. The combustion of fuel and air produces the hot gases. These gases enter through the flue pipe into the combustion chamber.
(2) The hot gases then enter horizontal fire tubes and transfer large portion of heat to the water by convection.
(3) The hot gases coming out of the fire tubes enter the smoke box and finally they are discharged to the atmosphere through chimney. The ash is collected in the ash pit below the grate.
(4) After passing through anti-priming pipe, steam is collected from top of the shell by operating the steam stop valve.

Advantages

1. It is compact, requires minimum floor area.
2. Initial cost of the boiler is low.
3. Any type of fuel can be used with this boiler.
4. All fire tubes are of same size, so one tube in spare is sufficient for replacement.

Disadvantages

1. For small size boiler, efficiency is low.
2. Steam space is less, due to which water particles along with steam may enter the steam pipe. Such steam is not desirable for power production.
3. Interiors are not readily accessible for cleaning, maintenance and repair due to vertical design.
4. It is difficult to maintain steady steam pressure as the water storing capacity is small.

Specifications

Shell diameter = 2.75 m
Height = 5.75 m
Working pressure = 6.5 bar
Heating surface area 120 m2
Steam capacity = 3500 kg/hr (Max. = 4000 kg/hr)
Efficiency = 70 to 75 %

LANCASHIRE BOILER

It is stationary, fire tube, multi-tubular (two tubes), internally fired, horizontal, natural circulation type boiler. This boiler produces steam at maximum pressure up to 16 bar with maximum evaporating capacity of 9000 kg/hr. The boiler efficiency is 50-70 %. This boiler is widely used in sugar mills, textile and chemical industry where steam is required for power generation as well as for process work.

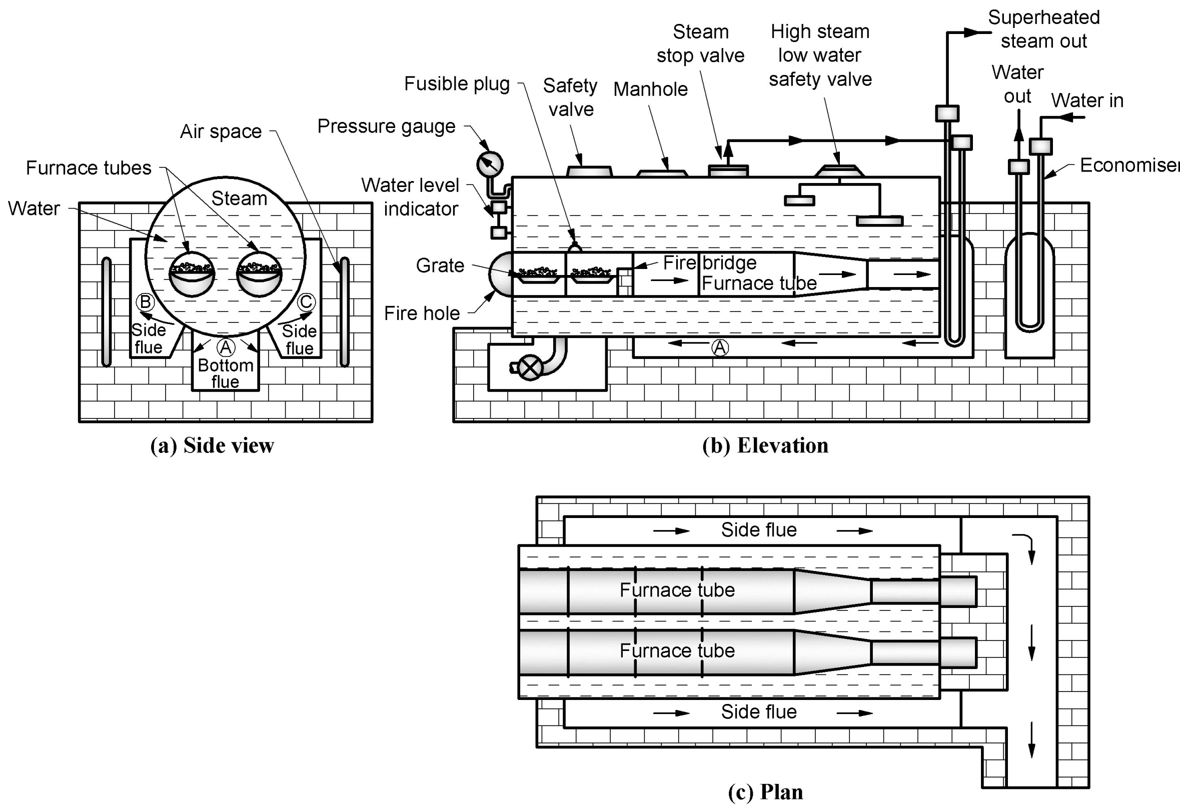


Fig. 1.4 Lancashire boiler

Construction

(1) The boiler consists of cylindrical shell placed over the brick structure. The shell is 2 to 3 m in diameter and 7 to 9 m in length. It has two internal flue tubes having diameter between 80 to 100 cm.

(2) The brick work forms one bottom flue and two side flues. Both the flue tubes which carry the hot gases lay below the water level as shown in Fig.1.4(a). Grate is provided at the front of the flue tube and coal is fed to the grate through the fire doors.

(3) A fire brick bridge is provided at the end of the grate to prevent the flow of coal and ash particles into interior of the furnace tubes. By deflecting the hot flue gases upwards, fire bridge helps in providing better heat transfer. Air space is provided in the brickwork setting to prevent cracks in the brickwork due to expansion of the walls because of heat.

(4) The diameter of flue tubes is larger at the front to accommodate grate and tapered at the end. The smaller diameter at the end increases the velocity of gases coming out of the flue pipes. Super heater is placed at the end of the main flue tube. The hot gases before entering the bottom flue are passed over the super heater tubes as shown in Fig.1.4(b).

(5) The economiser is placed at the end of side flues before exhausting the hot gases to chimney. The feed water is heated by absorbing the heat from the exhaust gases, thus leading to better boiler efficiency. Dampers in the form of doors are placed at the end of side flues to control the flow of gases.

(6) This regulates the combustion rate as well as steam generation rate. These dampers are operated by chains passing over a pulley at the front of the boiler.

(7) The boiler is fitted with usual mounting and accessories. The top view of the boiler shell has anti-priming pipe, safety valve, low water and high steam alarm and man hole.

(8) Pressure gauge and water level indicator are provided in front of the boiler and blow off cock at the bottom of the shell. Fusible plug is mounted on top of each main flue tube just above the grate.

Working

(1) Fuel is burnt on the fire grate and hot flue gases pass through the two internal fire tubes and reaches the back end of the boiler where they dip and enter into the bottom flue passage (Fig.1.4 a) 'A'.

(2) After coming out from passage 'A' at the front of the boiler, the hot flue gases then divide into two and pass through the two side flues B and C (Fig.1.4a).

(3) Then they move along the two side flues and then are discharged through the chimney (Fig.1.4.c).

(4) As the heat is transferred by two internal flue tubes, bottom flue and side flue, heat of flue gases is utilized effectively.

Advantages

1. Its heating surface area per unit volume of the boiler is considerably large.
2. It is easy to inspect and clean.
3. Less operating and maintenance cost.
4. Load fluctuations can be easily met by this boiler due to large reserve capacity of water.
5. By incorporating economiser and super heater, overall efficiency of the boiler can be increased upto 80-85 %.

Disadvantages

1. Boiler has considerable brickwork which occupies large floor area.
2. Furnace is inside the flue tubes which reduces the surface area available for burning of coal.
3. Maximum pressure is limited to 16 bar because of huge size of shell and brickwork setting.
4. Rate of generation of steam is slow due to large reservoir capacity of the boiler.

Specifications

Shell diameter = 2 to 3 m
Length of the shell = 7 TO 9 m
Working pressure = 16 bar
Steam capacity = 8000-9000 kg/hr
Efficiency = 50 to 70 %

BABCOCK ANDWILCOX BOILER

It is a horizontal, stationary, multi-tubular, externally fired, natural circulation type boiler. This boiler produces steam at maximum pressure up to 40 bar with maximum evaporating capacity of 40,000 kg/hr. Its efficiency is 60 to 80 %. It is suitable for power generation in small size thermal power plant and for process heating.

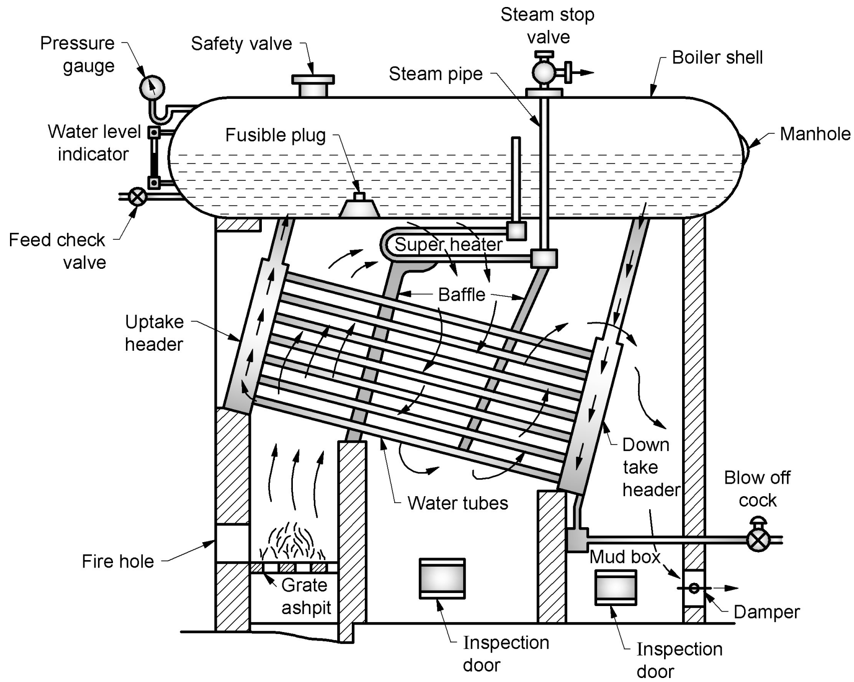


Fig. 1.5 Babcock and Wilcox boiler

Construction

(1) It consists of three main parts: boiler shell, water tubes and furnace. Boiler shell, also known as water and steam drum is made of high quality steel and lies in horizontal position.

(2) Water tubes are placed below the shell. Shell is connected by short tube with the uptake header or riser and by longer tube with down take header as shown in Fig. 1.5.

(3) Water level is kept slightly above the centre line of the drum. Water tubes of around 10 cm in diameter are connected to the uptake and down take header and kept inclined at an angle of 15° to the horizontal to promote natural circulation of water.

(4) The headers are provided with hand holes in the front of the tubes and are covered with caps. The furnace is arranged below the uptake header. A super heater is placed between the drum and water tubes. Baffle plates are provided around the water tubes to improve circulation of hot gases.

(5) A mud box is fitted to the down header. The impurities in water and mud are collected in the mud box and are blown-off periodically by blow off valve. To access the interior of the boiler it is provided with doors.

(6) This is necessary for cleaning the outer surface of the water tubes and to remove soot from the surface. The damper is placed at the inlet of the chimney to regulate the draught.

(7) Various mountings like steam pressure gauge, water level indicator, feed check valve, safety valve etc. are provided for proper functioning of the boiler.

Working

(1) Water is fed to the drum through the feed check valve. Water flows by gravity and fills the inclined tubes and the headers. Thereafter water is collected in the drum. Coal is fed to the grate through the fire door. Combustion of fuel produces flue gases.

(2) The hot gases rise upward and pass across the left side portion of the water tubes. The baffles deflect the flue gases due to which flue gases travel in zigzag manner over the water tubes and along the super heater.

(3) The flue gases finally escape to the atmosphere through chimney. The damper is fitted as shown in the Fig. 1.5 to regulate the flue gas outlet and hence the draught.

(4) Front portion of the water tubes just above the furnace are at higher temperature than the rear portion of the water tubes. When water is heated inside the tubes it becomes lighter due to decrease in density and rises up in the tube.

(5) Due to continuous heat supply, some of the water gets vaporised into steam inside the tubes and the mixture of water and steam enters the boiler drum through the uptake header. The cold water from the boiler drum comes down through downtake header and enters the lower end of the water tubes for getting heated further.

(6) This continuous circulation of water due to temperature difference of water is known as 'natural circulation'. Steam generated gets collected in the steam space above the water space in the boiler drum. Steam then enters the anti-priming pipe and passes in the superheated tubes in order to remove all water particles.

(7) Superheated steam is then taken out of the boiler through steam stop valve.

Advantages

1. Steam generation capacity and operating pressure of this boiler is high and can meet load fluctuation requirements.
2. Draught loss is minimum compared to other boilers.
3. Defective or over burnt tubes can be replaced easily.
4. Overall efficiency is higher than fire tube boilers.
5. Boiler rests over a steel structure independent of brickwork.

Specifications

Diameter of the drum = 2000 to 4000 mm

Length = 6000 to 9000 mm.

Size of the water tube = 76.2 to 101.6 mm

Size of upper header tube = 38.4 to 57.1 mm

Maximum working pressure = 42 bar

Maximum steam capacity = 40,000 kg/hr

Efficiency = 60 to 80 %

Practical No.2

AIM: To understand construction and working of different boiler mountings & accessories

THEORY: Different fittings and devices necessary for operation and safety of a boiler are known as boiler mountings. They are mounted on the boiler and are compulsory as per IBR for safe operation of the boiler.

According to Indian boiler regulation (IBR) following mountings should be fitted to the boiler.

Sr. No.	Name of mounting	Quantity (in number)
1	Safety valve	2
2	Water level indicator	2
3	Pressure gauge	1
4	Steam stop valve	1
5	Feed check valve	1
6	High steam and low water safety valve	1
7	Blow off cock	1
8	Fusible plug	1
9	Man hole	1
10	Mud hole	1

Pressure Gauge

Function : It measures and indicates the steam pressure in the boiler.
Location : It is mounted in front and top of the boiler shell so that it is easily visible to the operator.

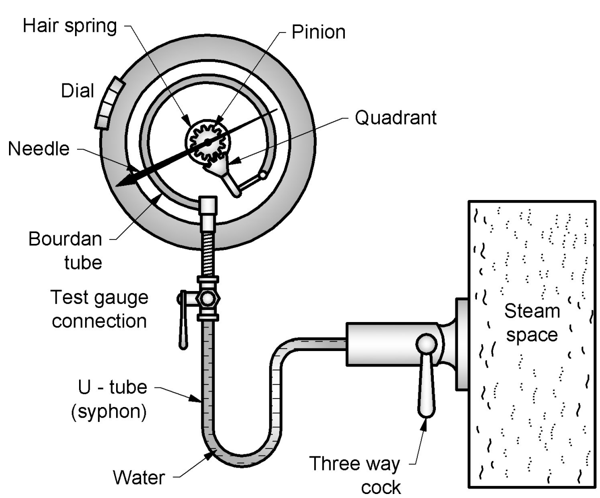


Fig. 2.1 Pressure gauge

Construction

(1) Commonly used pressure gauge known as Bourdon pressure gauge is shown in Fig. 2.1. It consists of elastic metallic tube made from high quality phosphor bronze. It is of elliptical cross-section and bend in the form of circular arc.

(2) One end of the tube is closed by plug and other end is connected to steam space of the boiler.

(3) The pressure gauge is connected to the steam space of the boiler through U-tube siphon. Siphon is filled with water which prevents the hot steam from entering the Bourdon tube and keeps the gauge comparatively cool.

(4) The closed end of the tube is attached by links to a toothed quadrant which in turn meshes with a small pinion fitted on the central spindle.

(5) A pointer as shown in Fig. 2.1 is attached to the spindle on a dial gauge. The dial gauge is usually constructed to indicate up to double the maximum working pressure.

Working

(1) The steam pressure forces the water from the siphon tube into elliptical tube and this causes the tube to become circular in cross-section and straightens the tube, causing the tube at the end to move outwards.

(2) This outward movement is magnified and transmitted by link, toothed quadrant and pinion causing the pointer to move and show pressure on the graduated dial.

(3) The movement of the free end of the elliptical tube is proportional to the difference between external and internal pressure on the tube.

(4) Since the outside pressure is atmospheric, pressure gauge measures steam pressure minus atmospheric pressure i.e. gauge pressure.

Water Level Indicator

Function : It indicates water level inside the boiler to the observer and warns the operator to take corrective action if the level of water falls below the minimum level.

Location : It is located in front of the boiler in such a position so that it is easily seen by boiler operator.

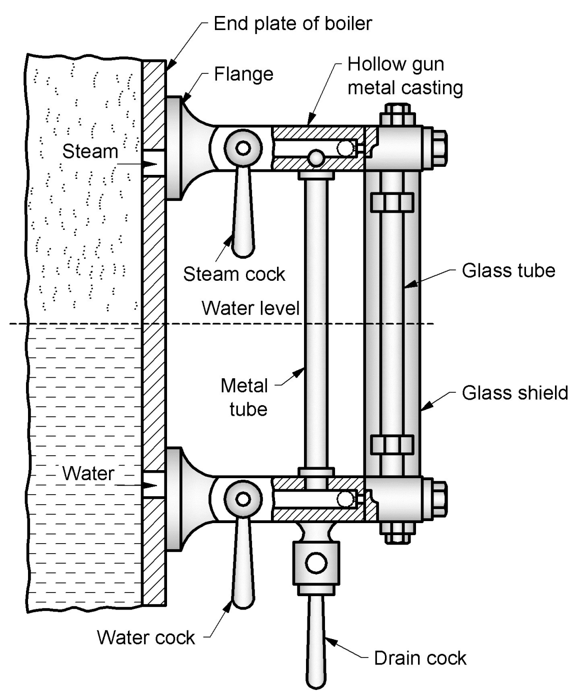


Fig. 2.2 Water level indicator

Construction

(1) Fig. 2.2 shows schematic diagram of water level indicator. Two water level indicator are provided on all the boilers.

(2) The water level indicator is attached to front plate of the boiler. It consists of a metal tube and a

glass tube with marking whose end pass through stuffing box. Glass tube is made of toughened glass so that it can withstand the boiler pressure.

(3) The upper and lower end of these tubes are connected to two hollow gun metal casting. Upper casting has steam cock and lower casting has water cock.

(4) Upper casting is bolted to the boiler plate in the steam space by flange while lower casting is bolted to the boiler plate in the water space by flange. Steam cock and water cock open in vertical position.

(5) A third cock called drain cock is provided to blow out water at intervals so that any sediment present in water do not accumulate and this ensures that steam and water passages are clear. Drain cock closes in vertical position.

(6) Glass tube is protected by glass shield made of toughened glass. Shield holds flying pieces of glass in the event the glass tube breaks, protecting the operator from being hurt. It is provided with screw caps for cleaning purpose.

Working

(1) When the steam cock and water cock are opened, the two balls provided inside the gun metal casting remain in position as shown in Fig. 2.2.

(2) So steam rushes from upper passage and water rushes from lower passage to the glass tube. The level of water inside the boiler will be same as seen in the glass tube.

(3) In case glass tube breaks accidently, water and steam simultaneously rush out through gun metal casting.

(4) Force is exerted on two balls any they are carried away by water and steam, closing the passage as shown by dotted balls in Fig. 2.2. Water and steam cocks are then closed and glass tube is replaced.

Steam Stop Valve

Function : The function of steam stop valve is to regulate the flow of steam from boiler to the steam pipe or from one steam pipe to other and to shut off the steam flow when not required.

Location : It is located to the highest part of boiler shell i.e. top of the shell.

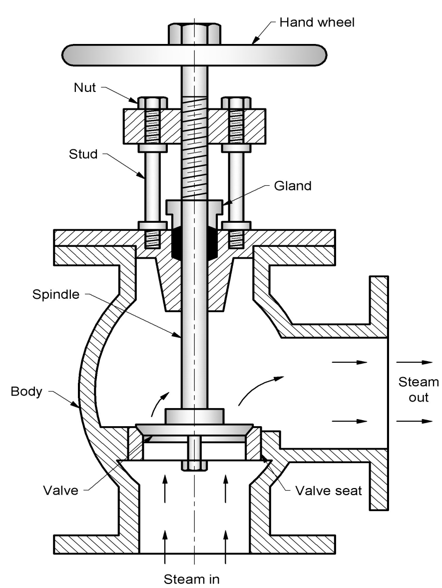


Fig. 2.3 Steam stop valve

Construction

(1) When the steam stop valve is placed on the top of shell then it is called junction valve and when it is placed near to prime mover then it is called steam stop valve. Fig. 2.3 shows schematic diagram of a steam stop valve.

(2) The main body is made of cast iron. The valve, valve seat and nut through which valve spindle

works are all made of brass for smooth working. The valve body has two flanges at right angle to each other.

(3) The stop valve is connected to the boiler through bottom flange and other is connected to the outlet. The lower end of the spindle is connected to the valve and upper end is connected to the hand wheel through a gland. The gland prevents leakage of steam.

Working

(1) The spindle is rotated by means of a hand wheel. The rotation of the spindle causes the valve to move up and down.
(2) When the hand wheel is rotated anticlockwise, the valve lifts up and steam is allowed to pass through the clearance between valve and its seat.
(3) The amount of steam passing to the steam pipe is controlled by the valve lift. When hand wheel is rotated clockwise, it closes the steam passage.
(4) When the valve touches the valve seat, flow of steam completely stops.

Feed Check Valve

Function : Its function is to supply high pressure feed water to the boiler and to prevent back flow of water from the boiler when the feed pump is not working or when feed pump pressure is less than the boiler pressure.

Location : It is fitted to the boiler shell slightly below the normal water working level of the boiler.

Construction

(1) It consists of non-return valve, water inlet pipe, water outlet pipe, spindle, gland, and hand wheel as shown in Fig. 2.4.
(2) Check valve also known as non-return valve automatically moves up and down on its seat. It operates automatically due to pressure difference of water and allows water to flow in one direction only i.e. from feed pump to boiler.
(3) Valve can be raised or lowered on the gun metal sheet with the help of spindle and hand wheel.
(4) The inlet pipe is connected with delivery pipe of feed pump while the outlet pipe is connected to the boiler.

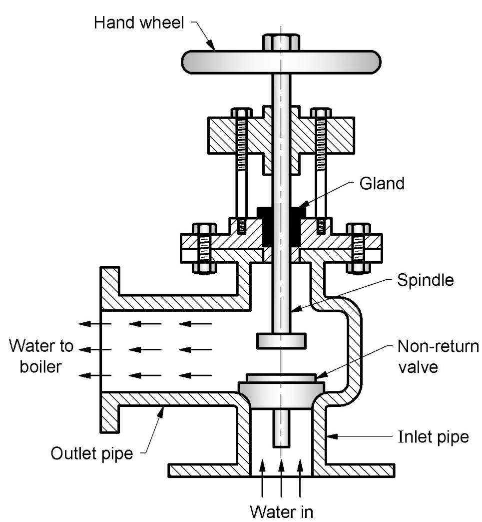


Fig. 2.4 Feed check valve

Working

(1) When the feed pump is operating, it generates pressure which is higher than the boiler pressure.
(2) This causes the non-return valve to open and allows flow of water in the boiler. The lift of the valve is controlled by moving the spindle up and down with the hand wheel. Thus the flow of water to the boiler can be controlled.
(3) In case of pump failure or when the pump is not operating, boiler pressure becomes more than

the pressure of feed water.

(4) This causes the non-return valve to rest on its seat closing the water passage and stops the return flow of water from boiler to delivery pipe of water.

Blow off Cock

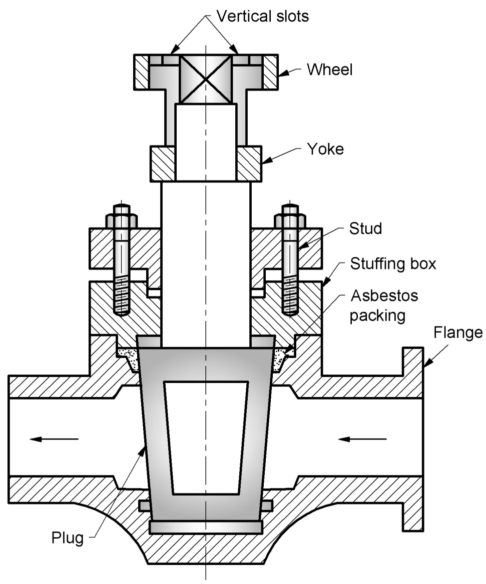


Fig. 2.5 Blow off cock

Function

It performs two functions:

1. To discharge mud, sediments and heavy deposits periodically which settle down at the bottom of the boiler while the boiler is in operation.
2. To empty the boiler for cleaning, inspection and repair.

Location:

It is fitted to the lowest part of the water space either directly on the boiler shell or to a pipe connected with the boiler.

Construction

(1) It consists of a conical gun metal plug fitted accurately in a conical casing. The plug has a slot in it. The casing consists of two flanges, one is connected to the boiler shell and other one to pipe which takes discharge out of the boiler.

(2) Casing is packed with asbestos packing in grooves around top and bottom of the plug.

(3) The shank of the plug passes through stuffing box and gland which are provided to avoid leakage of water.

(4) Yoke provided at top of shank keeps the plug in its position.

(5) Two vertical slots are provided at the top for fixing the box spanner. The plug shank can be rotated by means of box spanner.

Working

(1) When the plug is rotated, the slot in the plug is brought in line with the passage of the casing. This causes the water to flow out of the boiler.

(2) The flow of water through the boiler can be stopped by rotating the plug in such a way that solid portion of the plug comes in line with the passage of the casing as shown in Fig. 2.5.

Fusible Plug

Function

The function of the fusible plug is to put off the fire in the furnace of a boiler when the water level in the boiler falls below the safe minimum level thereby preventing an explosion which may take place due to overheating of tubes and shell.

Location

It is fitted in the crown plate of the furnace or over the combustion chamber in a fire tube boiler.

Construction

(1) Fig. 2.6 shows schematic diagram of fusible plug. It consists of hollow gun metal body ‘A’ screwed into fire box crown plate.

(2) The body has hexagonal flange to tighten it into the shell. ‘B’ is second hollow gun metal plug provided with hexagonal flange and is screwed into plug ‘A’.

(3) A third plug ‘C’ with conical top and rounded bottom, made from copper is locked with plug ‘B’ by pouring low melting point metal such as lead or tin between the groove as shown in Fig. 2.6.

(4) The inner surface of ‘B’ and outer surface of ‘C’ are grooved so as to lock the plugs ‘B’ and ‘C’ when fusible metal is poured.

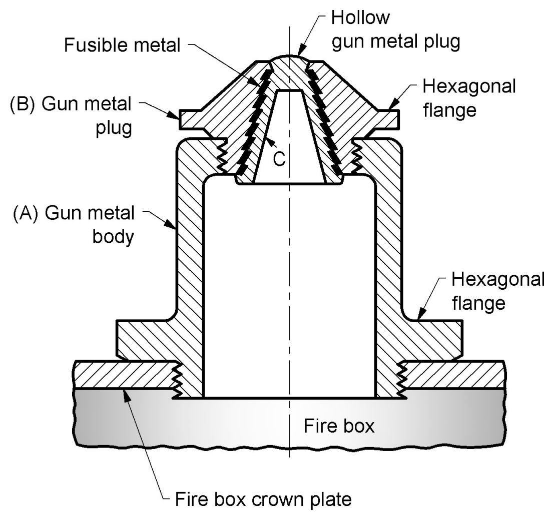


Fig. 2.6 Fusible plug

Working

(1) During normal boiler operation, fusible plug remains under water which keeps the temperature of the fusible metal below its melting point.

(2) But when the water level falls too low in the boiler, it uncovers the fusible plug.

