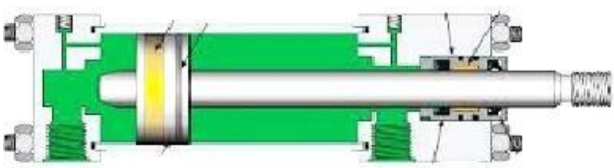
3

HYDRAULIC PUMPS, MOTORS, VALVES AND ACTUATORS



Course Contents

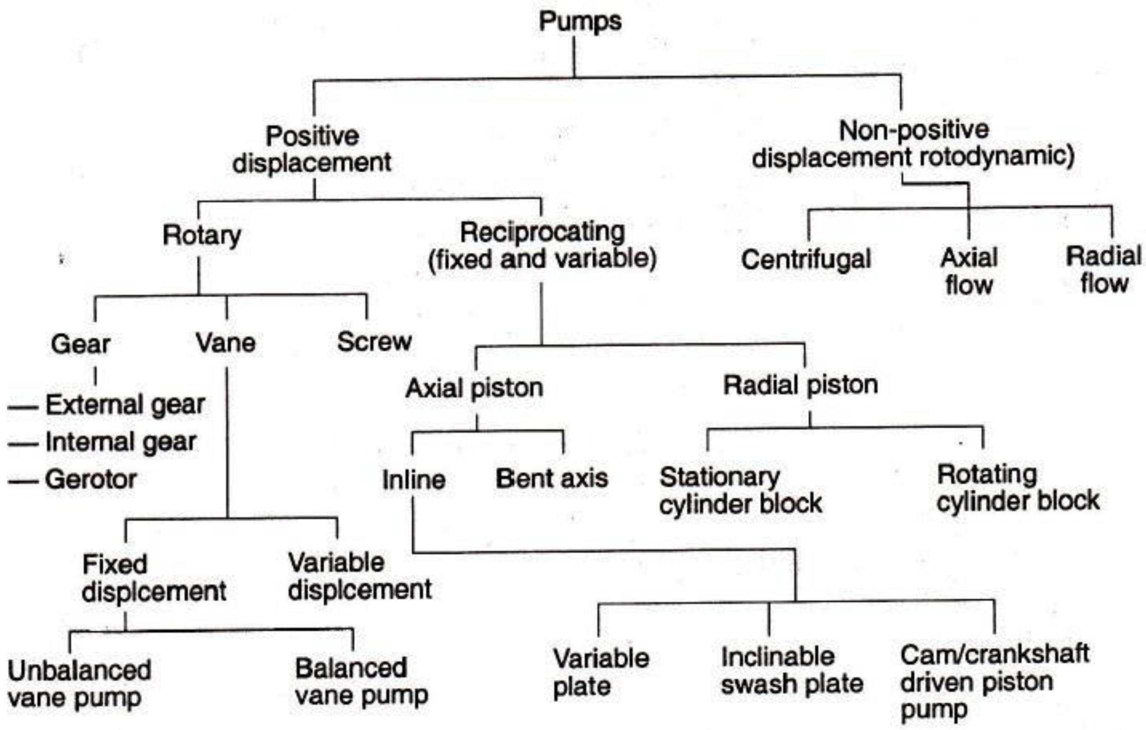
3.1 HYDRAULIC PUMPS

A pump will have an inlet called suction and an outlet called delivery. It converts mechanical energy in to hydraulic energy. Pump is also known as heart of hydraulic system. The basic principle is that Due to mechanical action, the pump created partial vacuum at its inlet. This permits atmospheric pressure to force the fluid through the inlet line and in to the pump, then pump pushes the fluid into the hydraulic system.

− These are mainly classified into two categories:

(a) Non-positive displacement pumps (Hydrodynamic/Rotodynamic)

(b) Positive displacement pumps (Hydrostatic)



(a) Non-positive displacement pumps (Hydrodynamic/Rotodynamic)

− In these pumps the fluid is pressurized by the rotation of the propeller and the fluid pressure is proportional to the rotor speed. These pumps can not withstanding high pressures and generally used for low-pressure and high-volume flow applications.

− The fluid pressure and flow generated due to inertia effect of the fluid. The fluid motion is generated due to rotating propeller. These pumps provide a smooth and continuous flow but the flow output decreases with increase in system resistance (load).

− Simply external work is imparted to fluid in the control volume in the form of kinetic energy and change in pressure energy is almost negligible.

− The important advantages of non-positive displacement pumps are lower initial cost, less operating maintenance because of less moving parts, simplicity of operation, higher reliability and suitability with wide range of fluid etc. These pumps are primarily used for transporting fluids and find little use in the hydraulic or fluid power industries. ***Centrifugal pump*** is the common example of non-positive displacement pumps.

(b) Positive displacement pumps (Hydrostatic)

− These pumps deliver a constant volume of fluid in a cycle. The discharge quantity per revolution is fixed in these pumps and they produce fluid flow proportional to their displacement and rotor speed. These pumps are used in most of the industrial fluid power applications. The output fluid flow is constant and is independent of the system pressure (load).

− Simply the energy transferred to the fluid purely in pressure energy form and change in kinetic energy is almost negligible. It is important to note that the positive displacement pumps do not produce pressure but they only produce fluid flow.

− The important advantage associated with these pumps is that the high-pressure and low-pressure areas (means input and output region) are separated and hence the fluid cannot leak back due to higher pressure at the outlets. These features make the positive displacement pump most suited and universally accepted for hydraulic systems.

− The important advantages of positive displacement pumps over non-positive displacement pumps include capability to generate high pressures, high volumetric efficiency, high power to weight ratio, change in efficiency throughout the pressure range is small and wider operating range pressure and speed. Important positive displacement pumps are ***gears pumps, vane pumps and piston pumps***. The details of these pumps are discussed in the following sections.

3.1.1 Gear Pumps

− Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids.

These pump includes helical and herringbone gear sets (instead of spur gears), lobe shaped rotors similar to Roots blowers (commonly used as superchargers), and mechanical designs that allow the stacking of pumps. Based upon the design, the gear pumps are classified as:

(a) External gear pumps

(b) Lobe pumps

(c) Internal gear pumps

− Generally gear pumps are used to pump:

- Petrochemicals: Pure or filled bitumen, pitch, diesel oil, crude oil, lube oil etc.
- Chemicals: Sodium silicate, acids, plastics, mixed chemicals, isocyanates etc.
- Paint and ink
- Resins and adhesives
- Pulp and paper: acid, soap, lye, black liquor, kaolin, lime, latex, sludge etc.

• Food: Chocolate, cacao butter, fillers, sugar, vegetable fats and oils, molasses, animal food etc.

(a) External gear pumps

− The external gear pump consists of externally meshed two gears housed in a pump case as shown in figure 3.1 one of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear.

− The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion whereas the gear teeth come out of the mesh.

− When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears.

− The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth.

− The clearance between gear teeth and housing and between side plate and gear face is very important and plays an important role in preventing leakage. In general, the gap distance is less than 10 micrometres. The amount of fluid discharge is determined by the number of gear teeth, the volume of fluid between each pair of teeth and the speed of rotation.

− The important drawback of external gear pump is the unbalanced side load on its bearings. It is caused due to high pressure at the outlet and low pressure at the inlet which results in slower speeds and lower pressure ratings in addition to reducing the bearing life.

− Gear pumps are most commonly used for the hydraulic fluid power applications and are widely used in chemical installations to pump fluid with a certain viscosity.