(3) The fusible metal melts by the heat of the furnace as it gets exposed to steam space instead of water. The plug ‘C’ falls down creating a hole.

(4) The water and steam from the boiler then rushes in the furnace and fire is extinguished, thus preventing the boiler from being overheated.

Safety Valves

Function

(1) The function of safety valve is to maintain safe pressure inside the boiler.

(2) When the pressure of steam exceeds the design pressure, safety valve automatically opens and discharges the excess steam to the atmosphere, maintaining safety of the boiler.

(3) Thus the pressure of steam in the drum falls and steam escapes with an audible sound warning the boiler operator.

- **There are four types of safety valves:**
  1. Dead weight safety valve
  2. Lever loaded safety valve

3. Spring loaded safety valve
4. High steam and low water safety valve

Dead weight Safety Valve

Construction

- Fig. 2.7 shows schematic diagram of dead weight safety valve.
- It is very similar to dead weight (whistle) loaded on a pressure cooker and functions in a similar way.
- It consists of cast iron vertical pipe having a flange at the bottom for fixing it on the boiler.
- A gun metal valve seat is fixed at the pipe top on the steel pipe. A gun metal valve rests on the valve seat.
- The valve is fastened to the weight carrier.
- Dead weight of the cast iron rings enclosed in cast iron cover is placed on the weight carrier.
- The load on the valve consists of weights, weight of weight carrier and weight of the valve itself.

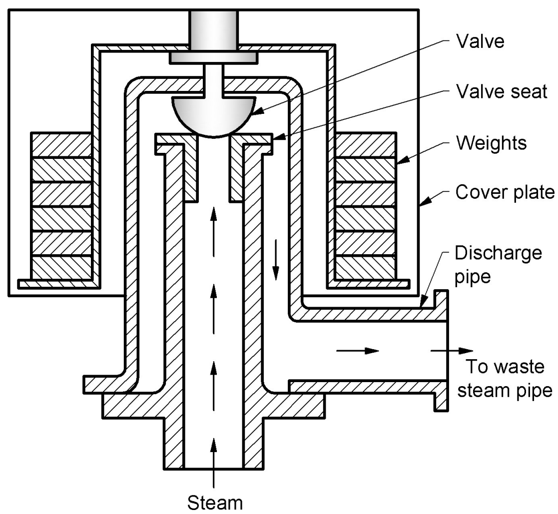


Fig. 2.7 Dead weight safety valve

Working

- When the force due to steam pressure is less than the total dead weight on the valve, valve remains closed.
- When the force due to steam pressure exceeds the total dead weight acting downward, the valve lifts up from its seat and some quantity of steam escapes to atmosphere through the pipe.
- When steam escapes, pressure inside the boiler shell reduces and valve again returns to its original position due to gravity.

Advantages

1. It is very simple in construction.
2. These valves once designed for specific pressure cannot be tampered as any added weight must be equal to total increase of steam pressure on the valve.
3. It gives satisfactory performance during operation.

Disadvantages

1. These valves are not suitable where excessive vibration and movements are experienced like in locomotive or marine boilers.
2. It is not suitable for high pressure boilers as large amount of weight is required to balance the steam pressure.

Uses

It is mainly used for low pressure, low capacity stationary boilers.

Examples: Cornish and Lancashire boilers.

Lever Loaded Safety Valve

Construction

- Fig. 2.8 shows schematic diagram of lever loaded safety valve.
- A valve rests on the valve seat which is screwed to the mounting block.
- Both valve and valve seat are made from gun metal. The mounting block is fitted on the boiler shell with the help of flange.
- One end of the lever is held by fulcrum and other end carries weight 'W' as shown in Fig. 2.8.
- The guide prevents the lateral movement of the valve and also prevents its blowing off.
- The thrust of the lever with its weight is transmitted to the valve by a short strut.

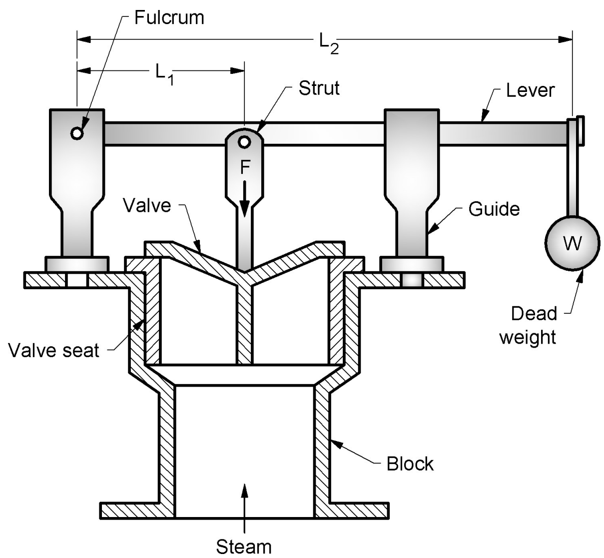


Fig. 2.8 Lever loaded valve

Working

- When the upward force due to steam pressure exceeds the load on the valve, the valve lifts from its seat and allows the steam to escape till the pressure falls back to the normal value.
- The valve then returns back to its original closed position.
- The required weight 'W' at the end of the lever for maintaining the pressure 'p' in the boiler is calculated as follows:
- Taking moment about the fulcrum, we get

$$F \times L_1 = W \times L_2$$

$$\text{or } (p \times A) \times L_1 = W \times L_2$$

where F = Downward force on valve through strut

W = Weight suspended at the end of the lever

- L_1 and L_2 are distances from the fulcrum to the valve centre and centre of weight respectively.

Uses and advantage

It is used for stationary boiler. Its advantage over dead weight safety valve is that its large dead weight is replaced by a lever with a smaller weight at its end.

Spring Loaded Safety Valve

Construction

- Fig. 2.9 shows schematic diagram of Rams bottom spring loaded safety valve which is commonly used in locomotive boiler. This valve uses spring and lever mechanism.
- It consists of cast iron body with two branch pipes. It has two separate valves of same size. These valves have their seatings in the upper ends of two hollow valve chest.
- The valves are held down on their seats by spring and lever pivots. Lever has two pivots, one pivot is forged on the lever and other is connected by a pin.
- Spring is made of round or square steel rod in helical form. Upper end of the spring is connected to the lever and the other to steam pipe block.

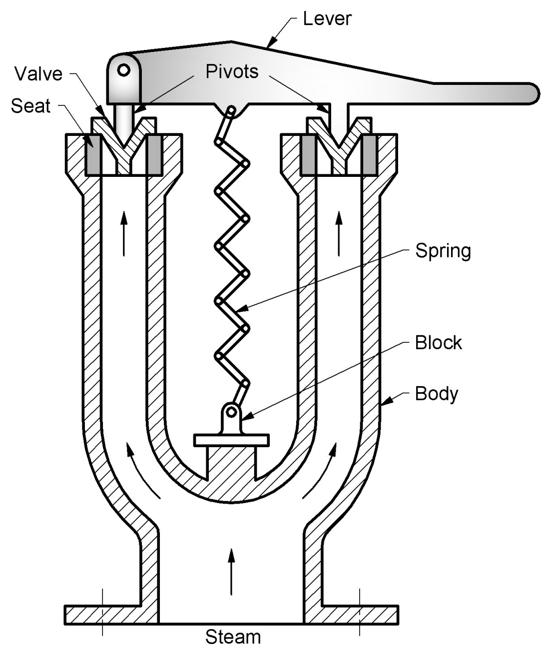


Fig. 2.9 Spring loaded valve

Working

- In the normal condition, the valve is closed as the upward force of steam is less than the downward force of the spring.
- When the pressure of steam exceeds the safe limit, it raises the valves from its seat as the upward force of steam is higher than the downward force of the spring.
- This allows the steam to escape to atmosphere till the pressure falls back to its normal value.
- The valve then returns back to its original position due to spring force.

Uses

It is used in stationary as well as mobile boilers such as locomotive and marine boilers as its operation is not affected by vibration and jerks.

High Steam and Low Water Safety Valve

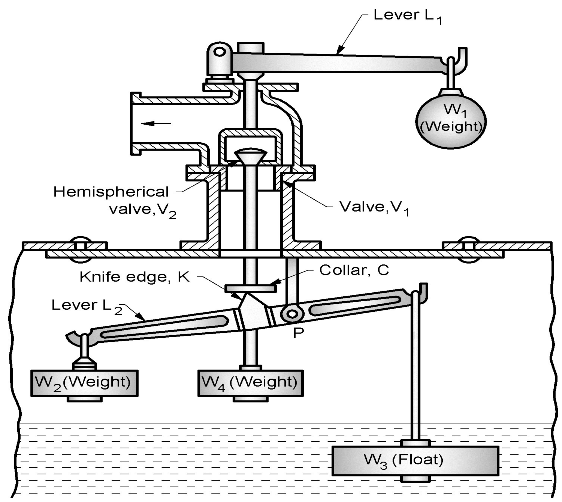


Fig. 2.10 High steam and low water safety valve

Function

It automatically blows off the excess steam when the working pressure of steam exceeds the normal pressure or when the water level in the boiler falls below the danger level.

Working

- When the pressure exceeds the normal limit, valve V_1 is lifted along with lever L_1 and valve V_2. So the steam escapes through the passage between valve seat and valve V_1 till the pressure becomes normal.
- Under normal circumstances, weight W_3 remains in water and complete system is under balance. When the water level falls below a certain level, float (weight W_3) is uncovered. This causes an increase in its weight according to Archimedes' principle which states that objects lose weight in water.
- This swings the lever causing knife edge to push collar 'C' which opens the valve V_2, thus allowing steam to escape between V_1 and V_2.
- The escaping steam makes a loud noise as it passes through the narrow opening. This noise warns the operator to start the feed pump to increase the level of water in the boiler.

Uses

This valve is used in Cornish and Lancashire boiler.

BOILER ACCESSORIES

Auxiliary parts that are required for smooth operation of a boiler and to increase the overall efficiency of the boiler are called boiler accessories. Accessories are not compulsory but optional as per Indian boiler regulation act. Different accessories are : feed pump, steam injector, economiser, exhaust steam feed water heater, superheater, air pre-heater, steam separator and steam trap.

✍ **Feed Pump**

Function

Its function is to deliver pressurised feed water to the boiler.

Location

- It is located before the feed check valve.
- **These pumps are classified as:**
  (i) Reciprocating pump – simplex, duplex and triplex
  (ii) Rotary pump

(iii) Centrifugal pump

Construction and working of Duplex reciprocating feed pump

(1) Fig. 2.11 shows schematic diagram of duplex reciprocating feed pump. Duplex pump consists of two steam cylinders and two water cylinders which are placed side by side.

(2) Each pump has one steam and one water cylinder. Steam enters from one end of steam cylinder, moves the piston and exits from the other side.

(3) A D-slide valve controls the admission and exhaust of steam. The slide valve in each cylinder steam chest is operated by the cross head on the piston rod of the opposite cylinder through an arrangement of rods and levers.

(4) The piston of steam cylinders is connected with piston of water cylinders. Movement of the piston towards the right side in water cylinder creates positive pressure on right side and negative pressure on the left side.

(5) Positive pressure opens the delivery valve and closes the suction valve on right side, hence water is delivered to the boiler through the feed check valve. When the piston changes the direction of motion, suction and delivery sides are also reversed.

(6) Duplex type reciprocating pumps are commonly used for medium size boiler. Centrifugal pumps are used for small as well as large plants.

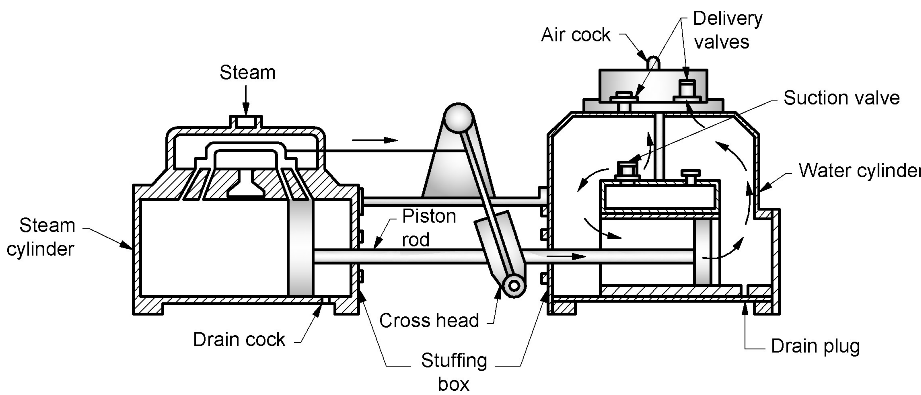


Fig. 2.11 Duplex feed pump

Economiser

Function

The function of an economiser is to heat the feed water before it is supplied to the boiler by utilizing the waste heat of flue gases.

Location

It is placed in the path of flue gases at the exit of the boiler, before the air-pre-heater and chimney.

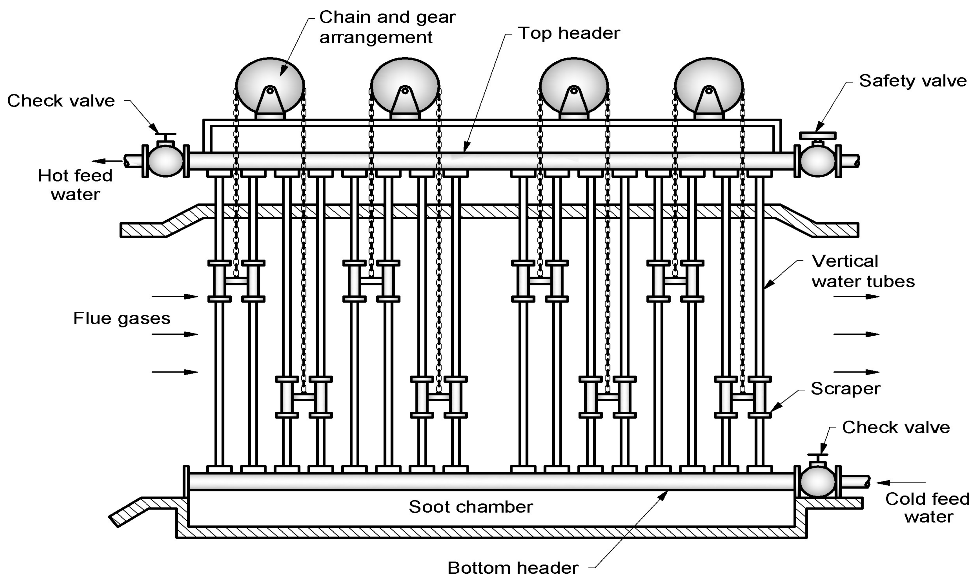


Fig. 2.12 Economiser

Construction

(1) Fig. 2.12 shows schematic diagram of Green's vertical tube economiser used in Lancashire boiler. It consists of series of vertical tubes made of cast iron.

(2) These tubes are connected at the top and bottom header. Bottom header is connected to a feed pump.

(3) A safety valve is fitted on the top header for the safety of pipes against any high pressure of water that may be developed.

(4) A blow off valve (not shown in Fig.2.12) is also fitted at the lowest point of the economiser to discharge mud or sediments present in feed water.

(5) Each vertical pipe is fitted with a scraper which moves up and down with the help of chain and gear arrangement.

Working

(1) Feed water is pumped to the bottom header by feed pump. From the header, water enters into the top header through vertical pipes. Water then enters the boiler through the feed check valve.

(2) The hot gases pass over the external surfaces of the vertical water tubes. The heat from the hot gases is given to the feed water through the tube surface.

(3) To keep the surface of the tubes clean from soot and ash deposits, scrappers are slowly moved up and down. The scrapping action on the tubes is in opposite direction i.e. when one scrapper moves up, the other goes down.

(4) The soot removed from the pipes is collected in soot chamber situated below the bottom header and is removed periodically. In case of failure of economiser, a by-pass arrangement is provided for diverting the hot flue gases directly to the chimney.

Advantages

1. It increases the boiler efficiency.
2. It reduces the temperature stresses in boiler joints, hence the life of boiler is increased.
3. It reduces the consumption of fuel.
4. It increases the evaporative capacity of the boiler.

Disadvantages

1. It increases the initial and maintenance cost of the plant.
2. It is placed in the path of flow of flue gases, so pressure drop takes place of flue gases which causes loss of draught.

Exhaust Steam Feed Water Heater

Function

The function of exhaust feed water heater is to increase the temperature of feed water before it enters the boiler by utilizing the heat from exhaust steam of steam turbine or steam from the boiler.

Location

It is located near the feed check valve.

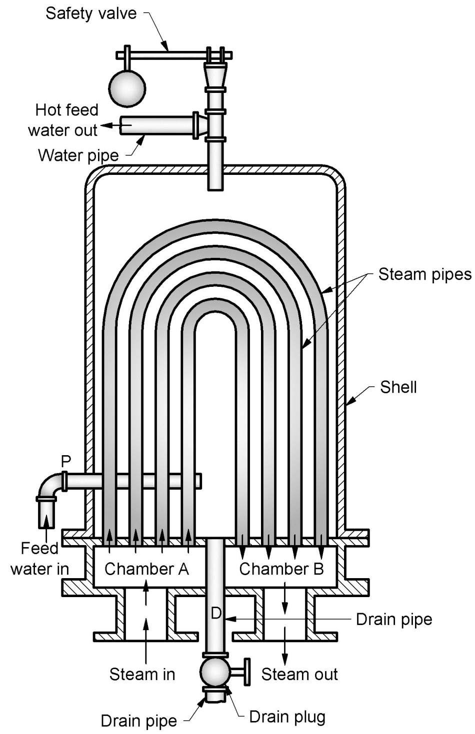


Fig. 2.13 Exhaust steam feed water heater

Construction and working

(1) It consists of cylindrical shell and series of bent U-tubes which are placed inside the shell as shown in Fig. 2.13.

(2) Exhaust steam enters into the chamber A and passes through the U-tubes and finally it is discharged from chamber B.

(3) Feed water enters into the shell through pipe P where it gets heated due to heat transfer between tubes and water.

(4) Hot water is supplied to the boiler through outlet pipelocated at the top of the shell. Any impurities deposited inside the shell is discharged through drain pipe D.

Superheater

Function

(1) The function of a superheater is to dry the wet steam and then raise the temperature of the steam above its saturation temperature by utilizing the waste heat of flue gases.

(2) During superheating of steam pressure remains constant and its volume and temperature increases.

Location

It is placed in the boiler shell or drum in the path of flue gases.

Construction

(1) Fig. 2.14 shows schematic diagram of Surgden superheater used in Cornish and Lancashire boiler. It consists of two headers and set of superheater tubes made of high quality steel in the form of U-tube.
(2) Superheater is located in the path of flue gases where the temperature of the gases is above 500°C. The superheater is located just before the gases enter the bottom flue.
(3) The amount of flue gases that passes over the superheater tubes is controlled by damper which is operated by hand wheel. Valves A, B and C are provided in the header as shown in Fig. 2.14.

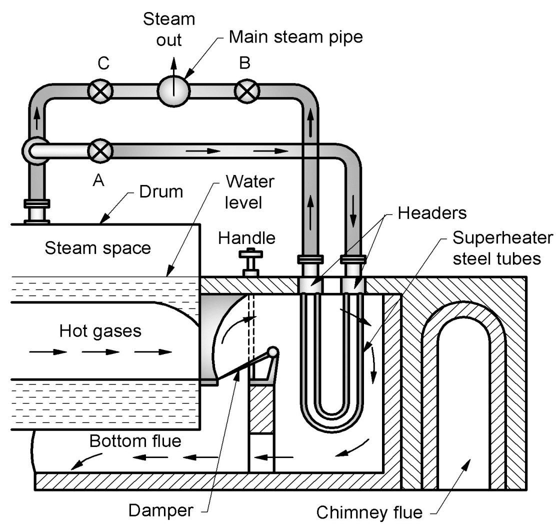


Fig. 2.14 Superheater

Working

(1) For getting the superheated steam, valves A and B are opened, valves C is closed and damper is kept open as shown in Fig. 2.14. The wet steam from the boiler enters the intake header through valve A.
(2) The steam flows through U-tube where it receives the heat from the hot flue gases and becomes superheated. The superheated steam then passes to the discharge header, valve B and then to main steam pipe.
(3) When superheated steam is not required, then valves A, B and damper are kept closed and valve C is kept open. In this case, the steam directly comes out through valve C.
(4) The amount of hot gases passing over the superheater tubes should be in proportion to the amount of superheated steam passing through the tubes and the degree of superheat required. To avoid overheating, some amount of hot gases may be diverted using damper.
(5) When the damper is horizontal hot flue gases pass directly to the bottom flue. If the damper is kept inclined, some of the flue gases will pass over the superheater tubes and remainder will pass directly to the bottom flue.

Air-preheater

Function

The function of air pre-heater is to increase the temperature of air before it enters the furnace by utilizing the heat energy from the waste flue gases.

Location

- It is placed in the path of flue gases between the economizer and the chimney.
- **The commonly used types of air pre-heater are:**
  1. Recuperative air pre-heater
  2. Regenerative air pre-heater

Construction and working

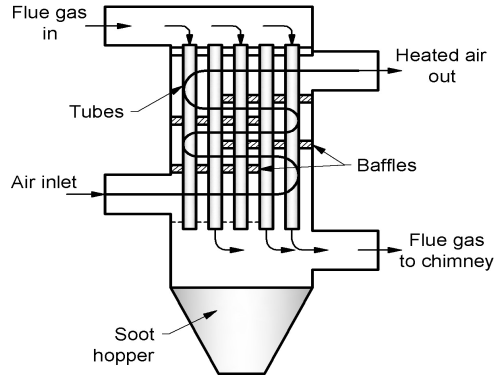


Fig. 2.15 Air pre-heater

(1) Fig. 2.15 shows schematic diagram of recuperative tubular type air pre-heater. In this type of air pre-heater, the passage of air and hot gases are separated by metallic wall.

(2) It consists of large number of tubes which are enclosed in a casing. After leaving the economiser, the flue gases pass inside the tubes of air pre-heater and air flows over the tubes as shown in Fig 2.15. Air and flue gases flow in opposite directions.

(3) Baffles are provided across the tubes to make the air follow zig-zag path number of times. By doing so, the time taken by the air to pass through the tube increases and more amount of heat is absorbed by the air from the flue gases. Preheated air is then supplied to the furnace for combustion.

(4) Soot obtained due to cleaning of tubes is collected at the bottom in a soot hopper.

Advantages of preheating air

1. It increases the boiler efficiency. There is an increase of around 2 % in boiler efficiency if the temperature of air rises by 35-40°C.
2. 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.
3. It results in better combustion with less unburnt fuel particles in flue gases with less soot, smoke and ash.
4. Low grade and inferior quality fuel can be burnt with less excess air.
5. It results in saving of fuel.

Disadvantages

1. Higher combustion temperature results in formation of clinkers on the grate.
2. As temperature of flue gases is reduced and pressure drop takes place in flow of gases, forced draught is required which increases the power consumption.
3. Maintenance cost increases.

Steam Separator

Function

The function of steam separator is to separate suspended water particles carried by steam on its way from boiler to steam turbine.

Location

It is installed near to steam turbine in the main steam pipe.

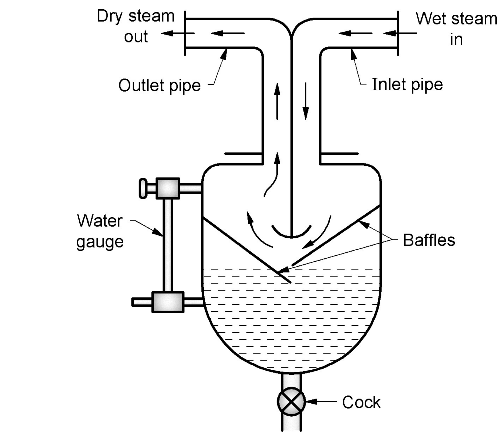


Fig. 2.16 Steam separator

Construction and working

(1) It consists of inlet and outlet pipes provided with flange, baffles and water drain cock as shown in Fig. 2.16.

(2) Wet steam from the boiler enters the steam separator through inlet pipe and flows down.

(3) In its passage downwards, it strikes the baffles and gets deflected upwards but water particles having greater density and greater inertia fall to the bottom of the separator.

(4) Dry steam moves up and is discharged through outlet pipe.

(5) A water gauge indicates the level of water in the separator.

(6) The water collected in the separator is removed periodically through the drain pipe by opening the drain cock.

Steam Trap

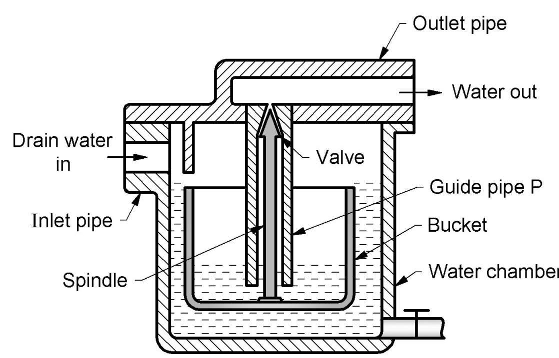


Fig. 2.17 Steam trap

Function

The function of steam trap is to drain away the water obtained by partial condensation of steam from steam separator or steam pipe without allowing any steam to escape.

Location

It is installed in steam pipe after steam separator and near to steam turbine in such a way that condensed water flows to it by gravity.

Construction

(1) Fig. 2.17 shows schematic diagram of bucket type steam trap.

(2) It consists of a bucket which is fitted with spindle at its centre. The upper conical end of spindle acts as valve.

(3) A guide pipe is fitted inside the chamber which has an outlet at its top. This outlet opens or closes by the valve which moves downward or upward with spindle.

Working

(1) At normal condition, the bucket floats over the water and outlet is closed by the valve. As the condensed water enters the water chamber, the level of water rises.
(2) As the water enters the bucket, weight of water causes the bucket to move downward along with the spindle, thereby opening the valve at outlet.
(3) This discharges the water through the outlet passage. After sufficient water is drained out, the weight in bucket reduces and bucket starts floating again.
(4) The rise in bucket causes the valve to rise up and closes the outlet.

Steam Injector

Function

(1) The function of the steam injector is to supply feed water to the boiler by utilizing steam from the same boiler.
(2) Kinetic energy of the steam is used to increase the pressure and velocity of feed water.

Location

It is located before the feed check valve.

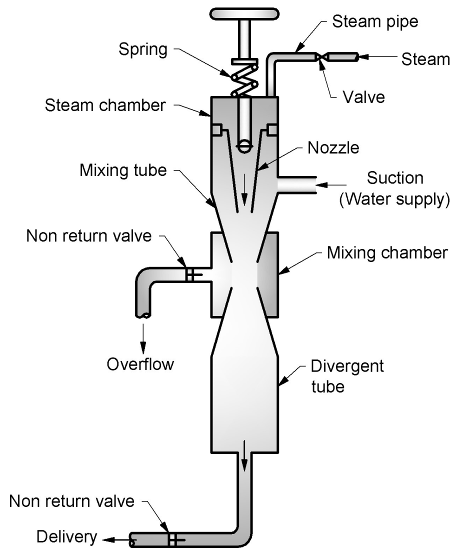


Fig. 2.18 Steam injector

Construction

(1) Fig. 2.18 shows schematic diagram of steam injector. It does not have any moving parts hence its operation is silent.
(2) It consists of spindle with hand wheel, steam chamber, mixing chamber, divergent tube as shown in Fig. 2.18.
(3) The spindle upper end is provided with handle and lower end is provided with valve.
(4) With the rotation of handle, steam nozzle moves up and down, so steam flow through the nozzle can be controlled.

Working

(1) Steam coming from the steam pipe enters into the convergent nozzle. In the nozzle, velocity of steam increases forming jet of steam while pressure decreases below atmospheric pressure.
(2) Since partial vacuum is created at the exit of the nozzle, feed water from the tank is sucked into

the mixing tube. Steam and water are mixed in the mixing chamber and condensation of steam takes place. Excess water flows out through overflow pipe.

(3) The mixture then enters a divergent tube which acts as diffuser that converts the kinetic energy of the mixture of steam and water into pressure energy.

(4) This forces the water into the boiler through the feed check valve. In this device, steam is utilized to heat as well as to feed the water. It is used only for small capacity boilers.

Practical No:3

Aim: To understand construction features of two/four stoke petrol/diesel engines

INTRODUCTION:

An engine is a device which converts one form of energy into mechanical energy. A heat engine is a device that converts chemical energy of the fuel into thermal energy and utilizes this energy to produce mechanical work. Heat engines are classified into two types:

1. External combustion engines: Combustion of fuel takes place outside the engine cylinder
2. Internal combustion engines: Combustion of fuel takes place inside the engine cylinder.

CLASSIFICATION OF INTERNAL COMBUSTION ENGINES:

I.C. Engines are classified as shown below:

1. **Type of fuel used**
   i) Petrol engineii) Diesel engine iii)Gas engine iv)Bi-fuel engine
2. **Number of strokes required to complete the cycle**
   (i) Four stroke engine: When the cycle is completed in four strokes (i.e. two revolutions of crankshaft), the engine is called four stroke engine.
   (ii) Two stroke engine: When the cycle is completed in two strokes (i.e. one revolution of crankshaft), the engine is called two stroke engine.
3. **Cycle of operation**
   i) Otto cycle or constant volume cycle
   ii) Diesel cycle or constant pressure cycle
   iii) Dual cycle or semi-diesel cycle
4. **Method of ignition**
   i) **Spark ignition (SI) engine:** Engine in which air-fuel mixture is ignited by an electric spark is called spark ignition engine. e.g. Petrol and gas engines.
   ii) **Compression ignition (CI) engine:** Engine in which fuel is ignited as it comes in contact with hot compressed air in the cylinder is called compression ignition engine. e.g. Diesel engine.
5. **Method of cooling**
   i) **Air cooled engine:** Small capacity engines are air cooled. e.g. Scooter engine.
   ii) **Water cooled engine:** Large capacity engines are water cooled. e.g. car, bus, truck engines.
6. **Method of governing**
   i) **Quantity governing:** Quantity of air-fuel mixture is changed maintaining the air-fuel ratio of the mixture constant. e.g. petrol engines.
   ii) **Quality governing:** Quantity of fuel supplied is changed according to the load, hence air-fuel ratio (quality of mixture) varies with load. e.g. Diesel engine.
7. **Speed of engines**
   i) Low speed engine ii) Medium speed engine iii) High speed engine
   Petrol engines are usually high speed engines while diesel engines are low or medium speed engines.
8. **Number of cylinders**
   i) Single cylinder engine ii) Multi cylinder engine
9. **Arrangement of cylinders**
   i) Horizontal engine ii) Vertical engine
   iii) V-type engine iv) Radial engine
   v) Opposed piston engine vi) Opposed cylinder engine
10. **Combustion of fuel on one or both side of piston**
    i) Single acting ii) Double acting (Usually I.C. engines are single acting)

11. **Fuel supply system**
    - **i) Carburettor:** Mixture of petrol and air is prepared in the carburettor and is supplied to engine during suction stroke.
    - ii) Solid or airless injection: A fuel pump is used to inject the fuel in diesel engines.
    - iii) Air injection: Fuel is supplied under pressure to the engine cylinder of diesel engines by using compressed air.
12. **Lubrication system**
    - **i) Splash lubrication:** Used for small capacity engines.
    - **ii) Pressure lubrication system:** Used for heavy duty engines
13. **Location of valves**
    - i) Overhead valve engine ii) Side valve engine
14. **Application**
    - i) Stationary engines ii) Aircraft engines iii) Automotive engines
    - iv) Locomotive engines v) Marine engines

I.C. ENGINE COMPONENTS AND THEIR FUNCTION:

1. Frame

It supports the cylinder block of the engine. It consists of bed plate and crankcase. Bed plate is rigidly fixed with foundation. Lower part of crankcase contains lubricating oil.

2. Cylinder

It is the main body of the engine in which piston reciprocates to develop power. It has to withstand high pressure and temperature; hence it is made strong. Generally, it is made of cast iron, but in case of heavy duty engines, alloy steel is used. It is provided with liner on the inner side and a cooling arrangement on its outer side.

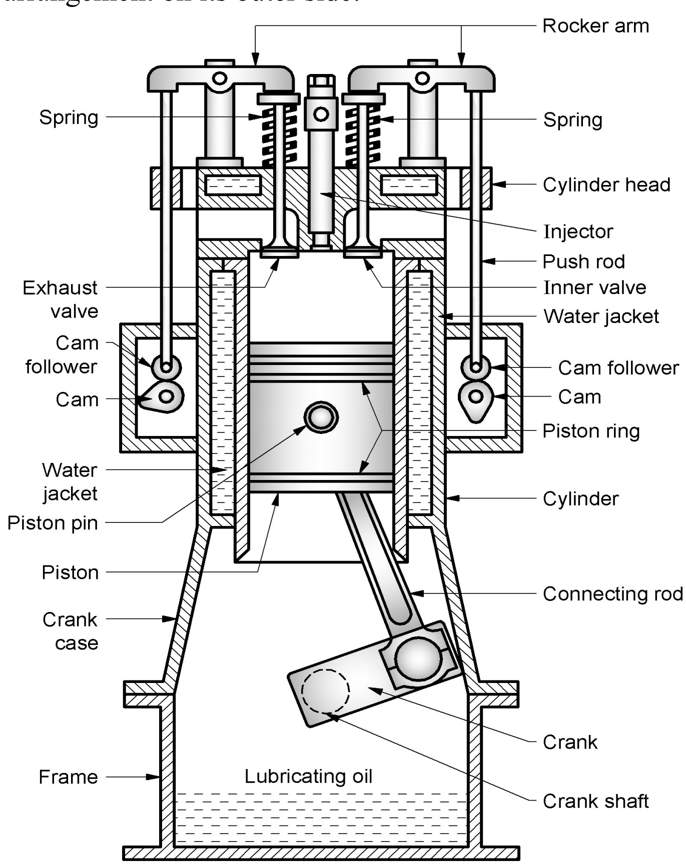


Fig.3.1): I.C. engine parts

3. **Cylinder head**

One end of the cylinder is closed by cylinder head. It contains inlet valve for admitting fresh charge and exhaust valve for exhausting burnt gases. It also contains spark plug in petrol engines and fuel injector in diesel engines. It is made from cast iron.

4. **Piston**

It is a movable cylindrical disc which slides up and down in the cylinder. Its function is to transmit the force created by combustion process to the crankshaft through connecting rod. It is usually made from aluminum alloy.

5. **Piston rings**

They are metallic rings inserted in the circumferential grooves provided on the outer surface of the piston. There are two sets of piston rings:

i) Upper rings are called compression rings. Their function is to provide gas tight seal and to prevent leakage of high pressure gas.

ii) Lower piston rings are called oil rings. Their function is to provide gas tight seal and prevent leakage of oil into the engine cylinder.

6. **Piston pin or Gudgeon pin**

It is a pin or link that connects the piston with small end of the connecting rod.

7. **Connecting rod**

It connects the piston at one end and crank at the other end. Its function is to convert the reciprocating motion of the piston into rotary motion of the crankshaft. It is made from forged steel.

8. **Crankshaft**

Crankshaft is the main rotating part of I.C. engine. It is supported in the main bearings. Mechanical work is available at the crankshaft. It drives various accessories like camshaft, lubricating oil pump, cooling water pump, fuel pump, dynamo, spark distributer etc. Flywheel is mounted on crankshaft. It is made from forged steel.

9. **Valves**

There are two valves for each cylinder. The inlet valve controls the admission of the charge into petrol engine or air into diesel engine. The exhaust valve controls the removal of exhaust gases after doing work on the piston.

These valves are operated by means of cam shaft, cam, cam follower, push rod, rocker arm and spring mechanism. The combination of these parts is known as valve gear. Valves are made from nickel steel or chrome steel.

10. **Camshaft**

Its function is to operate the intake and exhaust valves through cam, follower, push rod and rocker arm. It is driven from crankshaft by timing gear at half the speed of crankshaft.

11. **Cam**

The cam profile is made to give desired motion to the valve through the push rod and rock arm.

12. **Push rod and rocker arm**

The motion of the cam is transmitted to the valve through the push rod and rocker arm.

13. **Flywheel**

It is a heavy wheel fitted on the crankshaft. It reduces the cyclic variation of speed by storing energy during power stroke and using it during other strokes.

14. **Crank case**

It holds the cylinder and crankshaft. It also serves as sump for the lubricating oil.

15. **Governor**

Its function is to maintain the engine speed constant by regulating the charge in case of petrol engine and amount of fuel in case of diesel engine when the load requirement varies.

16. **Carburettor**

It is provided in petrol engine and its function is to properly mix petrol and air.

17. **Spark plug**

It is provided in petrol engine and is fitted in the cylinder head. Its function is to provide spark to ignite air-fuel mixture.

18. **Fuel injector**

It is provided in diesel engine. Its function is to inject diesel fuel in the cylinder in the form of fine atomized spray under high pressure**.**

19. **Fuel pump**

It is provided in diesel engine and its function is to pump the diesel fuel from storage tank to injector at high pressure.

WORKING OF FOUR STROKE PETROL ENGINE

Petrol engine works on **constant volume (Otto) cycle** and uses petrol as fuel. In this engine, spark is used to ignite the charge (air-fuel mixture) hence it is also called spark ignition (SI) engine. All the operations are carried out in four strokes of the piston i.e. two revolution of the crankshaft, hence the engine is called four stroke engine. Crank rotates 180° i.e. half revolution during each stroke. The four strokes are suction stroke, compression stroke, expansion or power stroke and exhaust stroke

1. **Suction stroke**

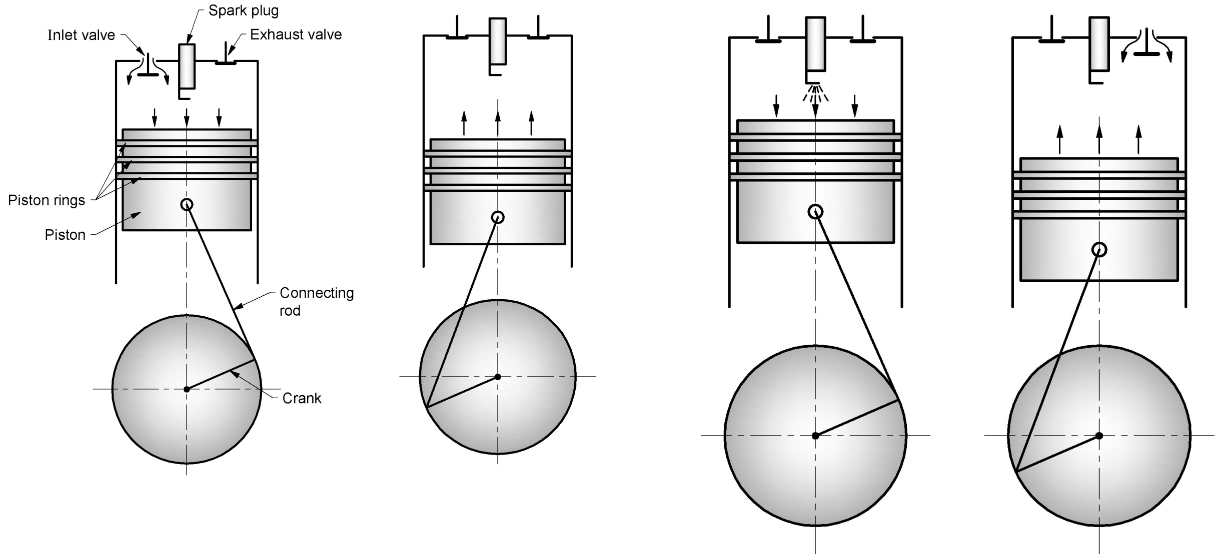
- The suction stroke starts when the piston is at the top dead centre (TDC) and about to move downwards from TDC to BDC. During this stroke, the inlet valve opens and exhaust valve remains closed as shown in Fig. 3.2(a).
- As the piston moves downwards towards BDC position, pressure inside the cylinder is reduced to a value below atmospheric pressure. The vacuum thus created causes the fresh charge of air-fuel mixture from the carburetor to enter the cylinder through the inlet valve.
- When the piston reaches BDC position, the suction stroke ends and inlet valve closes. During this stroke, pressure remains constant with increase in volume. This is represented by 0-1 on p-v diagram, Fig.3. 3

2. **Compression stroke**

- As shown in Fig. 3.2(b), during this stroke, both the inlet and exhaust valves are closed, piston moves from BDC to TDC and compresses the charge of air-fuel mixture. Pressure and temperature of the charge are increased and volume is decreased. This is represented by 1-2 on p-v diagram.
- At the end of compression stroke, the charge is ignited by means of electric spark produced by spark plug causing instantaneous combustion.
- Combustion occurs at constant volume and is represented by 2-3 on p-v diagram. Pressure and temperature rapidly increases due to combustion.

3. **Expansion or power stroke**

- As shown in Fig. 3.2(c), both inlet and exhaust valve remain closed during this stroke. Piston moves from TDC to BDC. High pressure burnt gases forces the piston to move downwards. Thus, work is done during this stroke, hence it is also called working or power stroke.
- The expansion of gas is adiabatic and is represented by 3-4 on p-v diagram. The pressure decreases and volume increases.
- At the end of this stroke, exhaust valve opens and burnt gases are discharged into the atmosphere at constant volume with decrease of pressure. This is represented by 4-1 on p-v diagram.



3.2(a) Suction Stroke

Inlet valve open
Exhaust valve closed

3.2(b) Compression Stroke

Inlet valve closed,
Exhaust valve closed

3.2(c) Power stroke

Inlet valve closed,
Exhaust valve closed

3.2(d) Exhaust stroke

Inlet valve closed
Exhaust valve open

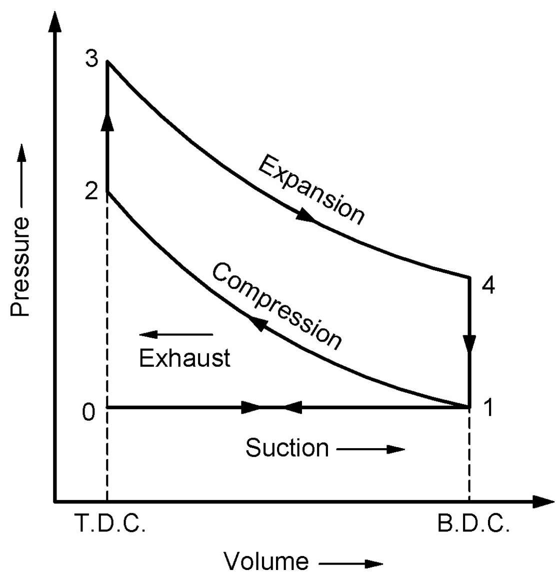


Fig. 3. 3: p-v diagram of four stroke petrol engine

4. Exhaust stroke

- As shown in Fig. 3.2(d), the inlet valve is closed and exhaust valve is opened. Piston moves from BDC to TDC. During the upward movement of piston, it pushes the exhaust gases from the engine cylinder through the exhaust valve into the atmosphere at constant pressure. This is represented by 1-0 on p-v diagram.
- This completes the cycle and again the inlet valve opens, the engine cylinder sucks the fresh charge into it and the cycle is repeated.

WORKING OF TWO STROKE DIESEL ENGINE

First stroke

(1) Assume that the piston is at BDC position as shown in Fig.3. 4(a). During this stroke, the piston moves upwards from BDC to TDC. Air has already entered into the cylinder from the crankcase through the transfer port.

(2) During the upward motion, it first closes the transfer port and then the exhaust port. So the air is compressed. Pressure and temperature of air increases and volume decreases. This is represented by 1-2 on p-v diagram as shown in Fig. 3.5

(3) Due to upward movement of the piston, a partial vacuum is created in the crankcase. The inlet port opens and air is sucked into the crankcase through the inlet port as shown in Fig.3. 4(b)

(4) Just before the end of compression stroke diesel fuel is forced under pressure in the form of fine atomized spray into the engine cylinder through the fuel injector. The temperature of the compressed air is high enough to ignite the diesel fuel.

(5) The rate of diesel injection is such that constant pressure is maintained during combustion. Thus, heat addition is at constant pressure and is represented by line 2-3 on p-v diagram. At the end of first stroke, piston reaches TDC position.

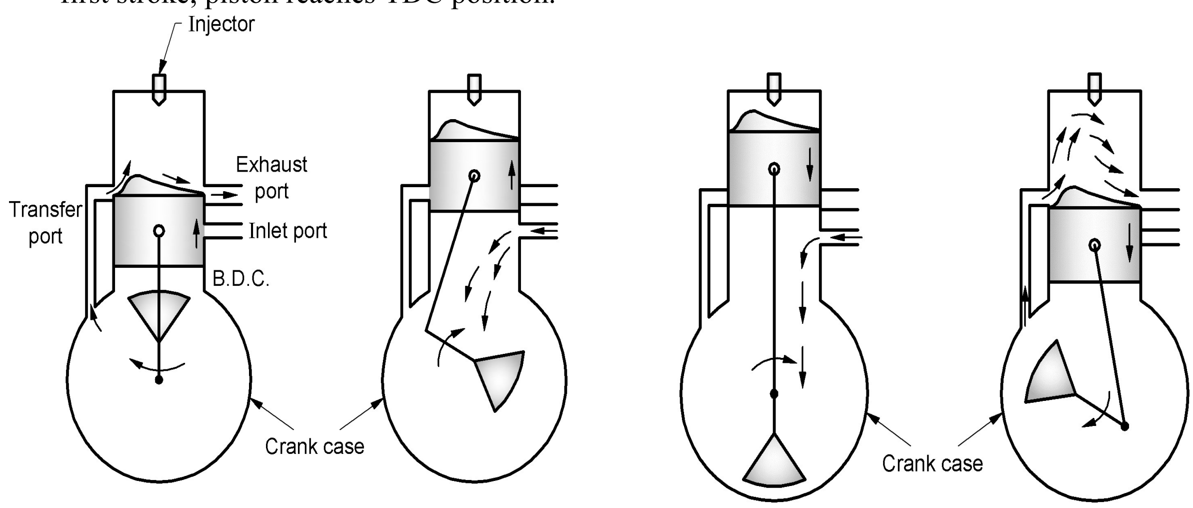


Fig 3.4(a) Fig 3.4(b) Fig 3.4(c) Fig 3.4(d)

Working of two stroke diesel engine

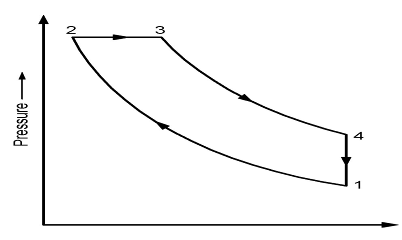


Fig 3.5 p-v diagram of two stroke diesel engine

Second stroke

(1) During this stroke, piston moves from TDC to BDC position. Hot gases at high pressure and high temperature act on the piston, pushing the piston downwards producing useful power.

(2) During the downward motion, piston opens the inlet port and fresh air is compressed in the crankcase fig 3.4(c)

(3) Further downward motion of the piston opens the exhaust port and then the transfer port as shown in Fig.3.4(d) The exhaust gases start escaping through the exhaust port.

(4) At the same time, fresh air which is already compressed in the crankcase is forced into the cylinder through the transfer port.

(5) The air strikes the deflector on the piston crown, rises to the top of the cylinder and pushes out the exhaust gases. When the piston reaches BDC, cylinder is completely filled with fresh air. The cycle is then repeated.

COMPARISON BETWEEN PETROL AND DIESEL ENGINE

Sr. No.	Parameter	SI engine (Petrol engine)	CI engine (Diesel engine)
1.	Basic cycle	Otto cycle (Constant volume cycle)	Diesel cycle (constant pressure cycle)
2.	Fuel	Petrol (Gasoline)	Diesel
3.	Introduction of fuel	A mixture of fuel and air is introduced in the cylinder during suction stroke. The mixture is prepared in carburettor.	No carburettor is needed. Fuel is injected directly into the combustion chamber using fuel pump and fuel injector.
4.	Ignition	Spark plug is used to ignite the fuel-air mixture.	The temperature at the end of compression stroke is sufficient to ignite the fuel. Self-ignition of fuel takes place.
5.	Compression ratio	6 to 10	14 to 22
6.	Speed	They are **highspeed** engines due to light weight.	They are **lowspeed** engines due to heavy weight.
7.	Thermal efficiency	Due to use of low compression ratio thermal **efficiency is low.**	Due to use of high compression ratio thermal **efficiency is high.**
8.	Weight	They are light in weight due to use of lower peak pressures.	They are heavy in weight due to use of high peak pressures.
9.	Starting	Easy to start	They are difficult to start as they require greater crank effort due to use of high compression ratio.
10.	Initial and maintenance cost	Low	High
11.	Governing	Quantity governing method is used for controlling the speed.	Quality governing method is used for controlling the speed.
12.	Vibration and noise	**Lower** due to use of lower cylinder pressure	**Higher** due to use of higher cylinder pressure.
13.	Fire risk	More	Lower due to higher ignition point of diesel.
14.	Applications	Employed for light duty vehicles eg. Scooter, motor cycle, auto rickshaw, car etc.	Employed in heavy duty vehicles such as bus, truck, tractor, locomotive engine etc.

COMPARISON BETWEEN FOUR STROKE AND TWO STROKE ENGINE

Sr. No.	Parameter	Four stroke engine	Two stroke engine
1.	Number of strokes and crank revolution	Cycle is completed in four strokes of the piston or in two revolutions of the crank shaft.	Cycle is completed in two strokes of the piston or in one revolution of the crankshaft.
2.	Number of power strokes	It has one power stroke for every two revolution of crankshaft.	It has one power stroke for each revolution of crankshaft. So theoretically power developed is twice that of four stroke engine Actually it develops about 1.7 to 1.8 times power that of four stroke engine.
3.	Flywheel	Torque fluctuation on the crankshaft is high hence it requires heavier flywheel.	More uniform turning moment is obtained hence lighter flywheel is required.
4.	Weight and space requirement	Engine is heavy and bulky. It occupies more space.	Engine is light and compact. It occupies less space.
5.	Admission of charge	Charge is directly admitted into the engine cylinder during suction stroke.	Charge is first admitted into the crankcase and then transferred to the engine cylinder.
6.	Construction	Construction is complicated due to presence of valve and valve gear mechanism.	Construction is simple due to absence of valve and valve gear mechanism. In place of valves, ports are used which are operated by movement of the piston.
7.	Thermal efficiency	Higher thermal efficiency as there is no mixing of fresh charge with exhaust gases.	Lower thermal efficiency as there is mixing of fresh charge with exhaust gases and some fuel leaves along with exhaust gases without burning.
8.	Cooling and lubrication requirement	Lesser cooling and lubrication needed since it has only one power stroke per revolution of crankshaft. Normally water cooled.	More cooling and lubrication needed since it has one power stroke per revolution of crankshaft. Normally air cooled.
9.	Lubrication system	They have separate lubrication system. (Wet sump lubrication system).	Lubricating oil is mixed with petrol in two stroke petrol engine and then admitted into the engine. (Mist lubrication system).
10.	Volumetric efficiency	It is higher as more time is available for induction of charge.	It is low due to less time is available for induction of charge.
11.	Mechanical efficiency	It is low due to more number of parts.	It is high due to less number of parts.
12.	Noise	Less	Exhaust is more noisy due to sudden release of burnt gases.
13.	Lubricating oil consumption	Less	Consumption of lubricating oil is more as it is subjected to higher temperature.
14.	Applications	Preferred for large cars, buses,	Preferred for scooters, motor

Sr. No.	Parameter	Four stroke engine	Two stroke engine
		trucks, aeroplanes, power generators etc.	cycles, mopeds, lawn movers etc.

PRACTICAL 4:

AIM: TO DETERMINE BRAKE THERMAL EFFICIENCY OF AN I. C. ENGINE.

INTRODUCTION:

With a growing demand for transportation IC engines 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. IC engine Test rigs are used to find out the performance of an IC engine. It consists of an IC Engine, Rope brake dynamometer, fuel measuring, air intake measuring and various other
arrangements.

TECHNICAL TERMS RELATED TO ENGINE PERFORANCE TRIAL:

Different technical terms/ parameters related to engine performance are as shown below:

1. **Indicated power (IP):** The power developed inside the engine cylinder is known as indicated power.

   It is given by

$$IP = \frac{p_m L A n}{60}$$

Where, p_m = Indicated mean effective pressure in N/m^2

$$= \frac{\text{Area of indicator diagram } (cm^2)}{\text{Length of indicator diagram (cm)}} \times \text{Spring scale } (N/m^2/cm)$$

L = Stroke length in m

n = Number of working strokes per minute

= N/2 (For four stroke engine) = N (For two stroke engine)

For four stroke engine,

$$IP = \frac{p_m L A N}{60 \times 2}$$

For two stroke engine,

$$IP = \frac{p_m L A N}{60}$$

For multi-cylinder engine,

$$IP = \frac{p_m L A n}{60} \times \text{Number of cylinders}$$

2. **Brake power (BP) :**The power available at the engine crankshaft is known as brake power. It is measured by dynamometer with brake arrangement hence it is known as brake power.

$$BP = \frac{2\pi NT}{60} = \frac{p_{mb} L A n}{60}$$

Where N = Speed of the engine in rpm

T = Torque in N-m

P_{mb} = Brake mean effective pressure in N/m^2

Measurement of brake power by rope brake dynamometer

- The brake power is measured by coupling the rope brake dynamometer to the engine shaft. A rope is wound round the circumference of the drum as shown in Fig. 7.12.1.

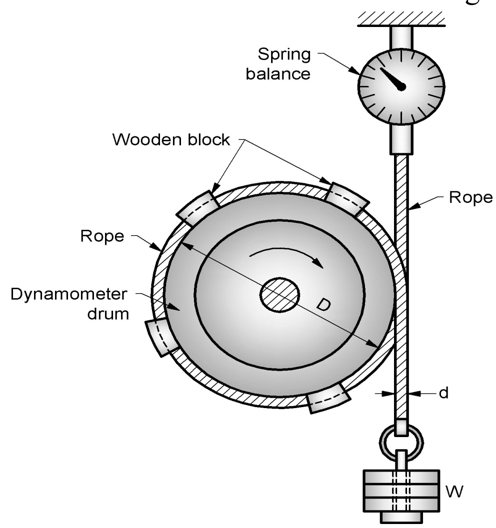


Fig. 4.1 : Rope brake dynamometer

- To prevent the rope from slipping small wooden blocks are fitted to rope. One end of the rope is attached to spring balance (S) and other end carries load (W). The speed of the engine is noted with tachometer.
- The power of the engine is absorbed as frictional heat created between the rope and the drum.

Let W = Dead weight in N

S = Spring balance reading in N

R_b = Effective radius of brake drum

$$= \frac{D + d}{2}$$

D = Brake drum diameter in m

d = Rope diameter in m

Brake load or net load = $(W - S)$

Braking torque = $(W - S) \times R_b$

$$\therefore \text{ Brake power} = \frac{2\pi NT}{60 \times 1000} \text{ kW}$$

$$= \frac{(W - S)\, R_b \times 2\pi N}{60 \times 1000} \text{ kW}$$

3. **Frictional power (FP) :**The difference between indicated and brake power is known as friction power

$$FP = IP - BP$$

The brake power is less than indicated power due to various losses. The friction power includes power required to operate the fuel pump, lubricating pump, water pump, valves etc.

4. **Thermal efficiency:** The ratio of work output of the engine to the heat supplied by the fuel is

known as thermal efficiency. It is of two types:

(a) Indicated thermal efficiency

(b) Brake thermal efficiency

(a) Indicated thermal efficiency (η_{ith})

It is the ratio of indicated power to the heat supplied by fuel per second.

$$n_{ith} = \frac{\text{Indicated power (kW)}}{\text{Fuel supplied}\left(\frac{\text{kg}}{\text{sec}}\right) \times \text{Calorific value of fuel}\left(\frac{\text{kJ}}{\text{kg}}\right)}$$

$$= \frac{IP}{m_f \times CV}$$

(b) Brake thermal efficiency (η_{bth})

It is the ratio of brake power to the heat supplied by fuel per second.

$$n_{bth} = \frac{\text{Brake power (kW)}}{\text{Fuel supplied}\left(\frac{\text{kg}}{\text{sec}}\right) \times \text{Calorific value of fuel}\left(\frac{\text{kJ}}{\text{kg}}\right)}$$

$$= \frac{BP}{m_f \,'\, CV}$$

5. **Mechanical efficiency (η_m) :** It is the ratio of brake power to the indicated power.

$$\eta_m = \frac{BP}{IP}$$

It is also expressed as

$$\eta_m = \frac{\text{Brake thermal efficiency}}{\text{Indicated thermal efficiency}} = \frac{\eta_{bth}}{\eta_{ith}}$$

$$\eta_m = \frac{\text{Brake mean effective pressure}}{\text{Indicated mean effective pressure}} = \frac{p_{mb}}{p_{mi}}$$

6. **Relative efficiency:** It is the ratio of indicated thermal efficiency to air standard efficiency.

$$\eta_r = \frac{\eta_{ith}}{\eta_a}$$

7. **Brake specific fuel consumption (bsfc):** It is the ratio of mass of fuel consumed per hour per unit brake power.

$$\text{bsfc} = \frac{m_f\,(\text{kg/hr})}{\text{BP (kW)}}\ \text{kg/kW-hr}$$

8. **Mean effective pressure (p_m) :** It is the hypothetical average pressure, which if acted on the piston during the entire power stroke will produce same power output as produced during the actual cycle.

$$p_m = \frac{\text{Work done}}{\text{Swept volume}} = W/v_s$$

ENGINE SPECIFICATIONS:

DESCRIPTION OF DYNAMOMETER:

APPARATUS / TESTING INSTRUMENTS REQUIRED:

1) **Tachometer 2) Stop Watch**

PROCEDURE FOR ENGINE TRIAL:

Laboratory Test Results for Fuel Used:

Sp Gravity:

Lower Calorific Value of Fuel Used:

Observation Table:

Sr. No.	Spring Balance Difference = W-S in N	Engine Speed (N) rpm	Time (t) for Fuel Consumption Of (20 ml) in Seconds
1			
2			

3			

Calculation Procedure:

1.Brake power $= \dfrac{2\pi NT}{60 \times 1000}$ kW

$= \dfrac{(W - S)\, R_b \times 2\pi N}{60 \times 1000}$ kW

Where W = Dead weight in N

S = Spring balance reading in N

R_b = Effective radius of brake drum

$= \dfrac{D + d}{2}$

D =Brake drum diameter in m

d =Rope diameter in m

2.Total Fuel Consumption = $\dfrac{\text{(Final Reading – Initial Reading)}}{\text{Time in seconds}} * \dfrac{\text{Sp. Gravity of Fuel}}{1000}$

TFC = $\dfrac{\textbf{CC (ml)}}{\textbf{Time}}$ * $\dfrac{\textbf{Sp Gravity of fuel}}{\textbf{1000}}$ kg/second

Brake Specific Fuel Consumption = $\dfrac{TFC}{BP}$ * 3600 Kg/Kw Hr

(Where TFC is in Kg Per Hour and BP is in kW)

Brake Thermal Efficiency = $\dfrac{BP}{TFC * CV}$ * 100

(Where BP is in kW, TFC in Kg / Sec, CV in KJ/kg)

Conclusion:

Practical No 5

Aim: To understand construction and working of different types of air compressors.

INTRODUCTION:

The compressor is a machine which handles the compressible fluid and pressurizes it by doing work on it. The fluid can either be an air or any gas.

Air compressor is a machine which takes in air at low pressure and compresses it to high pressure with the help of some suitable arrangement. i.e. reciprocating piston and cylinder arrangement or rotary arrangement and delivers the air to a storage tank (also known as receiver), from which compressed air is supplied to different users through pipe lines.

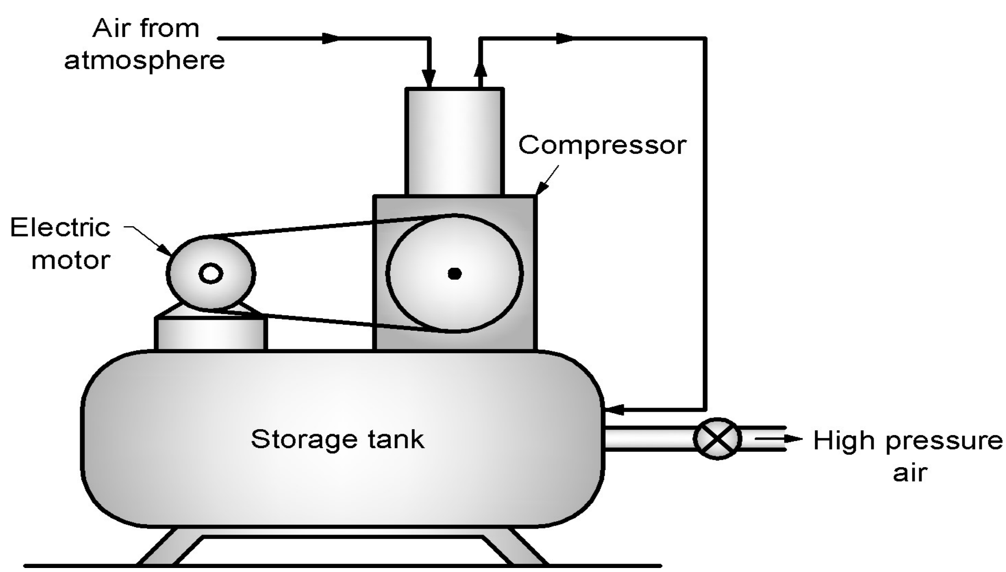


FIG. 5.1 AIR COMPRESSOR

Since the compression of air requires some work to be done on it, hence a compressor must be driven by some prime mover such as electric motor, internal combustion engine or a turbine.

USES OF COMPRESSED AIR

Compressed air is used for:

1) inflating tyres/ tyre tubes used either in automobiles or airplanes
2) spray painting
3) operating the airbrakes used in buses/ trucks/ trains etc.
4) starting and supercharging of internal combustion engines
5) driving air motors of pneumatic hoists used in coal mines, where electric motors and I.C.

engines cannot be used because of fire risks due to presence of inflammable gases.

6) To operate pneumatic tools such as drills, hammers, spanners, riveting machines etc.
7) cleaning of parts of machine and automobiles which are not accessible by hand.
8) conveying solid and powder materials in pipelines.
9) operating air motors to run water pumps (to supply water to extinguish fire) and elevators in industries following the safety norms
10) conveying solid and powder materials in pipelines (for eg supplying coal to the burner of steam boilers)
11) operating pneumatic control system used in different industries

CLASSIFICATION OF AIR COMPRESSORS:

Air ccompressors are classified as follows:

(1) According to principle of operation

(a) Positive displacement compressors

(b) Dynamic compressors

- In positive displacement compressors, the pressure of air is increased by decreasing its volume. Positive displacement reciprocating compressors use piston and cylinder arrangement to increase the pressure of air and decrease its volume. They are capable of producing very high pressure at low volume flow rate.
- In positive displacement rotary compressors, air is trapped in reducing passage formed between two set of engaging surfaces and the pressure rise is obtained either by back flow of air (e.g. roots blower) or by both squeezing (pressing) action and back flow of air (vane type compressor).

In dynamic compressor, kinetic energy imparted to the air by rotation of the rotor (impeller) is converted into pressure energy partly in the rotor and remaining in the diffuser. Thus, pressure rise is achieved due to dynamic action of the rotor. Here the air is not trapped in specific volume, but flows continuously through the compressor. e.g. centrifugal and axial flow compressor.

(2) According to delivery pressure

a) Low pressure compressor: Delivery pressure upto 10 bar
b) Medium pressure compressor: Delivery pressure from
c) High pressure compressor: Delivery pressure from 10 to 80 bar
d) Super high pressure compressor: Delivery pressure above 100 bar

(3) According to pressure ratio

a) Fan: Pressure ratio upto 1.1
b) Blowers: Pressure ratio from 1.1 to 2.5
c) Compressors: Pressure ratio above 2.5

(4) According to number of stages

a) Single stage: Delivery pressure upto 10 bar
b) Multi stage: Delivery pressure above 10 bar

(5) According to volume flow rate

a) Low capacity compressors: Volume flow rate upto 10 m^3/min
b) Medium capacity compressors: Volume flow rate from 10 to 300 m^3/min
c) High capacity compressors: Volume flow rate above 300 m^3/min

(6) According to the action of piston

a) Single acting compressor
b) Double acting compressor

(7) According to method of cooling

a) Air cooled   b) Water cooled

(8) According to power drive

a) Electric motor driven b) IC engine driven c) Gas turbine driven

(9) According to medium to be compressed

a) Air b) Gas

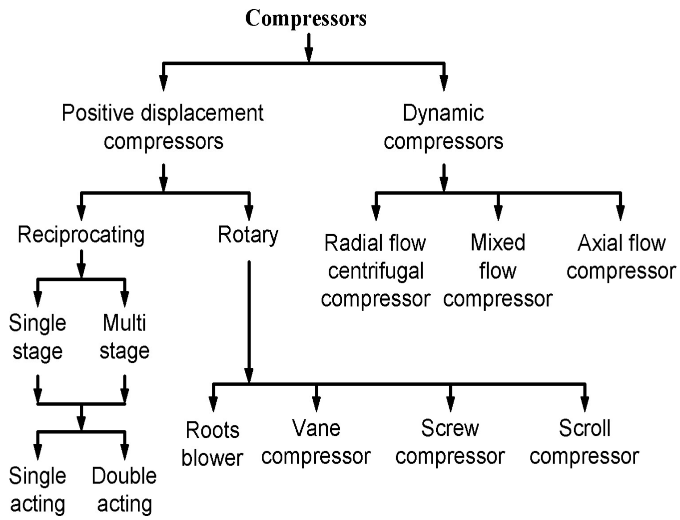
(10) According to arrangement of cylinders

a) Vertical b) Horizontal c) V-type d) W-type e) Radial

(11) According to nature of installation

a) Stationary b) Portable

Compressor are also classified as shown below:



IMPORTANT TERMS USED IN AIR COMPRESSOR:

1) **Compression or pressure ratio**
   It is the ratio of absolute discharge pressure to the absolute inlet pressure.
2) **Free air delivery (FAD) :**It is the actual volume of air delivered by the compressor reduced to intake pressure and temperature and is expressed in m^3/min. In absence of any given free air conditions, it is taken as 1.01325 bar and 15° C.
3) **Compressor capacity**
   It is the volume of air delivered by the compressor and is expressed in m^3/min. The capacity of compressor is always less than the swept volume of the compressor.
4) **Volumetric efficiency:** It is the ratio of actual volume of air taken in the cylinder (compressor capacity) to the swept volume of the compressor.

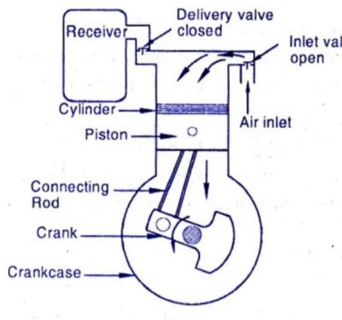
RECIPROCATING AIR COMPRESSOR:

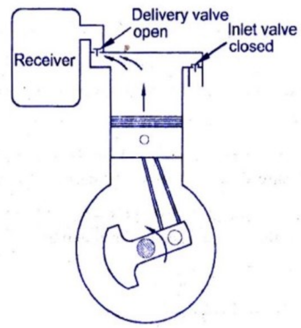
Construction:

It consists of the cylinder in which a piston reciprocates. The piston is driven by crank through connecting rod. The crank is mounted in a crankcase. There are two valves, i.e. intake valve and delivery valve. The valves are generally pressure differential type. Thus they operate automatically by the difference of pressure across the valve. Operation of a compressor

Case-(1) Operation without clearance.

It is assumed that in an ideal compressor there is no clearance volume at the end of the stroke. In this type of compressor, when piston is moving away from TDC as shown in fig 5.2, pressure inside cylinder will decrease and volume will increase. Hence pressure difference across the valve is created. The spring operated inlet valve will be opened automatically for intake of air. Therefore, the atmospheric air enters into the cylinder at constant pressure P1 with increase in volume. This process is shown by (4-1) on p- V diagram shown in fig. 5.4





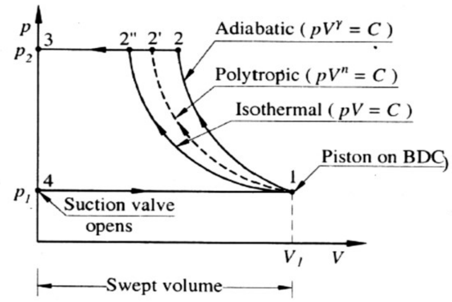


Fig. 5.2.Suction Stroke **Fig. 5.3 Compression & Delivery Stroke** **Fig. 5.4 P-V Diagram Neglecting Clearance Volume**

As shown in fig 5.3. The piston moves towards the TDC from BDC during the second stroke. The air is compressed adiabatically with increase of pressure. This is shown by the curve (1-2). When the pressure of compressed air becomes equal to the pressure of receiver in which the air is delivered, the spring operated delivery valve opens automatically and the air is forced into the receiver at constant pressure P_2 from the cylinder. This process is shown by horizontal line 2-3. Again piston moves away from TDC. Thus the cycle is completed and the same cycle will be repeated. Area of the diagram (1-2-3-4) represents the work required to compress air from pressure P_1 to P_2 for adiabatic compression.

Case- (2) Operation with clearance:

In actual compressor always there is clearance volume at the end of stroke. The small clearance is required because of, (1) Preventing striking of piston at cylinder head, (2) Thermal expansion due to high temperature at the end of compression, (3) Maintaining machine tolerance.

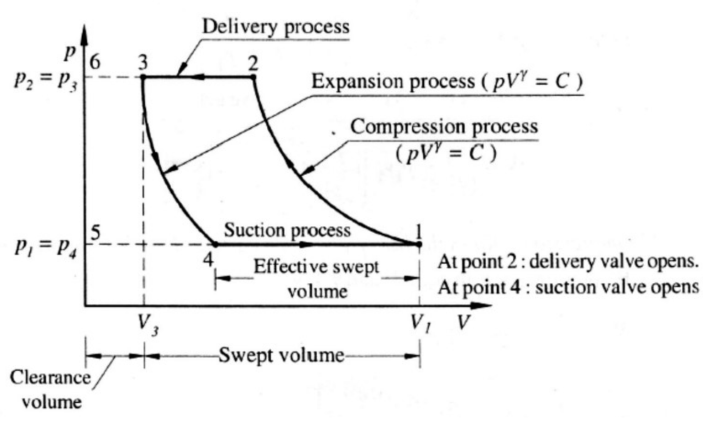


Fig. 5.5 P-V Diagram considering clearance volume

If the compression follows $PV^\gamma = C$, the clearance volume is denoted by Vc or V_3.The residual compressed air at a pressure $P_2 = P_3$ is filled in clearance volume at the end of upward stroke of piston. So during the suction stroke this residual compressed air expands and denoted by the curve (3-4) on p-V diagram in fig.5.5 This expansion will reduce pressure from $P_2 = P_3$ to intake pressure $P_4 = P_1$. Due to this reduction in pressure the in valve will begin to open. This will permit the intake of a fresh air. The volume (V_1 - V_4) known as suction volume, effective swept volume or free air delivery at suction condition. The work required to drive compressor per cycle is represented by area (4-1-2-3). At point 4 suction valve opens, at point 2

NEED FOR MULTISTAGING:

If single stage compression is used to produce high pressure air then following disadvantages occur :

i. As the delivery pressure is increased, the mass flow through the compressor decreases.
ii. If the delivery pressure is increased, delivery temperature also increases ($T_{2''} > T_{2'} > T_2$). If this high temperature is not required, then any increase in temperature represents energy loss.
iii. Due to rise in temperature of air, it is difficult to reject heat from air in small time available during compression.
iv. High temperature at the end of compression may result in burning of lubricating oil or heating of cylinder head.

(1) Fig. 5.6 shows schematic arrangement for a two-stage reciprocating air compressor with intercooler and Fig.5.7 shows p-v diagram. Fresh air is sucked from the atmosphere in low pressure (L.P.) cylinder during its suction stroke at intake pressure p_1 and temperature T_1.

(2) The air, after compression in the L.P. cylinder from 1 to 2, is delivered to the intercooler at pressure p_2 and temperature T_2.

(3) Air is cooled in the intercooler at constant pressure p_2 from temperature T_2 to $T_{2'}$. Air then enters high pressure (H.P.) cylinder, where it is further compressed polytropically to delivery pressure p_3. Compressed air from H.P. cylinder is finally discharged to a receiver.Curve 1-3' shows the compression process for single stage compression.

(4) Shaded area 2-2'-3-3'-2 shows saving in work done using multi-stage compression. Both L.P. and H.P. cylinder are mounted on same crankshaft and are driven by electric motor.

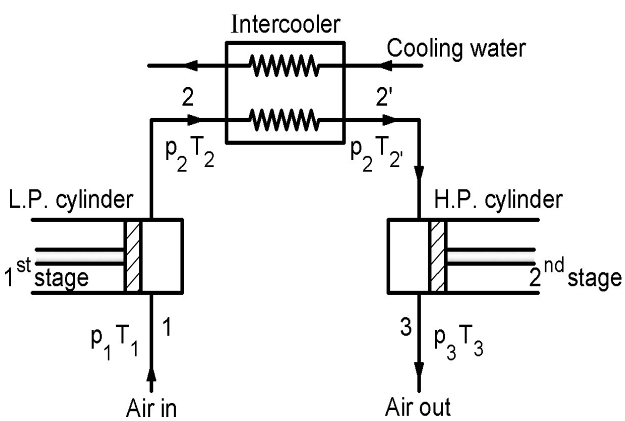


Fig.5.6 , Two Stage Compression

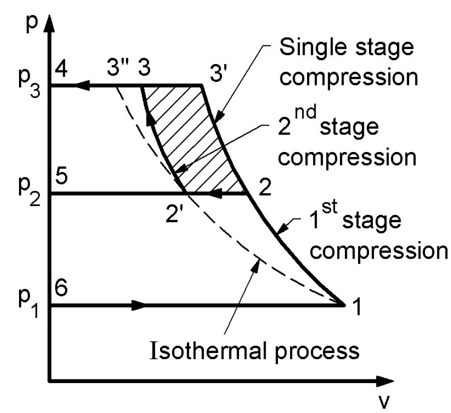


Fig.5.7 , P-V Diagram for two stage compression for comparison

ADVANTAGES OF MULTI-STAGE COMPRESSION

1. The power required to drive a multi-stage compressor is less than single stage compressor delivering same quantity of air at same delivery pressure.
2. As the volumetric efficiency is a function of pressure ratio, higher volumetric efficiency can be attained as pressure ratio in each stage is less than overall pressure ratio.
3. Better mechanical balance can be achieved.
4. Loss of air due to leakage is less.
5. Pressure and temperature range in each stage is reduced.
6. High pressure cylinder is designed to withstand high pressure whereas low pressure cylinder is designed to withstand low pressure.
7. It gives more uniform torque, hence smaller flywheel is required.

8. Effective lubrication is possible due to low temperature range.

DISADVANTAGES OF MULTI-STAGE COMPRESSION

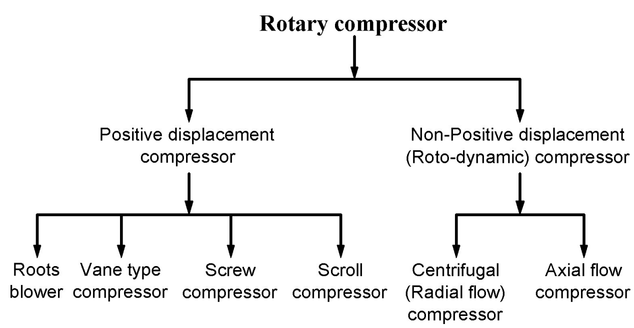
1. A multi-stage compressor with intercoolers is costlier compared to single stage compressor of same capacity.
2. Mechanical efficiency is slightly reduced.
3. System is more complicated.

DYNAMIC TYPE AIR COMPRESSORS:

- In positive displacement rotary compressor, air is entrapped in a reducing passage formed between two set of engaging surfaces and the pressure rise is obtained either by back flow of air (e.g. roots blower) or by both squeezing (pressing) action and back flow of air (e.g. vane type compressor).
- In a dynamic compressor, kinetic energy imparted to the air by rotation of the rotor (impeller) is converted into pressure energy partly in the rotor and remaining in the diffuser. Thus, the pressure rise is achieved due to dynamic action of the rotor. In dynamic compressor, air is not trapped in specific volume but flows continuously through the compressor.

CLASSIFICATION OF ROTARY AIR COMPRESSORS:

Rotary air compressors are classified as per follows:



ROOTS BLOWERS

Construction: The two lobe type roots blower is shown in fig. 5.8

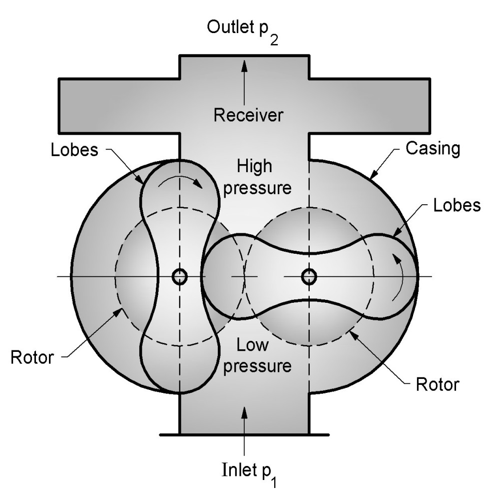


Fig.5.8, Roots Blower

One of the rotor is connected to the drive. The second rotor is gear driven from the first. Thus both the rotors, rotate in phase. In order to seal delivery side from the inlet side, the profile of the lobs is of cycloidal or involute. This sealing continues until delivery commences. To reduce wear, there must be some clearance between the lobes and between the casing and the lobes.

Although this clearance will form a leakage path for compressed air and will have an adverse effect on efficiency when pressure ratio increases. In order to achieve the acceptable efficiency of the blower a very small clearance of about 0.2 to 0.5 mm is provided. The pressure at the delivery is not constant. Single acting blower can develop the pressure up to twice the inlet pressure.

Principle of operation:

The operation can be considered as taking place in two distinct phases suction and discharge as described below:

Suction phase: The rotation of the rotors produces space, which increases the volume as rotation continues. The gas therefore flows into the machine to fill the space. The flow of gas into the blower continues involving both the rotors. A quantity of gas is trapped between one rotor and the casing for a very brief interval. This part of the blower is not open to the suction. No gas flows into it. The gas continues to flow into the space produced by the rotation of the other rotor. This rotor is carrying out the same cycle as the first but 90^{0} behind it.

Discharge Phase: The trapped volume is at suction pressure as it has simply been drawn in by the movement of the rotors. There is no internal compression of gas as there is no meshing of rotors prior to the release to discharge. Continued rotation of rotors, opens \ the trapped space to the discharge port. As the Pressure in the discharge port is higher than suction pressure, the movement that the trapped volume opens to the discharge Port, a back flow of gas from discharge takes Place. This will increase its Pressure up to discharge level. The continued rotation then pushes out the gas into the chamber (Receiver).

For higher pressure ratios, three and four lobes versions are used.

VANE COMPRESSOR

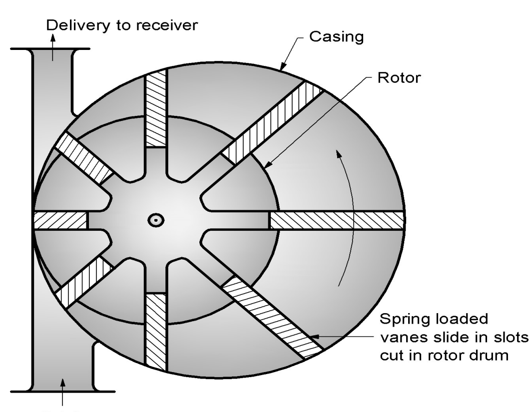


Fig. 5.9 Vane Blower

Construction: It consists of a rotor mounted eccentrically in the body. This rotor is supported by ball and roller bearings in the end cover of the body. The rotor is slotted to take the blades. These blades are made from non-metallic material usually fiber. The casing of the compressor is circular in which the drum rotates during rotation. The vanes remain in contact with the cylinder. The slots in which the blades are fixed are cut radially into the rotor. The blades or vanes can slide in and out due to the centrifugal forces setup by the rotary motion of the rotor. The circular casing is provided with one inlet and one outlet port. The space between the rotor and its casing is sub-divided into a number of compartments by these, vanes. Two consecutive vanes form one compartment. Due to eccentric motion of the rotor the volume of each compartment keeps on changing. It can develop the pressure up to 9 bar and delivered 15 m^3 /min of air.

Principle of operation: The operation can be considered to take place in three phases. Suction, internal compression and discharge.

Suction phase The relative position of the rotor and casing is clearly shown in fig. 5.9. The start of the suction phase is indicated for one space between two of the vanes. The rotation of the rotor causes space to be formed between the vanes, the rotor and casing. This space is connected to the suction port so that gas from the suction passes into the space to fill it. The continued rotation of the rotor increases the space open to the suction. Hence more gas flows in, to fill it. This process continues until the space into which the gas is flowing stops increasing. This will depend on the numbers of vanes in the compressor. After this point the enclosed volume starts to reduce if it is still connected to the compressor suction gas will be dispelled. The suction port is positioned to be cut off as soon as the vanes move beyond this point.

Internal Compression Phase The reduction in volume which occurs due to continued rotation, thus causes internal compression to take place. This will continue until the leading vane moves over discharge port. This will allow, the trapped gas to be released. The positioning of the discharge port determines the amount of internal compression.

Discharge phase It is the final phase of operation. When the leading vane passes the discharge port, the gas is open to discharge and is expelled.

CENTRIFUGAL AIR COMPRESSORS:

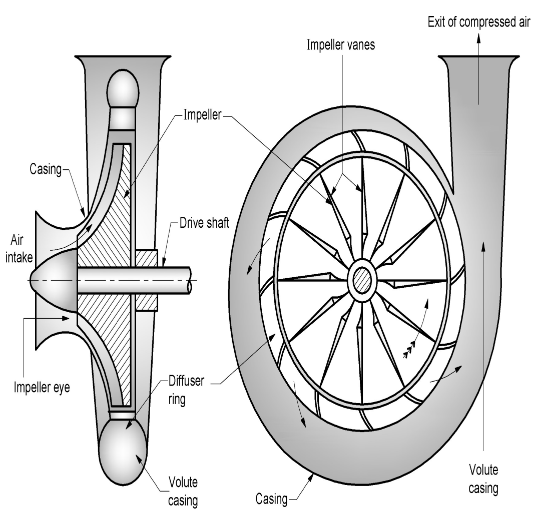


Fig. 5.10 Centrifugal Air Compressor

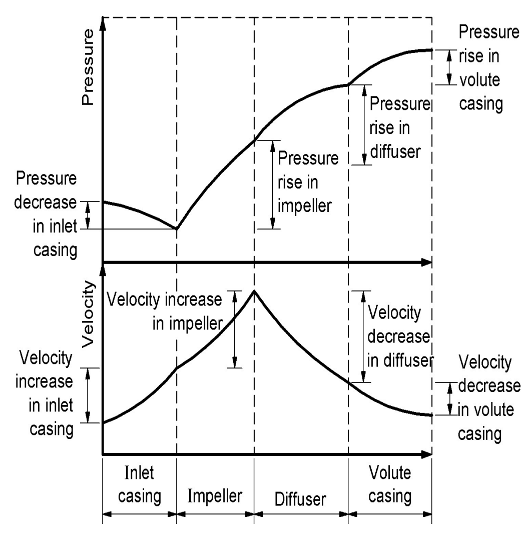


Fig.5.11 Pressure and velocity variation in a centrifugal compressor

The main components of a centrifugal compressor are shown in Fig. 5.10and are as follows:

(i) Inlet casing with convergent nozzle(ii)Inlet guide vanes (iii) Inducer section
(iv) Diffuser (v) Outer casing

(i) Inlet casing with convergent nozzle: The air enters the compressor through the inlet casing. The converging nozzle accelerates the flow.

(ii) Inlet guide vanes: It directs the flow from the inlet casing to the eye of the impeller (inducer section).

(iii) Inducer section: The function of inducer is to increase the angular momentum of air and directs the flow in radial direction.

(iv) Impeller: It consists of a disc on which series of radial blades are attached. It rotates at high speed
(up to 20,000 to 30,000 rpm). The function of the impeller is to increase the angular momentum of air by whirling the air outwards. The kinetic energy and static pressure of the air are increased by the rotating impeller.

(v) Diffuser: The function of the diffuser is to reduce the velocity of the air at the impeller outlet, thereby increase the pressure of air.

(vi) Outlet casing: The air leaving the diffuser is collected in a spiral passage known as volute casing. The spiral passage further converts the kinetic energy of air into pressure energy.

Working:

(1) When power is given to the compressor, due to rotation of the impeller, vacuum is created at the eye of the impeller, hence air is sucked axially from the inlet casing provided with accelerating nozzle.

(2) Due to acceleration of flow in the inlet casing, velocity increases, pressure and temperature of air decreases. The air then flows radially from the impeller eye (inlet diameter) to the tip (outer diameter) of the impellerblade.

(3) Due to centrifugal action of the impeller, there is increase in momentum of air flowing through it, causing a rise in static pressure, velocity and temperature of air.

(4) The air leaving the impeller enters the diffuser which consists of fixed blades. The velocity of air is reduced and pressure is increased in the diffuser.

(5) The high pressure air leaving the diffuser then passes to volute casing from where air is discharged through the compressor.

(6) The volute casing is of spiral passage with increased cross-sectional area which helps in further reducing the velocity of air and raising its pressure. Fig.5.11 shows pressure and velocity variation in a centrifugal compressor.

AXIAL FLOW AIR COMPRESSOR:

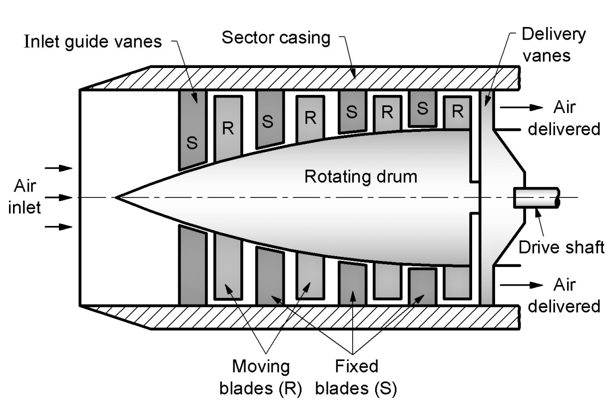


Fig 5.12 Axial Flow Air Compressor

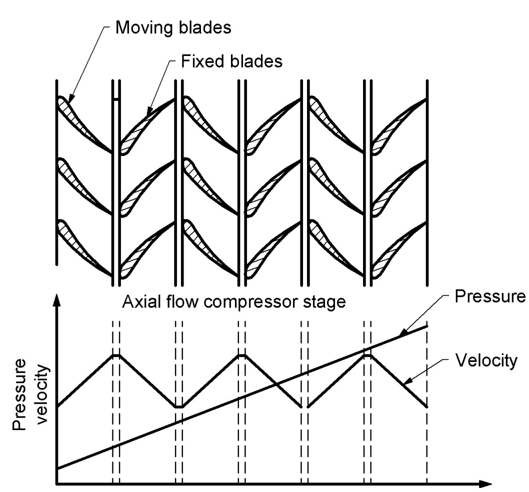


Fig. 5.13Pressure and velocity variation in Axial Flow Compressor

Construction:

(1) In an axial flow compressor, air enters and leaves along the axial direction.

(2) It consists of alternate rows of moving and fixed blades. The moving blades are fixed on a central drum called rotor and the fixed blades on the outer casing called stator.

(3) One set of fixed blade and one set of moving blade constitute a stage. The number of stages depends on the pressure ratio required.

(4) At the inlet of the compressor extra row of fixed vanes known as inlet guide vanes (IGV) are provided. These are not part of the stage but are provided to guide the air at correct angle to the first row of moving blades.

Working:

(1) When the power is given to the compressor, the rotating drum rotates and it creates suction in the compressor. Due to suction, air enters through the compressor inlet and passes through inlet guide vanes, rotor and stator blades.

(2) The work input to the rotor shaft is transferred by moving blades to air, thus accelerating the air flow. This increases the absolute velocity of air.

(3) This increase in kinetic energy is partly converted into pressure energy as the air passes through the space between the blades which form diffuser passage.

(4) Fig. 12 shows pressure and velocity variation of air through several stages of an axial flow compressor. The absolute **velocity of air increases in the rotor blade but decreases in stator blade passages.** The pressure continuously rises through the successive stage of the compressor.

(5) In the fixed blades, the air is turned through an angle so that its direction is such that it can be allowed to pass to second row of moving rotor blades and same process is repeated through remaining compressor stages.

(6) The pressure and temperature rise of air is almost same in moving as well as fixed blades and the axial velocity remains constant throughout the compressor.

(7) The pressure rise per stage in case of axial flow compressor ranges from **1.1 to 1.25** due to which large number of stages ranging from **5 to 14** are used which give **pressure ratio upto 12:1**. Pressure can further increase by increasing the number of stages.

(8) Axial flow compressors are high speed machines with speed varying from **10,000 to 30,000 rpm.** It can supply **air upto 30,000 m^3/min.**

COMPARISON BETWEEN RECIPROCATING & ROTARY AIR COMPRESSOR:

Sr. No.	Reciprocating Compressor	Rotary compressor
1	Suitable for low discharge of air at higher delivery pressure.	Suitable for handling large volume of air at low pressure.
2.	Speed of rotation is low .	Speed of rotation is quite high upto 30,000 rpm.
3.	It has intermittent delivery of high pressure air, hence receiver is required to maintain continuous delivery of air.	It has continuous delivery of high pressure air hence receiver is not required.
4.	It is poorly balanced due to presence of reciprocating parts resulting in greater vibrations.	Due to absence of reciprocating parts, machine is better balanced.
5.	Lubricating system is generally complicated as reciprocating parts as well as rotating parts are to be lubricated.	Generally simple lubricating system is required.
6.	Air delivered is generally contaminated with lubricating oil as it comes in contact with lubricating oil during compression.	Air delivered is comparatively cleaner.

Sr. No.	Reciprocating Compressor	Rotary compressor
7.	The size of the air compressor is large for a given discharge.	The size of the compressor is small for same discharge.
8.	Mechanical efficiency is less due to presence of reciprocating parts.	Mechanical efficiency is high due to absence of reciprocating parts.
9.	They cannot be directly coupled to turbines, electric motors or IC engines due to slow speed.	They can be directly coupled to high speed prime movers.
10.	Maintenance cost is high.	Maintenance cost is low.

Practical No: 6

Aim: To demonstrate vapour compression refrigeration cycle of a domestic refrigerator OR a window air conditioner OR a split air conditioner*.

REFRIGERATION

Definition: It is defined as a process of reducing the temperature of an enclosed space below that of the surroundings and maintaining this lower temperature within the enclosed space by continuously abstracting heat from it. The device used to maintain the low temperature is called refrigerator.

APPLICATIONS OF REFRIGERATION:

The major applications of refrigeration are as follows:

1. Storage and transportation of perishable food items such as fruits, vegetables, fish, meat, poultry, dairy products, frozen food etc.
2. Preservation of medicines and serums etc.
3. Comfort air conditioning of residences, auditoriums, hospitals, hotels, offices, vehicles, computer rooms etc.
4. Manufacturing of ice, dry ice etc.
5. Industries like petroleum refineries, petrochemical plants, paper pulp industries etc. require large cooling capacities for efficient manufacturing and processing.
6. Processing of textiles, printing, photographic materials etc.
7. In air separation plants to obtain N_2, O_2.
8. For liquefying gases like N_2, O_2, H_2 etc.
9. Colling of water and beverages
10. Cooling of concrete for dams.
11. For precooling and pasteurization of milk and preparation of certain milk derived products

REFRIGERATING EFFECT AND UNIT OF REFRIGERATION

- The amount of heat absorbed by the refrigeration system from the space to be cooled in a given time is called refrigerating effect. Its unit is kJ/min.
- The capacity of a refrigeration system is expressed in tons of refrigeration which is the unit of refrigeration.
- A ton of refrigeration is defined as the amount of refrigerating effect produced by uniform melting of 1 short ton (1 short ton = 900 kg) of ice from and at 0°C in 24 hours. Since latent heat of ice is 335 kJ/kg, hence one ton (1 TR) of refrigeration is given by

$$1\text{ TR} = \frac{\text{Latent heat of ice x 1 short ton}}{24 \times 60}\ \text{kJ/min}$$

$$= \frac{335 \times 900}{24 \times 60} \approx 210\ \text{kJ/min} = 3.5\ \text{kJ/sec}$$

Coefficient of performance (COP)

The performance of a refrigeration system is measured by a factor known as coefficient of performance (COP). COP of a refrigeration system is defined as the ratio of the amount of heat removed from a given space (refrigerating effect) to the work required to compress the refrigerant in the compressor.

$$\text{COP} = \frac{\text{Refrigerating effect (Q)}}{\text{Work required by compressor (W)}}$$

Higher the COP, more efficient is the device

**** Write up of this practical is for split air conditioner***

REFRIGERANT:

The working fluid used in a refrigerant equipment is known as refrigerant. It is a chemical substance that absorbs the heat from the given space by evaporating at low temperature and pressure and rejecting the heat by condensing at a high temperature and pressure. It undergoes change of phase from liquid to vapour by absorbing heat (either by expansion or vaporization) and from vapor to liquid by rejecting the heat (condensation).

DESIRABLE PROPERIES OF A GOOD REFRIGERANT:

- **Physical properties**

1. It must have **low specific volume** as it reduces the compressor size for the same refrigeration capacity.
2. It must have **low liquid specific heat and high vapour specific heat** as both increase the refrigerating effect per kg of refrigerant circulated.
3. It must have high **thermal conductivity** so that heat transfer takes place easily.
4. It must have **low viscosity** as it results in better heat transfer and low pumping power.

- **Chemical properties**

1. It must be **non-toxic** as leakage of toxic refrigerant causes suffocation and pollutes the atmosphere.
2. It must be **non-flammable and non-explosive** to avoid fire risk and explosion.
3. It must be **non-corrosive** so that it does not corrode machine components in case of leakage.
4. It must have **good chemical stability** so that it does not decompose at operating conditions.
5. It must be odourless as bad odour spoils refrigerated products.

❖ **Thermodynamic properties**

1. It must have **low boiling point** at atmospheric pressure as it provides lower refrigeration temperature.
2. It must have **low freezing point** so that liquid refrigerant does not solidify under specified pressure.
3. It must have **high latent heat of vaporization** as it increases the refrigerating effect per kg of refrigerant circulated.

❖ **Other properties**

1. It should be easily available at low cost.
2. It should not have any impact on ozone layer.
3. Any leakage should be easily detected with available leak detectors.

CLASSIFICATION OF REFRIGERANTS

The refrigerants are classified into TWO groups as shown below:

1) **Primary Refrigerants**: When refrigerants are used directly as a working medium and as carrier of heat, it absorbs heat during evaporation in the evaporator and release heat during condensation in the condenser. For example, R-12 (CCl_2F_2 – Dichlorodifluoromethane), R-22 (Difluromonochoromethane), R600 (Butane, C_4H_{10}), R717- Ammonia (NH_3), R134 etc.
2) **Secondary Refrigerants**: In large refrigeration plants, a secondary coolant is used as cooling medium which absorbs heat from refrigerated space and transfers to primary refrigerant in the evaporator. For example, water, brines, glycols etc.

IMPORTANT REFRIGERANTS:

1. Ammonia (NH_3): It has low boiling point and low freezing point. It produces high refrigerating effect, costs less and does not harm the ozone layer. It is highly toxic, flammable and corrosive hence not used in domestic refrigerator. It is used in vapour absorption system like in ice manufacturing plants, cold storage, packaging plants etc.

2. Carbon dioxide (CO_2): It has low boiling point and is non-toxic, non-flammable, inexpensive and odourless gas. It is heavier than air, hence requires high operating pressure thereby lowering efficiency of refrigeration. Due to its low specific volume, it reduces the plant size hence it is used in large ships, theatre air conditioning etc. where space consideration is more important.

3. Freon (R-12 and R-22):

R-12 (CCl_2F_2 – Dichlorodifluoromethane): It is non- flammable, non-toxic, odourless and non-corrosive. It has low boiling point (– 30 °C). It is used in small capacity equipment such as domestic refrigerators, water coolers, air conditioners, automobile air conditioning etc.

R-22 (Difluromonochoromethane): It has properties similar to R-12. Its boiling point is 10° less than R-12 and is comparatively high pressure refrigerant. It is used in commercial and industrial air conditioning. These refrigerants are highly efficient but deplete the ozone layer.

4. **Modern refrigerants - HFC (Hydro Fluro carbon):**

It contains one or more fluorine atoms but no chlorine atoms hence do not deplete the ozone layer. R-134a refrigerant known as tetra fluromethane (CH_2FCF_3) is non-corrosive, nontoxic, non-flammable and has low boiling point. This refrigerant has replaced R-12 in domestic refrigerator and air conditioners.

VAPOR COMPRESSION REFRIGERATION CYCLE:

Fig. 6.1shows schematic diagram, Fig. 6.2 Shows pressure-enthalpy(p-h) and Fig. 6.3 shows temperature-entropy (T-s) of a vapour compression refrigeration system.

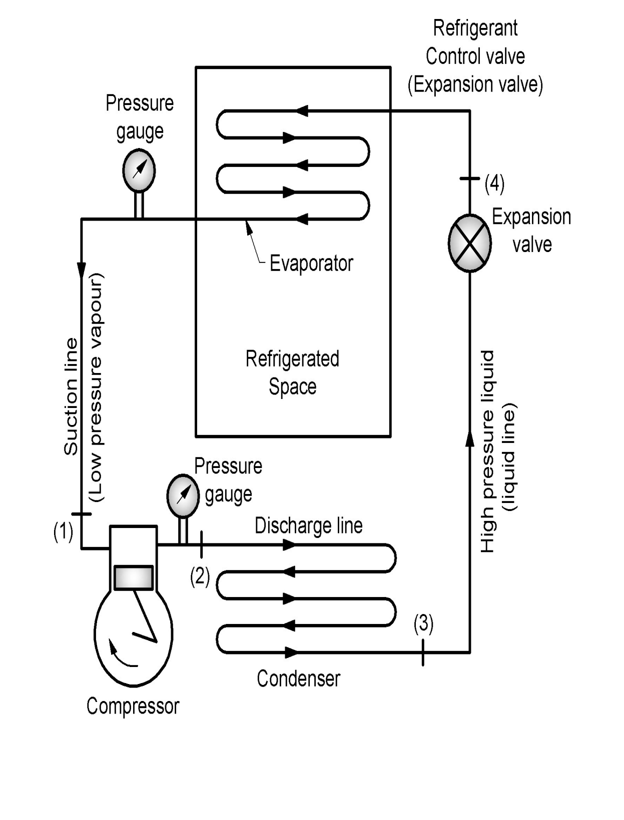


Fig.6.1: Schematic diagram of vapour compression refrigeration system

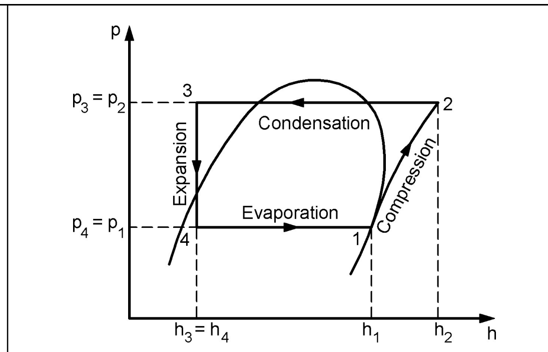


Fig. 6.2: Pressure - Enthalpy (p-h) diagram

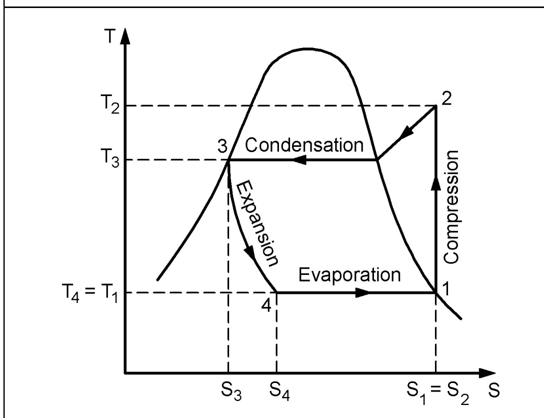


Fig.6.3 :Temperature - Entropy (T-s)diagram

It consists of four main components:

1. **Compressor**

   It draws vapor refrigerant at low pressure and low temperature from the evaporator, compresses to high pressure and temperature and supplies it to the condenser. The compression process is represented by 1-2 in p-h and T-s diagram.

2. **Condenser**

   It consists of coils (mostly made of copper / metal having good conductivity) in which refrigerant at high pressure and temperature gives away its latent heat to the cooling medium which is either air or water flowing around the condenser coils. As a result, the vapour refrigerant gets condensed to liquid state. The condensation process is represented by 2-3 on p-h and T-s diagram

3. **Expansion Device (Capillary Tube or Throttle Valve)**

   As an expansion device, capillary tube or throttle valve is used in which there is a small opening which allows the liquid refrigerant under high pressure and high temperature to pass at a controlled rate where it is expanded to low pressure and low temperature. The throttling process is represented by 3-4 on p-h and T-s diagram

4. **Evaporator**

   An evaporator consists of coils of pipe in which low pressure and low temperature liquid refrigerant is changed into vapour phase by absorbing the heat from the space being cooled (refrigerated space). The low pressure and low temperature vapour refrigerant now enters the compressor and the cycle is repeated. The evaporation process is represented by 4-1 on p-h and T-s diagram.

AIR-CONDITIONING:

- Air conditioning is defined as simultaneous control of temperature, humidity (moisture content in air), cleanliness and air motion in an enclosed space.
- Human feels comfort at following conditions:

  Temperature $\rightarrow 21 \pm 3$ °C , Humidity$\rightarrow$40 % in winter and 60 % in summer

  Air velocity$\rightarrow$0.1 to 0.25 m/sec.

SPLIT AIR CONDITIONER:

Construction

(1) A split air conditioner is similar in operation to a window room air conditioner except the components are split into two separate units instead of being entirely enclosed in a single unit as in window room air conditioner.

(2) In indoor unit (inside the room) consists of evaporator, blower driven by electric motor and capillary tube while the outdoor unit consist of compressor, condenser, fan driven by electric motor.

(3) The indoor unit may be mounted on the wall at suitable height or on the false ceiling. The two units are connected by set of electric wires and copper tubing.

(4) The distance between indoor and outdoor units must be maximum 10 to 12 m and elevation difference between them should be maximum 5 m as it causes pressure loss of the refrigerant.These units are available in capacity ranges from 1 to 3 Tons

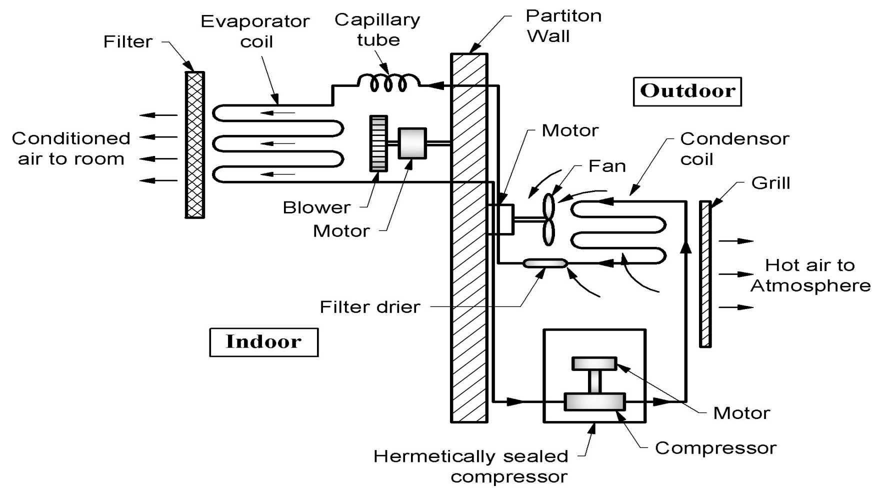


Fig.6.4:Split air conditioner

Working

(1) Low pressure and low temperature refrigerant vapour is drawn from the evaporator to the compressor and is compressed to high pressure and high temperature. This high pressure and high temperature vapour is passed through the condenser coils.The fan located at the outdoor side draws atmospheric air and blows over the condenser coils.

(2) The heat contained in the refrigerant is dissipated to the atmosphere and as a result, vapour refrigerant condenses to liquid state and passes through a filter drier. It filters the refrigerant and absorbs the moisture if it is present in the refrigerant.

(3) The liquid refrigerant at high pressure is passed through the capillary tube where it is expanded to low pressure and low temperature. The refrigerant then enters the evaporator coils.The blower draws the warm air from the room through the air filter.

(4) The low pressure and low temperature liquid refrigerant flowing through the evaporator coils absorbs the heat from the warm air and undergoes a change of phase from liquid to vapour.

(5) The air loses its heat and water removed from the air is led to the atmosphere through the drain pipe.The cooled and dehumidified air is delivered to the room by the blower through the grills which direct the flow of air.After the desired room temperature is achieved, thermostat in the air conditioner unit cuts the power supply to turn the compressor off.

(6) As the room warms up, thermostat initiates the power supply and cycle repeats till the desired temperature in the room is achieved.

When your air conditioning system has been open to the atmosphere for a period of time, it is susceptible to contamination by moisture or foreign particulate. It is important that the moisture be removed from the system, as it can be extremely harmful to the system components and to the A/C system operation due to 1) ice formation and choking the flow 2) corrosion of metallic parts resulting into presence of metallic rust in the system. In addition, even microscopic dirt or rust contamination can wreak havoc on the system. For these reasons, systems will include either a receiver dryer or an accumulator to help remove any moisture or contaminants contained within.

Receiver/Drier

The receiver/drier functions as the filter for the A/C system, removing contaminants and moisture from the refrigerant. Receiver/driers are always found on A/C systems which have an expansion valve and are located on the high side of the system, usually between the condenser and the internal expansion valve.

The receiver/drier consists of a cylindrical tank (which looks similar to a black metal can), and inside is a solid core filter which contains a drying agent (desiccant) and provides several important functions for the system:

1) The receiver/drier acts as storage tank. It receives the high pressure (hot) liquid refrigerant from the condenser and holds this liquid until the evaporator requires it. These requirements will vary according to operation conditions.
2) The solid core filter acts as a filter to capture dirt, rust, or any foreign particles.
3) The desiccant in the filter (usually in the form of silica gel or activated alumina) also serves to protect the system by removing harmful moisture from the refrigerant.

Accumulator

Alternately, many RAC systems have an accumulator instead of a receiver/drier. These systems will have a fixed orifice tube in place of the expansion valve. Although the function of an A/C accumulator is similar to the receiver/drier, it is designed a bit differently and is typically much larger. It is located on the low-pressure side of the refrigerant system, receiving low-pressure vapor from the outlet of the evaporator which it then passes along to the compressor. Some of its functions are:

1) To filter and store (accumulate) the refrigerant. If any liquid refrigerant passes out of the evaporator the accumulator will store it because liquid refrigerant is harmful to the compressor.
2) The accumulator also contains a desiccant to absorb the moisture. This is often found inside desiccant bag which can be changed when saturated.
3) Unlike the receiver-drier/expansion valve system, in this system the fixed orifice tube is responsible for filtering out impurities while restricting refrigerant flow, combining some functions of both the expansion valve and the receiver/drier.

Advantages of spilt air conditioner

1) There is negligible noise inside the room due to absence of compressor in the indoor unit.
2) It can be installed in interior room unlike in window room air conditioner which requires outside air for condenser cooling.
3) No window opening is required for fixing it. Only small hole is required to connect the indoor and outdoor unit.

Disadvantages of spilt air conditioner

1) Power consumption is higher as two separate motors are required, one each for operating blower in indoor unit and fan in outdoor unit. Also power consumption increases due to longer length of copper tubes.
2) Suction line requires better insulation.
3) It has no provision for ventilation.

Experiment No.7

AIM: To study about construction, working and applications of different types of coupling, clutch and brake.

OBJECTIVES:

1. To understand various types of couplings.
2. To be able to understand various types clutches
3. To be able to understand various types Brakes.

OUTCOMES: To understand working of couplings, clutches and brakes.

THEORY:

CouplingsCoupling is a device used to connect two shafts together at their ends for transmitting power. Shafts are usually available upto 7 m in length due to difficulty in fabrication and transportation. Long shaft is obtained by joining two or more shafts by coupling.

Shaft couplings are used in machinery for following purposes:

(1) To connect shafts of units that are manufactured separately such as motor and generator and to provide for disconnection for repairs and alterations.
(2) To join shaft having slight misalignment.
(3) To reduce the transmission of shock loads from one shaft to another.
(4) To provide protection against overloads.
(5) To alter the vibration characteristics of rotating units.

Classification of Couplings

Couplings are classified as shown in Fig. 7.1

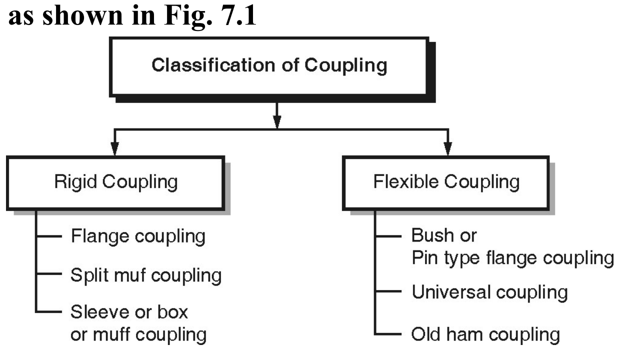


Fig. 7.1 Classification of Coupling

(1) Rigid coupling: It is used to connect two shafts which are in perfect axial alignment. They do not allow any relative motion between two shafts. The various rigid couplings are:
  (i) Sleeve or box or muff coupling
  (ii) Split muff coupling
  (iii) Flange coupling:
  (a) Protected type and (b) Unprotected type

(2) Flexible coupling: It is used to connect two shafts having both lateral and angular misalignments. They protect the driving and driven shafts from failure due to misalignment, vibrations, shock loads or thermal expansion.

The various types of flexible couplings are:
  (i) Bush - pin type flange coupling
  (ii) Universal coupling
  (iii) Oldham coupling

Sleeve or Box or Muff Coupling

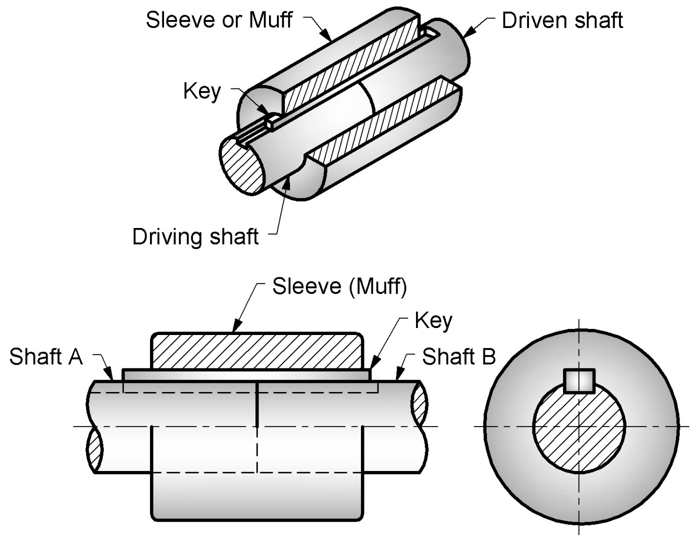


Fig. 7.2:Sleeve or box or muff coupling

It is the simplest type of rigid coupling made usually of cast iron. It consists of hollow cylinder called sleeve or box or muff whose inner diameter is same as that of the shaft. It is fitted over the ends of the two shafts with the help of gib headed or sunk taper key in the keyways of the shaft and muff as shown in Fig. 7.2. The power is transmitted from the driving shaft to key then to the muff and from the muff to the key and to the driven shaft without any relative motion between them. This coupling is used for transmission of power for small sizes of shaft. The disadvantage of this coupling is that it is difficult to assemble when there is no alignment between shafts.

Split muff or clamp or compression coupling

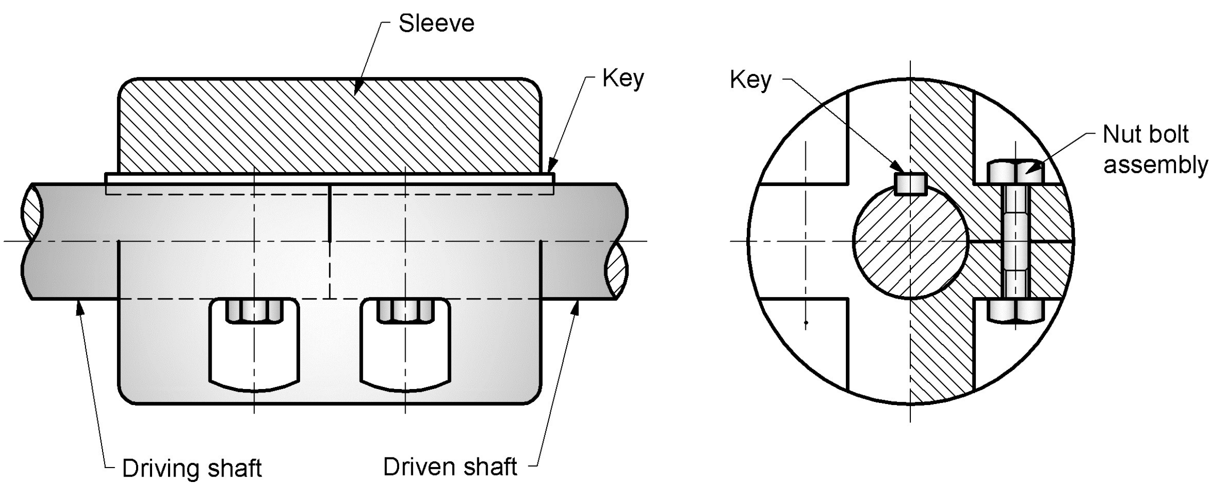


Fig. 7.3 :Split muff or clamp or compression coupling

It consists of muff or sleeve made of cast iron which is split in two halves and joined together by studs or nut bolts as shown in Fig.7.3. One-half of the muff is fixed from below and other half is placed from above. It is fitted over the ends of the two shafts with the help of key in keyways of shaft and muff. The advantage of this type of coupling is that assembling and disassembling is possible without changing the position of the shaft. This coupling is used for transmission of higher power at moderate speed.

Flange Coupling

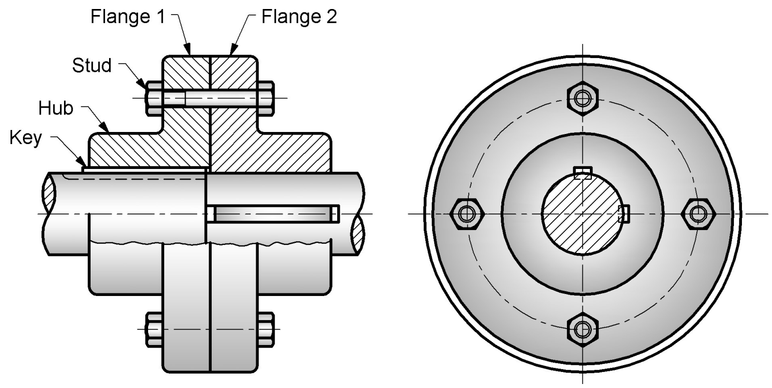


Fig. 7.4(a) :Unprotected type flange coupling

Fig. 7.4(a) shows unprotected type flange coupling. It consists of two cast iron flanges keyed to the ends of two shafts. The faces of the flanges are held together by series of bolts (usually 4 to 6) arranged concentrically about the shafts. In unprotected coupling, the heads of bolts and nuts protrude beyond the flat surfaces of the flanges. As the projections rotate with the shaft there are chances of accident as it may catch the clothes of workman. Hence in protected type flange coupling as shown in Fig. 7.4(b), a shroud or annular projection is provided which shelters the bolt and nuts. This ensures that clothes of workman are not caught during its operation. Flange couplings are used for transmission of higher torque from driving to driven shaft.

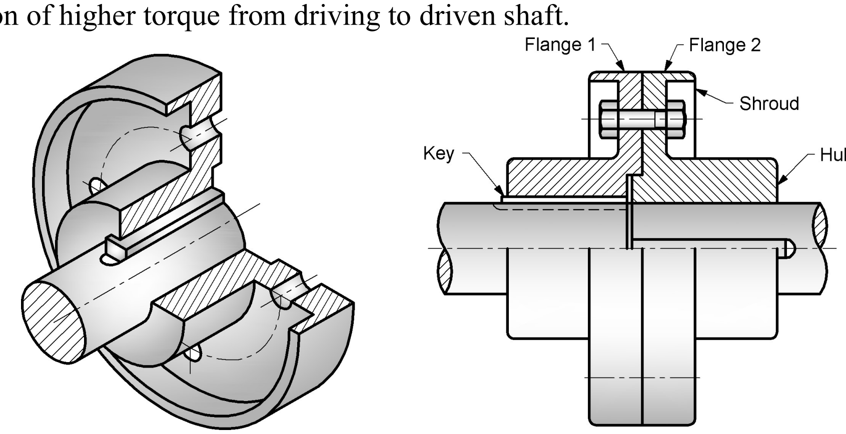


Fig. 7.4(b) Protected type flange coupling

Bush-pin Type Flange Coupling

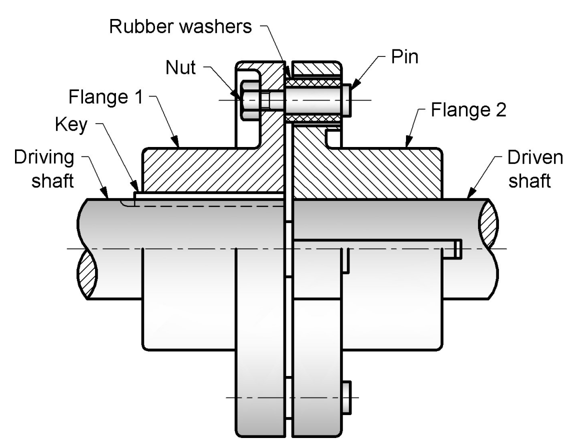


Fig. 7.5: Bush-pin type flange coupling

It is a modification of protected type flange coupling. It consists of pins which are fastened by nuts to one of the flanges and kept loose in the other flange as shown in Fig. 7.5. The pin is covered with flexible material such as rubber, leather etc. The two halves of the coupling are dissimilar in construction. This coupling is used to connect shafts which have small parallel misalignment, angular or axial displacement. The cushioning effect of the flexible material over pin helps in absorbing vibration and shock experienced by the coupling. This type of coupling is commonly used for directly connecting an electric motor to a machine.

Oldham's Coupling

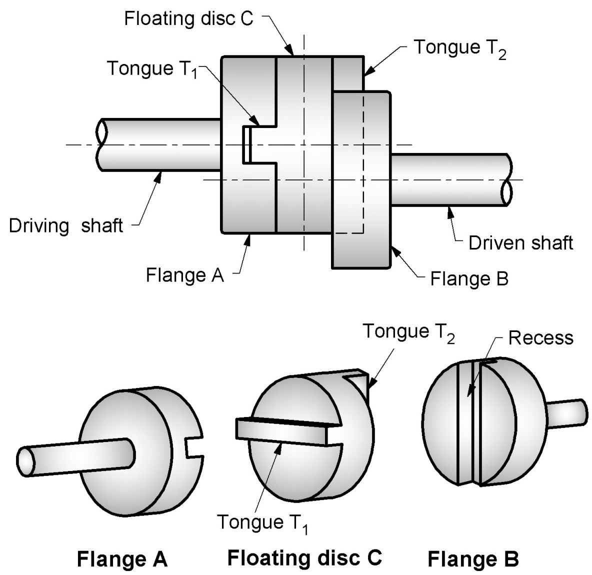
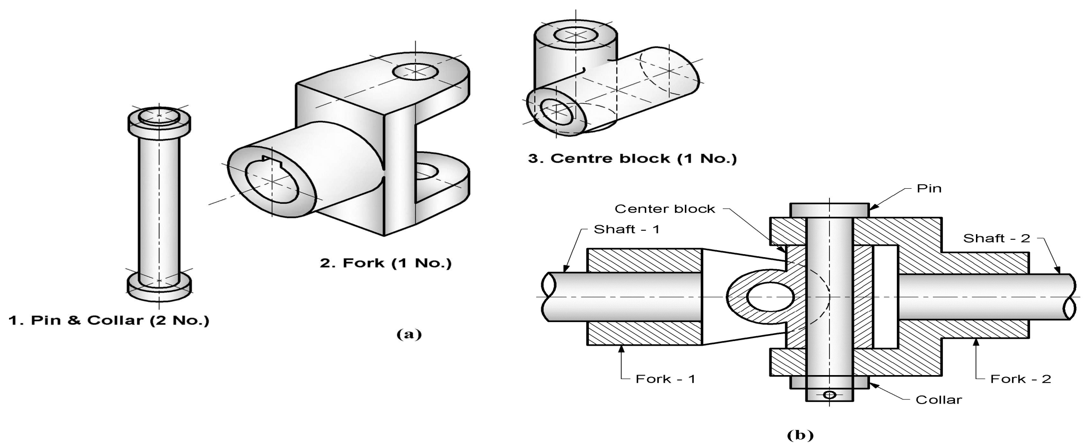


Fig. 7.6:Oldham's coupling

It is used to connect two parallel shafts when the axes are not aligned and are separated by a small distance. It consists of two flanges A and B with slots and a central floating disc C with two tongues T_1 and T_2 at right angles as shown in Fig. 7.6. Tongue T_1 is fixed in slot of flange A and allows for horizontal to and fro relative motion while tongue T_2 is fixed in slot of flange B and allows for vertical relative motion. By this arrangement, lateral misalignment of the shaft during rotation can be accommodated.

Universal Coupling or Hooke's Joint

It is used to connect two shafts whose axes intersect at a small angle. It does not allow parallel misalignment i.e. shaft must intersect. It is called universal coupling due to its multiple uses.



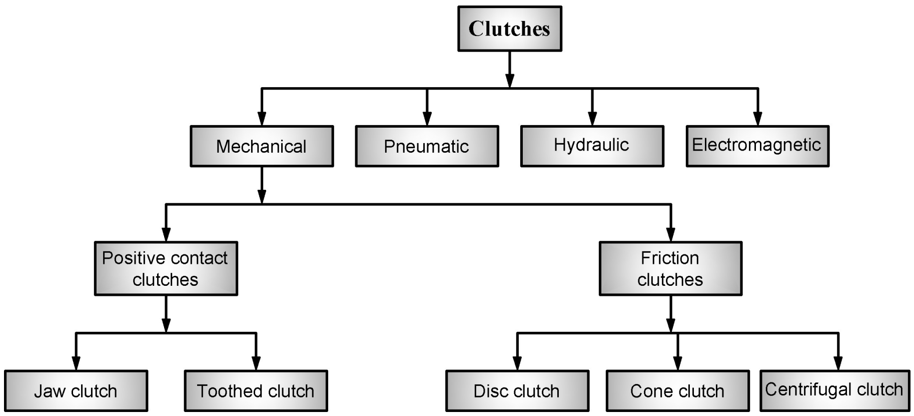
It consists of two similar forks and assembled to a central block by pin as shown in Fig. 7.7. A central block consists of two arms at right angle to each other. This type of coupling is widely used for transmitting power from gearbox of the engine to the rear axle and also in machine tools.

Clutch

A clutch is a mechanical device that is used to transmit power and motion from the driving shaft to driven shaft so that driven shaft can be started or stopped as per the need, without stopping the driving shaft. Clutch is installed between the engine and the gear box. In automobiles, while changing the gear clutch pedal is pressed to disengage the shaft and after changing the gear, the clutch pedal is released to the engine shaft.

Classification of Clutches

Clutches are classified as follows:



Friction Clutches

Friction clutches are mostly used for transmission of power and motion between two shafts which must be started and stopped frequently. They are known as friction clutches because force of friction is used for transmission of motion and power to the driven shaft. The clutch is usually engaged gradually so that the driven shaft picks up the speed without excess slipping of the friction surface. It is also used when power is fully or partially transmitted.

The various friction clutches are:

(1) Disc or plate clutch (2)Cone clutch (3)Centrifugal clutch

Single Disc or Single Plate Clutch

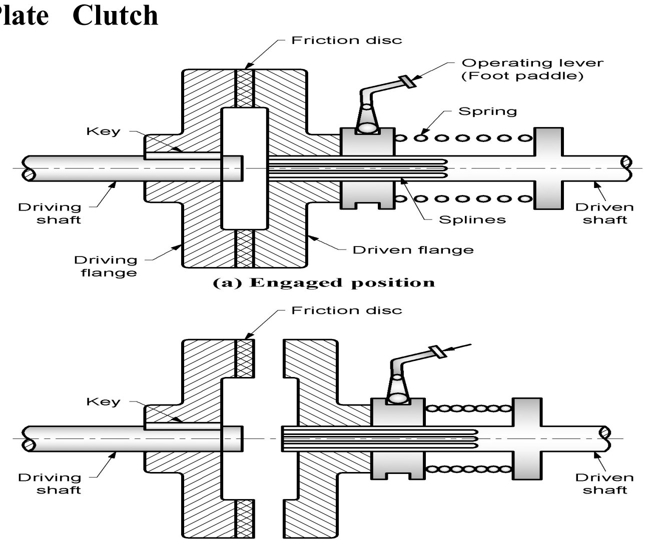


Fig. 7.8Single disc or single plate clutch

Fig. 7.8 shows schematic diagram of single plate clutch. It consists of two co-axial flanges, driving flange A and driven flange B.

(2) Flange A is rigidly fixed to the driving shaft and it cannot move axially while flange B is fitted to the driven shaft by splines so that it can slide on the driven shaft.

(3) During normal operation both the flanges remains engaged due to axial force produced by the spring.

(4) Torque and motion is transmitted from driving flange to driven flange through the friction disc when they press with each other.The amount of torque transmitted depends on the axial pressure exerted by the spring, contact surface area and coefficient of friction between the contact surfaces.

(5) Fig. 7.8 (a) and (b) show the engaged and disengaged position respectively of two shafts.

(6) Single plate clutch are used in automobiles. When large torque is to be transmitted, multi plate clutches are used. They have more than one driving and driven plates and contact surfaces.

Cone Clutch

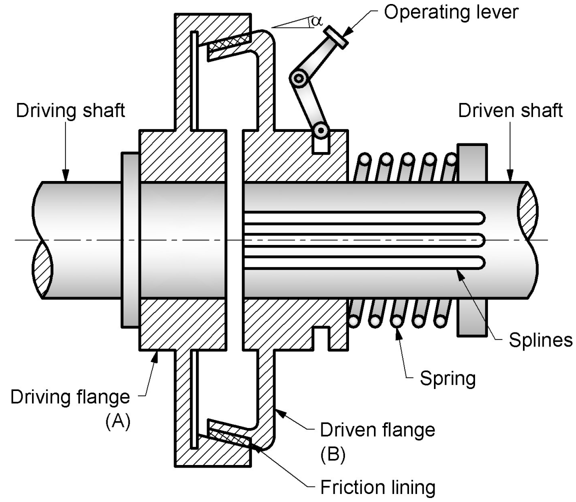


Fig. 7.9 Cone clutch

(1) It consists of driving cone fixed to the driving shaft and driven cone fitted on the drive shaft by splines so that it can slide on the driven shaft as shown in Fig. 7.9.

(2) The driven cone has an outer friction lining. The angle between the cone varies from 8° to 15°.During the normal operation, both the cones remain engaged due to the axial force produced by the spring.

(3) The torque and motion is transmitted from driving shaft to driven shaft by friction between the contact surfaces of the cones. When torque is not required to be transmitted, the cone on the driven shaft is disengaged by pressing the operating lever.

(4) This moves the driven shaft outwards and moves axially on the splines towards right side.Conical surfaces provide extra frictional force hence torque transmitted is higher than single plate clutch.

(5) Cone clutch was earlier used in automobiles but now has become obsolete because small amount of wear on the cone surface results in considerable axial movement of the driven cone which makes the life of the cone very short.

Centrifugal Clutch

The engagement of the shoe with the driven shaft takes place due to centrifugal force hence it is called centrifugal clutch.

(1) It consists of number of shoes (4 to 6) on inside of a rim of the pulley as shown in Fig. 7.10. The outer surface of the shoes is covered with friction lining.

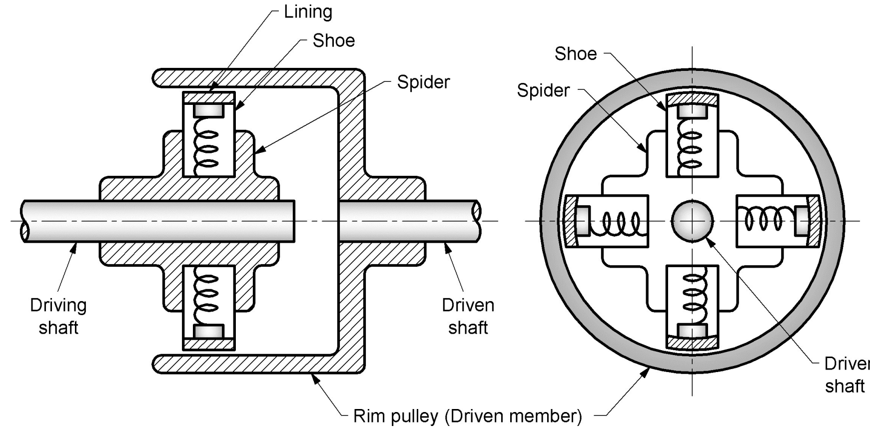
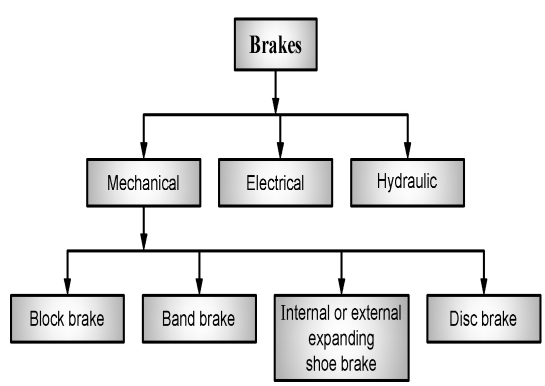


Fig. 7.10Centrifugal clutch

(2) The shoes are held in slots of the spider with springs which keep the shoe in disengaged position.When the speed of driving shaft increases, centrifugal force also increases which results in movement of shoe away from the centre in radial slots.
(3) When the centrifugal force exceeds the spring force, the shoe comes in contact with the rim of the pulley and power transmission starts.
(4) When the speed of driving shaft decreases, centrifugal force also decreases.
(5) When the centrifugal force is less than spring force, the friction shoe disconnects from the rim of the pulley and power transmission stops.
(6) Since centrifugal clutch transmits motion at certain speed and disengages below this speed, it is normally used where automatic engagement and disengagement takes place such as in gearless two wheelers like Activa, mopeds etc.
(1) A brake is a device by means of which artificial frictional resistance is applied to a moving machine member in order to retard or stop motion of a machine.
(2) In the process of performing this function, brake absorbs the kinetic energy of the moving member (eg. automobiles) or potential energy given up by the objects being lowered (eg. hoists, elevator etc.).
(3) The absorbed energy by brakes is released to the surroundings in the form of heat.
(4) This heat is dissipated to the surrounding air or water which is circulated through the passage in the brake drum.

Classification of Brakes

Brakes are classified as follows:



Single Block or Shoe Brake

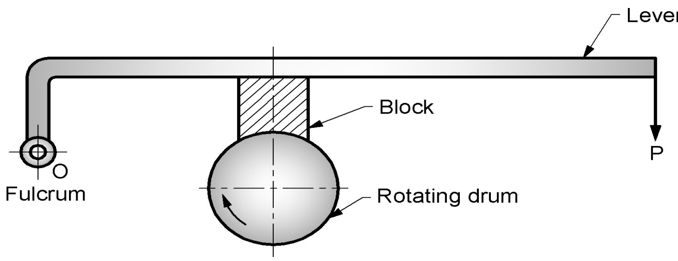


Fig. 7.11 Single block or shoe brake

(1) Fig. 7.11 shows schematic diagram of single block brake. It consists of a block which is pressed against the rim of a rotating drum.

(2) The block is made of softer material than rim so that block can be replaced when it gets weared out.
(3) The block is pivoted to the lever and is lined with frictional material.
(4) The frictional resistance between the block and rotating drum causes the braking force to act on the drum, retarding the rotation of the drum.

Applications : This type of brake is used in trains, trams cars etc.

Double Block or Shoe Brake

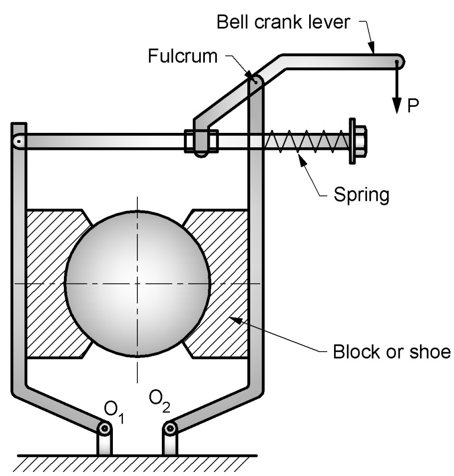


Fig. 7.12 Double block or shoe brake

(1) When a single block brake is pressed against a rotating drum an unbalance load acts on the shaft bearing supporting the drum. This produces bending in shaft.
(2) This drawback is overcome by using double block or shoe brake which consists of two blocks on opposite side of the rotating drum as shown in Fig. 7.12. This eliminates any unbalanced force.
(3) Upper end of the brake arm is held together by the spring as shown in Fig. 7.12. When the force is applied on the bell crank lever, spring is compressed and brake is released.

Applications : Double block brake is used in electric cranes.

Band Brake

(1) It consists of a flexible band of leather or rope or steel lined with frictional material which holds part of the circumference of the drum.
(2) A band brake as shown in Fig. 7.13 (a) is called simple band brakein which one end of the band

is attached to a fixed pin or fulcrum of the lever and other end at certain distance from the fulcrum on the lever.

(3) When the upward force P is applied to the free end of the lever at C, the lever turns around the fulcrum 'O' and tightens the band on the drum and hence brakes are applied. The friction between the band and the drum provides the braking force.

(4) In differential band brake, as shown in Fig. 7.13 (b) the ends are attached at a distance on either side of the fulcrum. The lever AOC is pivoted at fulcrum 'O' and two ends of the bands are attached at points A and B.

(5) Differential band brake provides higher braking torque compared to simple band brake for the same amount of effort 'P'.

Applications : Band brakes are widely used in construction equipment as well as in automobiles as hand brake.

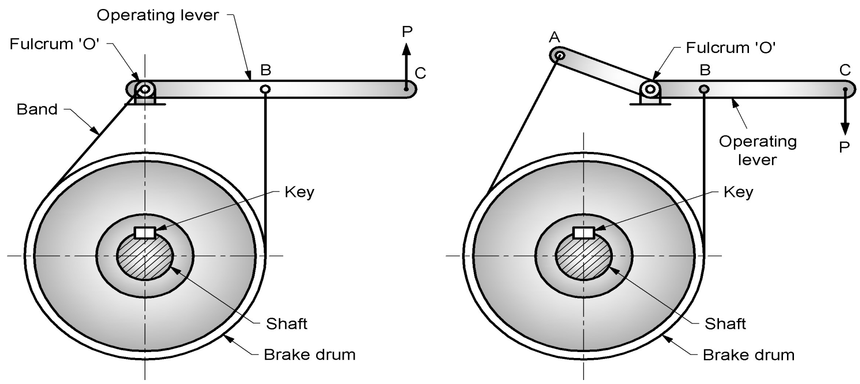


Fig.7.13 Band Brake

Internal Expanding Shoe Brake

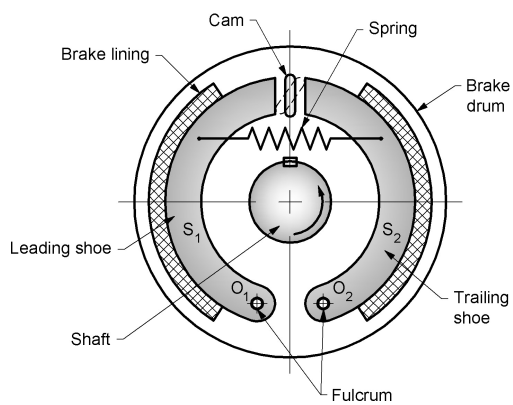


Fig. 7.14Internal expanding shoe brake

(1) The brake can be operated mechanically or hydraulically. Fig. 7.14 shows schematic diagram of mechanical operated internal expanding shoe brake.

(2) It consists of two semi-circular shoes S_1 and S_2 with lower end pivoted at fulcrum O_1 and O_2 respectively. The other free end is connected to a cam. The outer surface of the shoes is lined with frictional material.

(3) The shoes are connected by a spring which exerts inward force and keeps the brake in disengaged position with the drum.When the cam rotates, the shoes are pushed outwards against the rim of the drum.

(4) The friction between the shoes and the drum produces the braking torque thus reducing the speed of drum or stop it completely.

(5) When the cam is brought back to its original position, the spring force pulls the shoes inward and brakes comes back to its disengaged position with the drum.

Applications : These brakes are widely used in automobile vehicles such as motor cars and light trucks.

Disc Brake

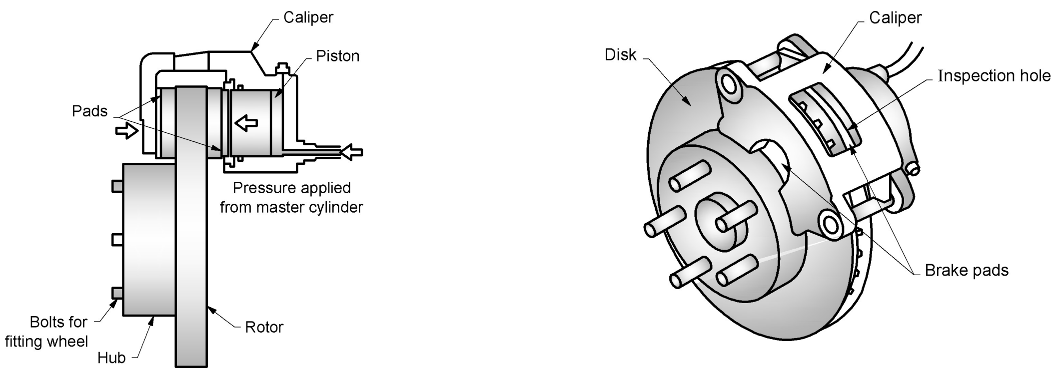


Fig. 7.15 Disc brake

(1) As shown in Fig. 7.15, it consists of a disc rotor which is attached to the wheel hub and it rotates with it. The wheel of the vehicle is bolted to the wheel hub.

(2) A brake calliper is mounted above the disc. It contains two brake pads on either side of the disc. Near the brake pad inside the calliper, piston is placed to provide brake force on the brake pads when brake pedal is pressed.

(3) When the brake pedal is pressed, the high pressure fluid from the master cylinder pushes the piston towards braking pad. The fluid pressure moves inwards and pulls the brake towards the rotating disc finally touching it.

(4) A large amount of friction is generated in between the pads and rotating disc and slows down the vehicle and finally stopping it.

(5) When the brake pedal is released, the piston is pulled back and brake pad moves away from the rotating disc and vehicle again starts moving.

Applications : Disc brakes are widely used in motor cycles and cars.

PRACTICAL NO: 8

Objective: To understand different arrangement and application of various power transmission drives

Introduction

Power is transmitted from prime mover (eg. electric motor) to the machine by means of intermediate mechanism known as drive. Themechanismswhichareusedtotransmittherequiredmotionandpowerfromone shaft to another shaft are called Mechanical drives. The various drives are belt, rope, chain and gears. Belt, rope and chain drives are flexible drives and is used when the distance between the shafts is large while gear is a rigid drive which is used when the distance between the shaft is small. These drives are extensively used in automobiles, workshops, processing and transportindustry,

1) To vary the speed and torque
2) To run several machines by single prime mover
3) To avoid thrust, shocks etc.
4) For convenience and safety purposes

Methods of drive

There are two methods of Drive:

1 Individual Drive
2 GroupDrive

Individual Drive

In this system as shown in Fig 8.1, each machine tool has its own electric motor which drives the machine through belt, chain, gearing or by direct coupling. The system is also called as self-contained drive.

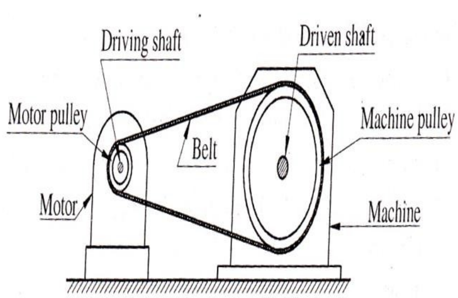


Fig.8. 1 Individual drive

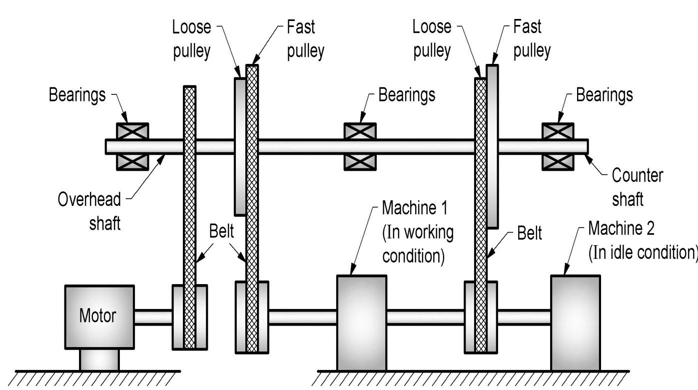


Fig. 8.2 Group Drive

Group Drive

This system as shown in fig 8.2 uses a high powered motor which drives an overhead shaft called main shaft by means of chain or belt. The main shaft runs across the workshop from one end to other end. The main shaft drives another shaft called counter shaft. Finally, the countershaft drives the group of machines through belting and pulleys.

COMPARISON BETWEEN INDIVIDUAL DRIVE AND GROUP DRIVE

Table 1 Comparison between Individual and Groupdrive

Sr.No.	Individual drive	Group drive
1.	Every machine has its own electric motor.	Large electric motor drives the main shaft. Power to different machines is transmitted through this main shaft.
2.	Motor failure causes a particular machine to remain idle and does not affect the working of other machines.	In case of motor failure, all machines become idle.
3.	Cost of power transmission is more due to large number of small motors.	Cost of machine is comparatively less.
4.	Supervision and maintenance cost of large number of small motors is more. Maintenance is easy.	Supervision and maintenance cost is less. Maintenance is difficult.
5.	Possibility of accident is less.	Possibility of accident is more due to large number of shafts, pulleys and belts.
6.	Power wastage is less hence efficiency is higher.	Power wastage is more in shafts, belts and pulley hence efficiency is less.
7.	Suitable for small workshops where machines are to be moved frequently and are scattered over large area	Suitable for medium and large workshops where machines are not scattered over large area. No flexibility in locating machines at convenient places.
8.	Individual speed control is possible	Range of speed control is wide for which cone pulleys can be used
9.	Machine shaft can be rotated inanydirection	Difficult to change the direction of mainshaft.

ELEMENTS OF POWER TRANSMISSION

The main elements of power transmission system are,

Nuts, bolts, pins, keys and couplings, etc. which are provided to hold the two components of machine elements together.

Driving and driven shafts for transmit motion and power from one place to another place.

Belts, chains, gears are as connectors for transmission of motion and power from driving shaft to drive shaft.

Axles, bearings, brackets etc. to provide support to other elements of a machine.

SHAFT, SPINDLE AND AXLE:

Shaft

A shaft is a rotating machine element which transmits power. The power is delivered to the shaft by the application of tangential force and the resulting turning moment set up in the shaft allows the power to be transmitted from one point to another point. Generally,shaftsofcylindricalshapeareusedbutshaftswithsquareandhexagonalcrosssectionarealsoused inpractice.Hollowshaftsarepreferredsincetheseare50%lighterinweightcomparedtosolidshaftsforthe same rigidity and stiffness. Hollow shafts also used whenever it is required to pass through components of a machine.

Fig 8. 3 Shaft

Fig 8.4 Spindle

Fig 8.5 Axle

Axle:

It is a stationary shaft which is used to support rotating parts such as pulleys and gears. They are subjected to bending moment only. Shaft transmits power while axles do not transmit any power.

Spindle:

It is a machine shaft that drives or supports either cutting tool or work piece during the machining operation. It is subjected to both twisting moment and bending.

TYPES OF MECHANICAL DRIVES

There are mainly three types of mechanical drives

1. Beltdrive 2. Rope drive 3. Chaindrive 4. Geardrive

Belt drive

The belts or ropes are used to transmit power from one shaft to another by means of pulleys which rotate at the same speed or at different speeds. The amount of power transmitted depends upon the following factors

1. The velocity ofbelt.
2. The tension under which belt is placed onpulleys.
3. The arc of contact between the belt and the smallerpulley.

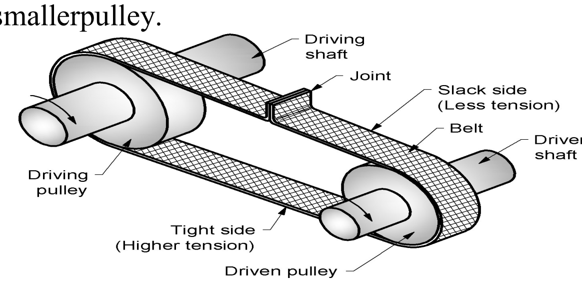


Fig 8.6 Belt Drive

Belt drives are one of the common methods used whenever power or rotary motion is required to transmit between two shafts.

1.Open belt drive

Thistypeofbeltdriveisusedtotransmitpowerwhentwoparallelshaftrotatingissamedirection.The lower side belt because of more tension is known as tight side whereas the upper side belt because of low tension is known as slack side. Due to lower tension on the slack side, the belt sags due to its own weight.

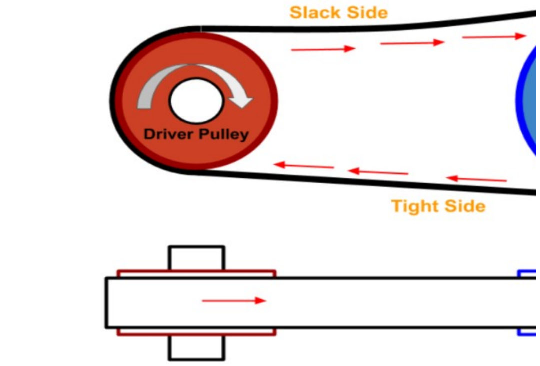


Fig 8.7Open belt drive

2. Cross Belt Drive

This drive transmits power when shafts are parallel but rotate in opposite direction. This type of drive should be used for large distance between two shafts and for lowerspeed.

Slip in the belt is low but is subjected to greater wear and tear compared to open drive

.

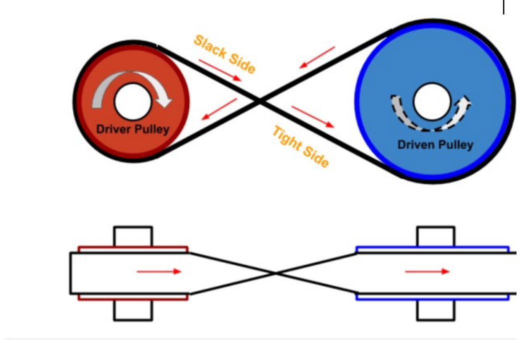


Fig 8.8. Cross Belt Drive

3.**Quarter turn beltdrive**

The quarter turn belt drive is also known as right angle belt drive. It is used to transmit power between two shafts at right angle. When the reverse motion is desired this arrangement is not suitable.

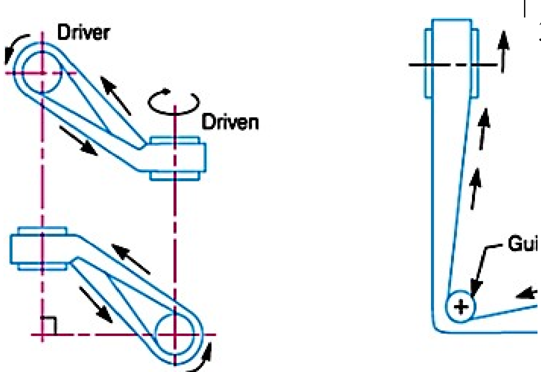


Fig 8.9 Quarter turn beltdrive

4.**Belt drive with Idler pulley**

After long time of running the length of belt may be increases, so angle of contact decreased. To increase it, it is required to increase tension. To increase tension in belt, Idler pulley is used.

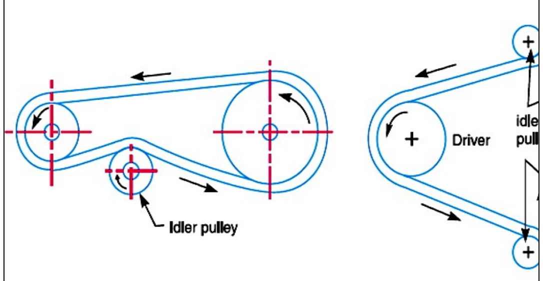
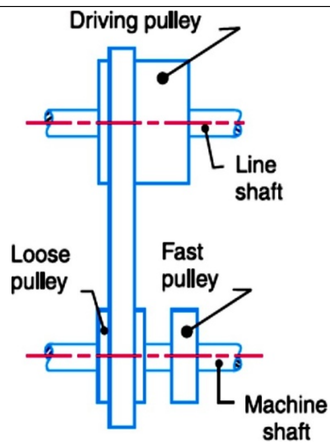
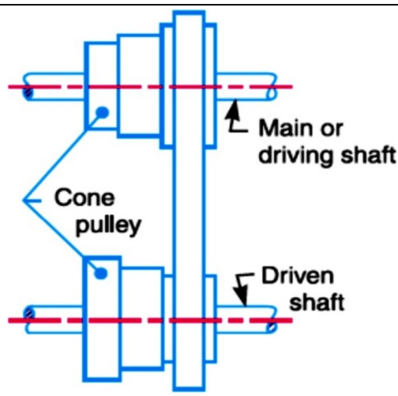
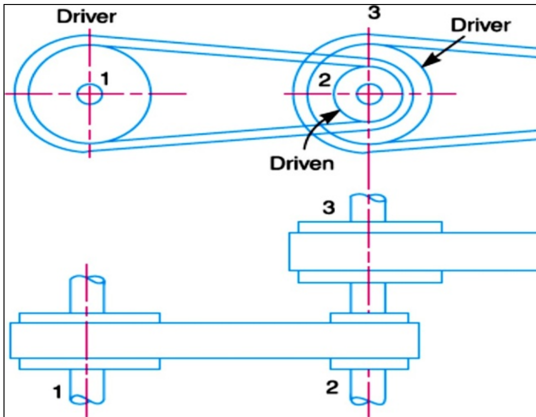


Fig 8.10 Belt drive with Idler

pulley	
 **Fig 8.11 Fast and loose pulley**	**5.Fast and loose pulley** A set of fast and loose pulley is used when the machine shaft is to be started or stopped whenever desired without stopping the driving shaft. Fast pulley is keyed to the shaft and loose pulley is free to rotate. When it is required to stop the driven pulley the belt is pushed to loose pulley with the help of belt shifter as shown in Fig 8. 11
 **Fig. 8.12 Stepped/Cone pulleydrive**	**6. Stepped/Cone pulleydrive** It is used for changing the speed of driven shaft while the driving shaft runs at constant speed. This is done by shifting the belt from one part of the step to the other.
	7. Compound beltdrive A compound belt drive is used when large speed ratio required and there is large center distance between two shafts. As shown in fig.13 power is transmitted from pulley 1 to pulley 4 through intermediate pulley 2 and 3.

 **Fig.8.13 Compound beltdrive**	

TYPES OF BELTS:

1.Flatbelt

The flat belt is mostly used in the factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another when the two pulleys are not more than 8 meters apart.

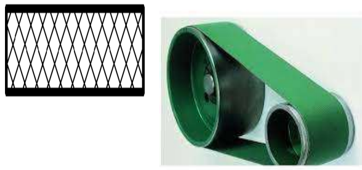


Fig.14 Flatbelt

2.V belt

It is trapezoidal in cross-section where the lower width is in contact with the pulley. It runs in the matching groove on the pulley which provides better grip. These belts are made of nylon, cotton, fabrics or vulcanized rubber. It is used for large power transmission for short distances between the shafts.

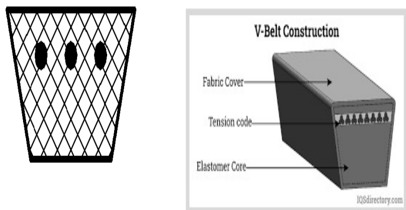


Fig.15 V belt

3.Circular belt orRope

Rope drive is used for transmission of power from one pulley to another over moderately long distance. Its central distance usually varies from 9 m to 30 m. The ropes are placed in grooved pulleys with groove angle of around 45°.For transmitting large power, number of ropes of smaller diameter is used rather than single rope of large diameter. Ropes are made from cotton, manila or hemp. Steel wire ropes are used where extra strength is required.Rope drive is used in cranes, elevators, hoists, aerial rope ways etc

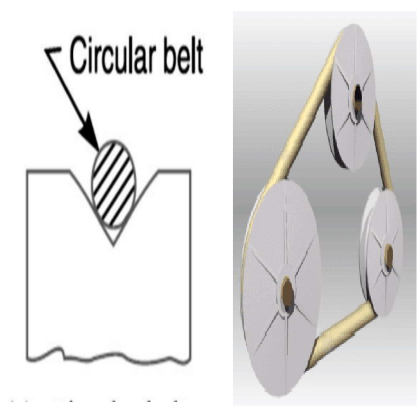


Fig.16 Circular belt orRope

4.Timing belt

It has teeth on the contact side of the belt. These teeth match with the grooves provided on the driver and driven pulleys on the respective shafts. Materials of the belt are similar as in V-belts. They are known as positive drive belts as the slip is negligible. They are costlier than V-belts and are used to transmit high power at relatively shorter distance

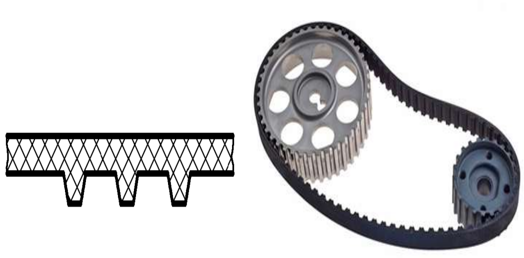


Fig.17 Timing belt

CHAIN DRIVE:

In this drive, series of connected links are hinged together to form a chain. The chain is wrapped over a toothed wheel known as sprocket. There are two sprockets driving sprocket and driven sprocket. The sprockets have projected teeth which fit into recesses in the links of chain as shown in Fig.8.18. Chain drive is used to transmit the motion from one shaft to other where constant velocity ratio is required without any slip. Chain drives are mostly used when the Centre distance between the sprockets is short. They can be used up to 8 m centre distance. They are used for transmission of power in agricultural machinery, textile machinery, motor vehicles, cycles, road rollers, material handling equipment etc. The main types of chain used for power transmission are roller chains, bush chains and silent chains. Roller and bush chains are used for low and medium velocity ratio whereas silent chain is used for high speed ratios due to its smooth and quiet operation.

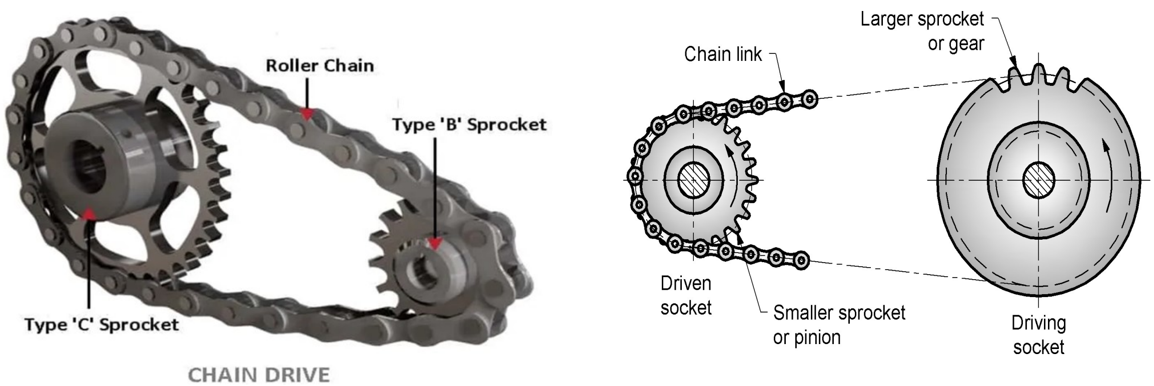


Fig. 8.18 Chain Drive

Advantages

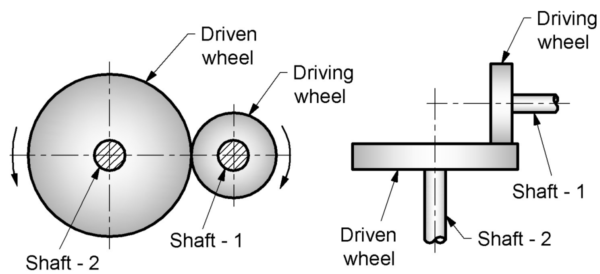
1. It is positive drive with negligible slip and gives constant velocity ratio.
2. It gives high transmission efficiency (up to 98 percent).
3. It can transmit higher power than belt drives.
4. They occupy less space than belt drives and are used when distance between the centre is small or medium.
5. They occupy less space in width compared to belt drives.
6. Chain drive has the ability to transmit motion to several shafts by one chain only.

Disadvantages

1. Due to wear, chain gets loosened so tightening is necessary after some interval of time. This results in velocity fluctuations.
2. Production cost of chain is comparatively high.
3. Driving and driven shaft should be accurately aligned.
4. It is noisy in operation.
5. It requires more lubrication, service, maintenance and repairs compared to belt drive.
6. The design is very complicated.

GEAR DRIVE AND FRICTION DRIVE

A gear is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit toque and power. Inordertotransmitadefinitepowerfromoneshafttoanothershafttotheprojectionononediscandreces ses on another disc can be made which can mesh with eachother.



(a) Drive with parallel axes **(b) Drive with intersecting axes**

Fig 8.19 Gear Drive And Friction Drive

Inearlydays,frictiondiscsasshowninfigure 19 wereusedfortransmittingthepowerfromoneshafttoanother shaft. In such a case, the power transmission capacity depends on friction between surfaces of two discs. Therefore, this method is not suitable for transmitting higher power as slip occurs between thediscs.

Advantages of gear drive

1. It is a positive drive (no slip) i.e. it transmits exact velocity ratio from one shaft to anothershaft.
2. It can transmit very largepower.
3. High transmissionefficiency.
4. It requires less space.
5. This drive is morereliable.

Disadvantages of gear drive

1. Manufacturing cost ishigh.
2. Maintenance cost is also high due to lubricationrequirements.
3. The error in cutting teeth may cause vibrations and noise duringoperation.
4. It requires precise alignment ofshafts.

TYPES OF GEARS:

Various types of gears commonly used in industry are:

(i) Spur gears (ii) Helical gears (iii) Spiral gears (iv) Bevel gears
(v) Worm gears (vi) Rack and pinion

Spur gear:

It is used to transmit motion between two parallel shafts. The teeth of the gear wheels are cut straight on the circumference of the wheel and are parallel to the axis of the wheel.

It can transmit higher power as the contact between the mating gears is along the line. They are used in machine tools, gear boxes, watches, precession measuring instruments etc.

The disadvantage of spur gear is that each time a gear teeth mesh, teeth collides and this impact makes a noise. It also increases the stress on the gear teeth.

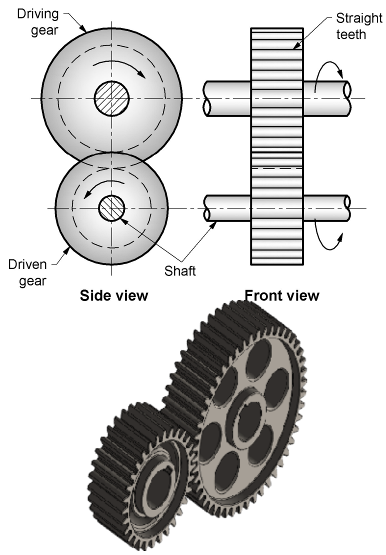


Fig 8.20 Spur Gear

Helical gears

These gears are similar to spur gear except that the teeth make an angle with the axis of the shaft called helix angle as shown in Fig. 21 .Helical gears are used for transmitting power between two parallel shafts and also between non-parallel, non-intersecting shafts.Always right hand helical gear meshes with left hand helical gear and helix angle is same for both mating gears.Theteeth of helical gears engage gradually and hence less noise is observed during its operation compared to spur gears. As the gear's teeth is inclined at an helix angle, it creates a thrust load on the gear when they mesh.

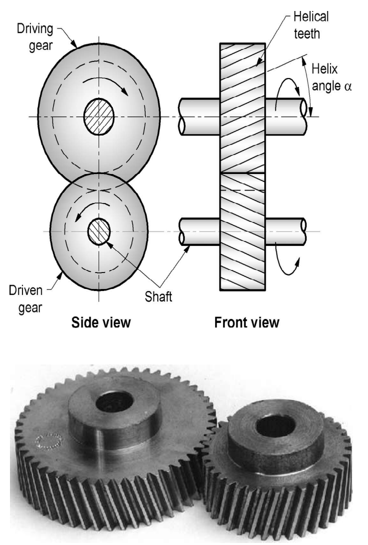


Fig8.21 Helical Gear

Doublehelical/herringbone gear

The problem of axial thrust is solved by use of double helical gears called herringbone gears in which two helical gears with of opposite hands (right and left hand) are used as shown in Fig. .22. As it runs, equal and opposite thrusts are produced on each wheel eliminating the axial thrust on the shaft.Helical gears are mostly used in automobile power transmission where smooth and quiet running is necessary at higher speeds.

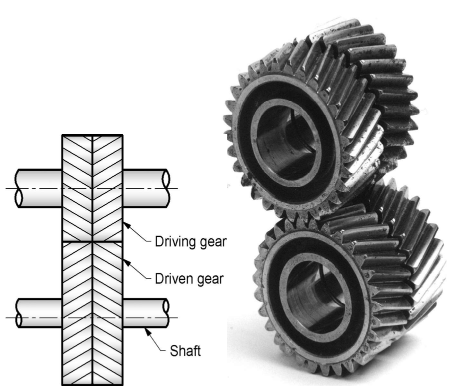


Fig.8.22 Doublehelical /Herringbone gear

Spiral gear

The teeth of spiral gears as shown in Fig 8.23 are similar to helical gears cut along the helical path on the periphery of the wheel. It is used to transmit power from one shaft to another shaft which are non-parallel and non-intersecting. Due to point contact between mating teeth it can transmit less power hence it is mostly used in instruments. It is also called skew gears or crossed helical gears.

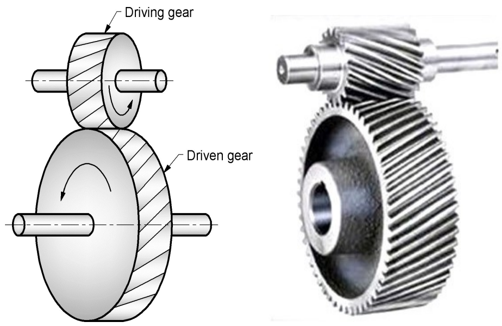


Fig 8.23 Spiral Gear

Bevel gears

Bevel gears are used for transmitting power between two intersecting shafts. The teeth are cut on the conical surface and vary in cross-section throughout their length.

These gears are mostly used when the two shafts are at right angles and both gears are of equal size as shown in Fig.8.24 Such gears are known as **mitre** gears. If the shaft is not at right angles, then such gears arecalled **angular bevel** gears.

If the teeth of bevel gears are spiral instead of straight, then it is called **spiral bevel** gears.Spiral bevel gears has very low noise and gives smooth running. It is used in locomotives, marine applications,automobiles,printingpresses,coolingt owers, power plants,steelplants,railwaytrackinspection machines, etc.

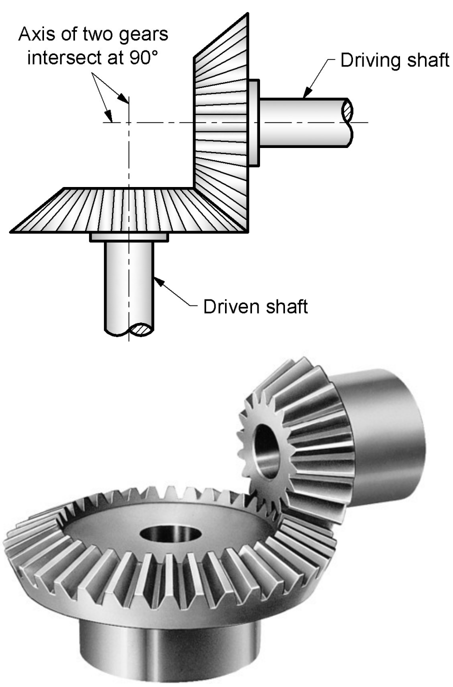


Fig 24 Bevel Gears

Rack and Pinion gear

Rack and pinion gears are used to convert rotary motion into linear motion. It is a special case of spur gear in which one gear is having infinite diameter called "Rack". A perfect example of this is the steering system of car. It is also widely used in measuring instruments.

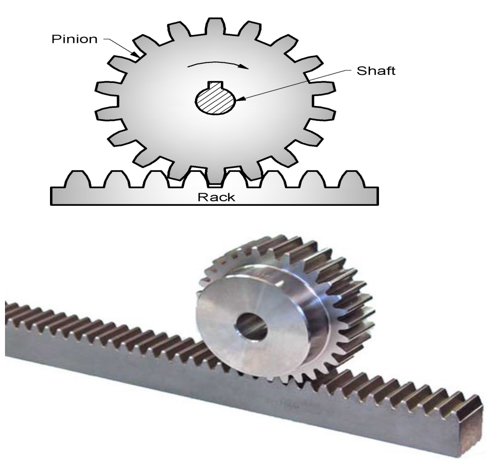


Fig25Rack and Pinion gear

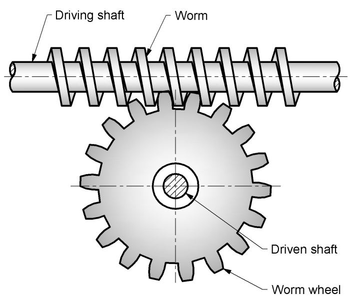


Fig 26 Worm and Worm wheel

Worm and Worm wheel

It is used to transmit power from one shaft to another shaft which are non-intersecting and their axes are normally at right angles to each other. Worm gears are used when large gear reductions are needed.

It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater. Worm gears are used widely in material handling and transportation machinery, machine tools, automobiles etc.

Experiment No. 9

Combined Separating and Throttling Calorimeter

AIM: To understand construction and working of combined separating and throttling calorimeter.

THEORY:

- Complete separation of water particles by mechanical means is not possible in separating calorimeter and throttling calorimeter cannot measure dryness fraction of very wet steam as very wet steam cannot become superheated after throttling.
- In order to overcome above limitations and for accurate measurement of dryness fraction of wet steam, a combined separating and throttling calorimeter is used as shown in Fig. 9.1.

Construction and working

(1) In this calorimeter, separating and throttling calorimeter are connected in series. Wet steam from the sampling tube is first passed through the separating calorimeter where most of the water particles present in the steam is separated, drained out and collected in a tank.

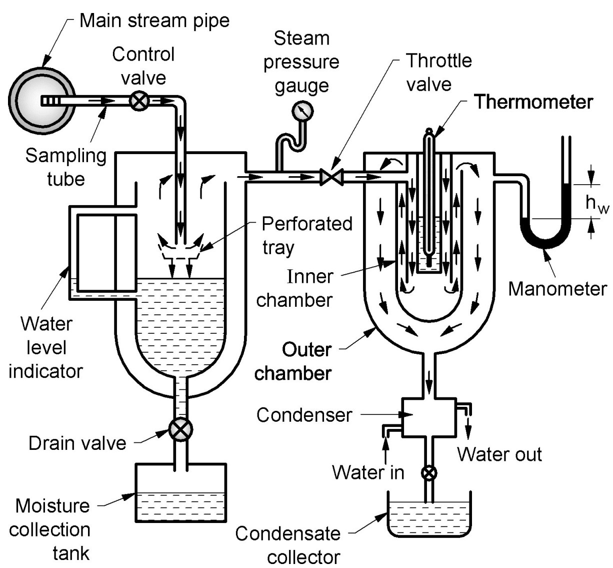


Fig. 9.1 Combined separating and throttling calorimeter

(2) This steam, instead of condensing in a barrel calorimeter, is now passed through throttling calorimeter where it gets superheated without any change in its enthalpy.

(3) The pressure and temperature of steam after throttling are measured by manometer and thermometer respectively.

(4) The steam which comes out of the throttling calorimeter is condensed in the condenser and weighed. It gives the mass of dry steam.

Calculation of dryness fraction

Let x_1 = Dryness fraction of steam measured by separating calorimeter

As per definition of dryness fraction

$$x_1 = \frac{m_s}{m_s + m_w} \qquad ...(9.1)$$

where

m_s = Mass of steam passing from the separating calorimeter into throttling calorimeter in kg

m_w = Mass of water collected in the separating calorimeter in kg

Let x_2 = Dryness fraction of wet steam measured by the throttling calorimeter

p_1 = Pressure in steam main

p_2 = Pressure of steam before throttling

Pressure in separator is small, hence $p_1 = p_2$

h_{f2} = Enthalpy of water at pressure p_2 in kJ/kg

h_{fg2} = Latent heat of steam at pressure p_2 in kJ/kg

p_3 = Pressure of steam after throttling in bar

h_{g3} = Enthalpy of saturated steam after throttling in kJ/kg

t_{sup3} = Temperature of superheated steam after throttling in°C

t_{s3} = Saturation temperature at p_3 in °C

For constant enthalpy process

$$h_{f2} + x_2\, h_{fg2} = h_{g3} + C_p\,(t_{sup3} - t_{s3})$$

$$\therefore x_2 = \frac{h_{g3} + C_p\,(t_{sup3} - t_{s3}) - h_{f2}}{h_{fg2}} \qquad ...(9.2)$$

If x is the initial dryness fraction of steam, then

Water droplets in the steam sample = $(1 - x)\,(m_s + m_w)$ kg

$\therefore$ Water droplets removed by separating calorimeter

$= (1 - x_1)\,(m_s + m_w)$ kg

Water droplet passing through throttling calorimeter

$= (1 - x_2)\, m_s$ kg

Now,

$$\begin{pmatrix}\text{Water droplet}\\ \text{in the steam}\\ \text{sample}\end{pmatrix} = \begin{pmatrix}\text{Water droplets}\\ \text{removed by}\\ \text{separating}\\ \text{calorimeter}\end{pmatrix} + \begin{pmatrix}\text{water droplets}\\ \text{passing through}\\ \text{throttling}\\ \text{calorimeter}\end{pmatrix}$$

$$\therefore\ (1 - x)\,(m_s + m_w) = (1 - x_1)\,(m_s + m_w) + (1 - x_2)\, m_s$$

$$\therefore\ (1 - x) = (1 - x_1) + (1 - x_2)\,\frac{m_s}{m_s + m_w}$$

$$\text{As } x_1 = \frac{m_s}{m_s + m_w}$$

$$\therefore\ (1 - x) = (1 - x_1) + (1 - x_2)\, x_1$$

$$\therefore\ (1 - x) = (1 - x_1) + (1 - x_2)\, x_1$$

$$1 - x = 1 - x_1 + x_1 - x_1 x_2$$

$$\therefore x = x_1 \cdot x_2 \qquad ...(9.3)$$

Experiment No. 10

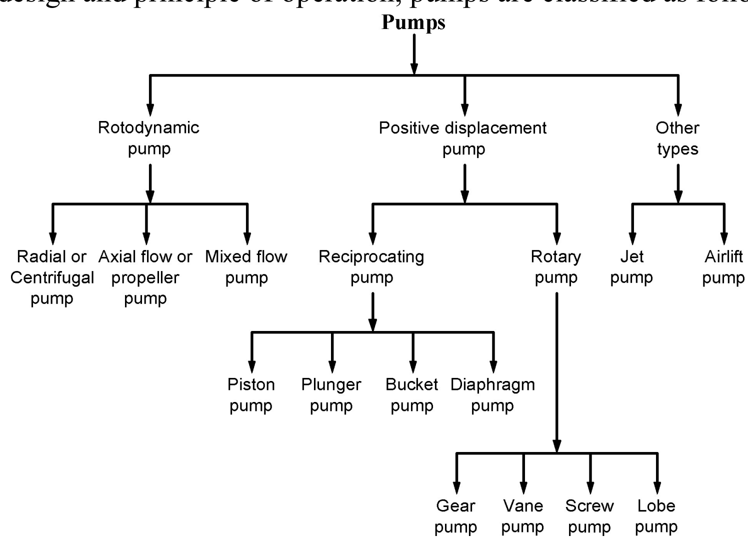
AIM: To understand construction and working of different types of pumps

THEORY:

A pump is defined as a machine which when driven from external source such as electric motor, lifts water or some other liquid from lower level to higher level. It converts the mechanical energy into hydraulic energy. The hydraulic energy is in the form of pressure energy.

Classification of pumps

According to the design and principle of operation, pumps are classified as follows:



Reciprocating pump

Components of Reciprocating Pump

Fig. 10.1 shows schematic diagram of single acting reciprocating pump. The function of different components is described as follows:

(1) Piston and cylinder: Piston reciprocates inside the cylinder. The reciprocating motion is obtained by means of connecting rod. The piston is connected to connecting rod by piston pin.

(2) Crank and connecting rod mechanism: Crank is mounted on the crankshaft which is driven by prime mover. Crank is connected to the piston by connecting rod which converts the rotary motion of the crank into reciprocating motion of the piston.

(3) Suction pipe: It connects the source of water (sump) and the cylinder.

(4) Suction valve: It is a non-return valve which admits the water from suction pipe into the cylinder.

(5) Delivery pipe: Water is discharged from the cylinder at high pressure to the required height by means of delivery pipe.

(6) Delivery valve: It is a non-return valve which admits water from the cylinder to the delivery pipe.

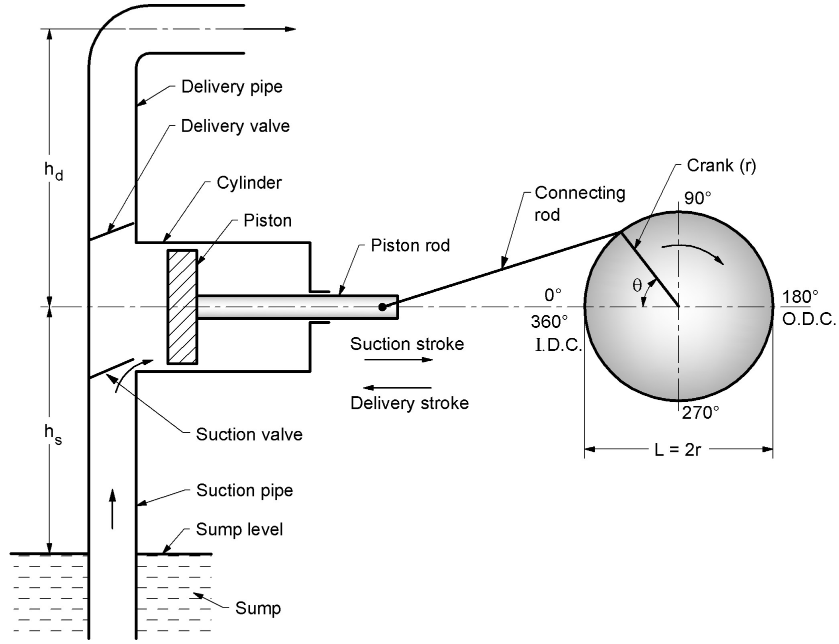


Fig. 10.1 Main parts of reciprocating pump

Working of single acting Reciprocating Pump

1. In a single acting pump, water acts on one side of the piston only as shown in Fig. 10.1. When the crank starts rotating, the piston moves forward and backward in a close fitting cylinder.
2. During the suction stroke, the piston moves towards right from inner dead centre (I.D.C) to outer dead centre (O.D.C) i.e. from 0 to 180° in clockwise direction, thus creating partial vacuum on the left side of the piston in the cylinder.
3. The pressure in the sump is atmospheric while pressure on left side of the piston inside the cylinder is below atmospheric. This pressure difference causes suction valve to open and water is forced to enter through the suction pipe to the left side of the piston.
4. When the crank reaches O.D.C, the piston is on extreme right position and suction stroke is completed. The cylinder is full of liquid.
5. During the delivery stroke, crank rotates from O.D.C to I.D.C i.e. 180° to 360°, in clockwise direction and the piston moves from extreme right position towards extreme left position.
6. This movement of the piston increases the pressure of the water in the cylinder which causes the suction valve to close and delivery valve to open.
7. Thus water is forced into the delivery pipe and is raised to the required height. At the end of delivery stroke, the crank comes to I.D.C and the piston to the extreme left position.

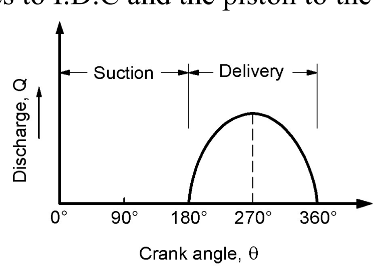


Fig.10.2Discharge (Q) v/s Crank angle (θ) variations for single acting pump

8. The variation of discharge of water (Q) through delivery pipe with crank angle (θ) for single acting reciprocating pump is shown in Fig. 10.2.
9. The discharge obtained in single acting pump is intermittent as discharge is obtained only during delivery stroke.

10. As the piston has simple harmonic motion, the discharge curve is a sine curve as shown in Fig. 10.2.

Centrifugal Pump

If the mechanical energy is converted into pressure energy by the action of centrifugal force acting on the fluid, the hydraulic machine is called centrifugal pump. Centrifugal pump is known as rotodynamic pump as dynamic pressure is developed to lift the liquid from lower level to higher level.

Main Components of Centrifugal Pump

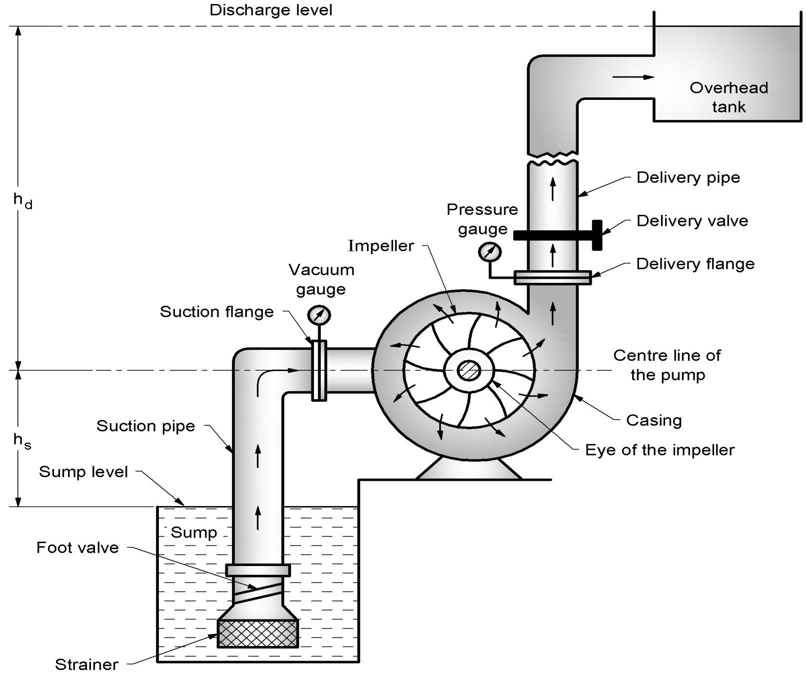


Fig. 10.3 Components of Centrifugal Pump

A centrifugal pump has the following main components as shown in Fig.10.3.

(1) Impeller: The rotating part of a centrifugal pump is called impeller. Whirling motion is imparted to the liquid by means of finite number of backward curved vanes (usually 6 to 12) provided on the impeller. The impeller is mounted on the shaft which is coupled to the shaft of the electric motor.

(2) Casing: It is an air tight passage surrounding the impeller.

The functions of casing are:

(a) To guide water to and from the impeller.

(b) It is designed with gradually increasing area, hence when water flows through the casing the kinetic energy of water is converted into pressure energy before water leaves the casing.

(3) Suction pipe with foot-valve and strainer

The upper end of the suction pipe is connected to the centre (eye) of the impeller and the lower end is submerged into the sump from which water is to be pumped. Suction pipe is provided with strainer at its lower end so as to prevent the entry of solid particles, debris etc. into the pump. A foot valve (non-return valve) is located above the strainer which allows the flow of water only in upward direction. Therefore, this valve does not allow the liquid to drain out of the suction pipe.

(4) Delivery pipe

One end of the delivery pipe is connected to the outlet of the pump and other end is connected to the overhead tank at required height. A valve is provided in the delivery pipe near the outlet of the pump called delivery valve. Its function is to regulate the supply of liquid from the pump to delivery pipe.

Working of Centrifugal Pump

A centrifugal pump works on the principle that when a certain mass of liquid is made to rotate by an external prime mover, it is thrown away from the central axis of rotation and a centrifugal head is imparted which raises the liquid to higher level. The steps involved in operation of centrifugal pump are as follows:

(1) The delivery valve is closed and the suction pipe, casing and portion of the delivery pipe upto the delivery valve is completely filled with the liquid so that no air pocket is left. This process is called priming.

(2) The electric motor is started which rotates the impeller. The delivery valve is kept closed. This creates strong suction or vacuum at the eye of the impeller and causes the liquid to rise into the suction pipe from the sump.

(3) The speed of the impeller is gradually increased till the impeller rotates at its normal speed.

(4) After the impeller attains its normal speed, the delivery valve is opened. Now the liquid is continuously sucked by the suction pipe and passes through the centre (eye) of the impeller. The liquid is allowed to flow through the impeller vanes and attains higher velocity and comes out at the outlet tip of the vanes into the casing.

(5) As the casing is designed with a gradually increasing area, the velocity of the liquid decreases and pressure head increases. From casing, the liquid passes into the delivery pipe and is lifted to the required height.

(6) When the pump is stopped, the delivery valve should be closed to stop the backflow of liquid, but if a foot valve (non-return valve) is provided then it is not necessary to close the delivery valve as it will not allow the back flow to occur.

Rotary pumps

It is a positive displacement pump with rotary motion. In a rotary pump, the liquid is entrapped in a reducing passage between two set of engaging surfaces such as gears, lobes, vanes, screws etc. and the pressure rise is obtained. They are suitable for pumping viscous fluids like vegetable oil, lubricating oil, grease, tar etc.

They are classified as

(i) Gear pump (ii) Vane pump and (iii) Screw pump

Gear Pump

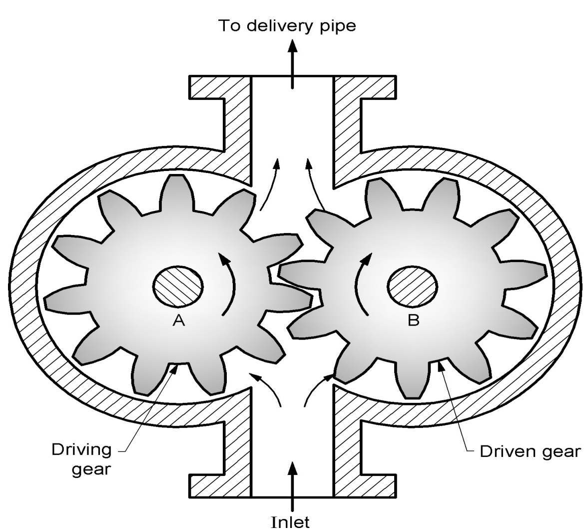


Fig. 10.4 Gear pump

It is a positive displacement pump with rotary motion. It consists of two identical intermeshing spur gears A and B with a fine clearance inside the casing as shown in Fig. 10.4. One gear is coupled to an electric motor and it drives the other gear (driven gear) in opposite direction. Before starting the pump, it is filled with the liquid. Due to rotation of gears, a partial vacuum is created on the suction side. This causes liquid to enter the pump. The liquid is trapped between pair of teeth and the casing. The rotating gears build up sufficient pressure to force the liquid into the delivery pipe.

Vane pump

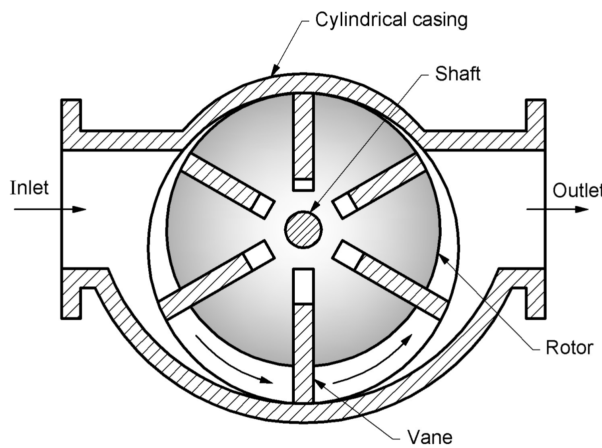


Fig. 10.5 Vane pump

Fig. 10.5 shows schematic diagram of vane pump. It is a positive displacement pump with rotary motion. It consists of a cylindrical casing in which an eccentric rotor is mounted. The rotor has about 4 to 8 slots containing sliding vanes. These vanes can slide radially into the slots. Springs are used to press the vanes against the casing. Before starting the pump, casing is filled with the liquid to be pumped. When the rotor rotates, vanes are driven out of the rotor towards the casing due to centrifugal force. The space between two adjacent vanes, rotor and casing increases creating vacuum. Thus liquid is drawn from the inlet pipe. As the rotor continues to rotate, the liquid is trapped in the pockets formed between the vanes and the casing. The vanes build up sufficient pressure to force the liquid into the delivery pipe.

Screw Pump

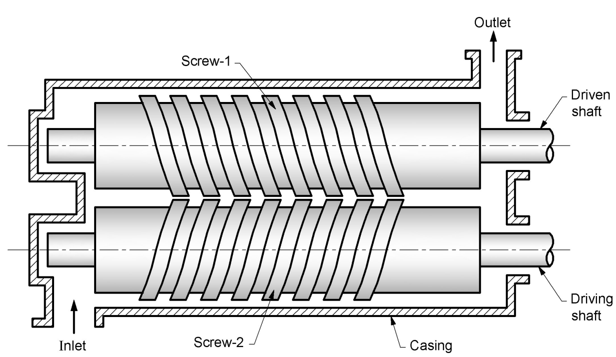


Fig. 10.6 Screw pump

It is a positive displacement pump with rotary motion. It consists of two mating helical grooved rotors with very small clearance. These two gears are housed in a cylindrical casing with inlet and outlet ports as shown in Fig. 10.6. Screw-2 shown in Fig. 10.6 is the driving rotor driven by an electric motor while screw-1 is the driven rotor. The two rotors rotate in opposite direction. As the rotors rotate, liquid is drawn through the inlet port to fill the space between two screws and the liquid is trapped between the two rotor space. The liquid is then displaced axially at outlet.

QUIZ

Practical No	Title of the Practical	Questions:
1	To understand construction & working of various types of Boilers	1. What is a boiler? Define boiler according IBR. 2. Classify boilers. 3. For following types of Boilers explain Fuel + Air to Gas circuit as well as Water to Steam circuit with neat diagram. a. Lancashire Boiler b. Babcock-Wilcock Boiler 4. Compare the fire tube boiler and water tube boiler.
2	To understand construction and working of different boiler mountings & accessories	1. State the function of boiler mountings and boiler accessories. 2. Differentiate between boiler mounting and accessories. 3. Which mountings are connected to only water space of steam boiler? State their function. 4. Which mountings are connected to only steam space of steam boiler? State their function. 5. Explain with neat sketch working of water level indicator, spring loaded safety valve and fusible plug. 6. State the function of Economizer ,Super heater , Air Preheater, Feed Water Pump, Steam Injector , Steam Trap etc.
3	To understand construction features of two/four stoke petrol/diesel engines	1. State function of following components of I.C. engines: Crank shaft b) Cam shaft c) Flywheel d) Fuel Pump e) Fuel Injector f) sparkplug g) carburetor 2. Explain with neat sketch construction and working of 4 stroke diesel engine 3. Explain with neat sketch construction and working of 2 stroke petrol engine 4. Differentiate between: a) Petrol & Diesel Engine b) 2 stroke and 4 stroke cycle I.C. engine
4	To determine brake thermal efficiency of an I. C.Engine.	1) Explain working of rope dynamometer to find brake power of I.C. engine 2) Define following terms related to I.C. Engines a) Brake Power b) Indicated Power c) Brake Specific Fuel Consumption

		d) Brake Thermal Efficiency
5	To understand construction and working of different types of air compressors.	1. Give classification of Air Compressor. 2. Explain importance of multi staging in compressors. 3. Explain with neat sketch construction and working of (i) Roots blower (ii) Centrifugal compressor 4. Differentiate between a) Pump & Compressor b) Positive Displacement Vs Dynamic Type Air Compressor
6	To demonstrate vapour compression refrigeration cycle of a domestic refrigerator OR a window air conditioner OR a split air conditioner.	1. Define following terms with respect to Refrigeration & Air Conditioning a)1 Tonne of refrigeration b) Coefficient of performance 2. Explain with neat sketch construction and working of vapour absorption type refrigeration cycle 3. Explain with neat sketch working of domestic refrigerator working on vapour compression cycle 4. State important properties of a refrigerant.
7	To study about construction, working and applications of different types of coupling, clutch and brake.	1. Classify couplings. 2. Explain following types of couplings with neat diagram. a. Sleeve or muff couplings b. Split muff coupling c. Flange couplings d. Oldham coupling e. Universal coupling 3. Discuss various types of clutches with diagrams. 4. Discuss various types of brakes with diagrams 5. Differentiate between brake and clutch.
8	To understand different arrangement and application of various power transmission drives	▪ State the difference between shaft, spindle and axle. ▪ Discuss with neat sketch gear terminology ▪ Explain with neat sketch construction and working of different types of gear trains. ▪ Compare belt drive, chain drive and gear drive.
9	To understand construction and working of combined separating and throttling calorimeter.	1. Define following terms related to steam: a. Wet steam b) Dry and saturated steam c) Superheated steam d) Dryness fraction f) Degree of super heat g) Enthalpy of formation h) Enthalpy of evaporation i) Heat of super heat 2. State different uses of steam.

		3. With a neat diagram explain construction and working of separating calorimeter. Derive an expression for determining its dryness fraction. 4. With a neat diagram explain construction and working of throttling calorimeter. Derive an expression for determining its dryness fraction.
10	To understand construction and working of different types of pumps	1. Define pump and classify them. 2. Describe construction and working of single acting reciprocating pump. 3. Describe construction and working of centrifugal pump & explain how priming is done in this type of pump 4. Define rotary pump. Describe construction and working of vane type of rotary pump. 5. Identify proper pump for following applications: a) To handle filtered water b) To handle crude oil c) To handle refined petroleum products and sediments d) To handle water having mud e) To handle vegetable oil in oil mill f) To handle precious chemicals which are in liquid state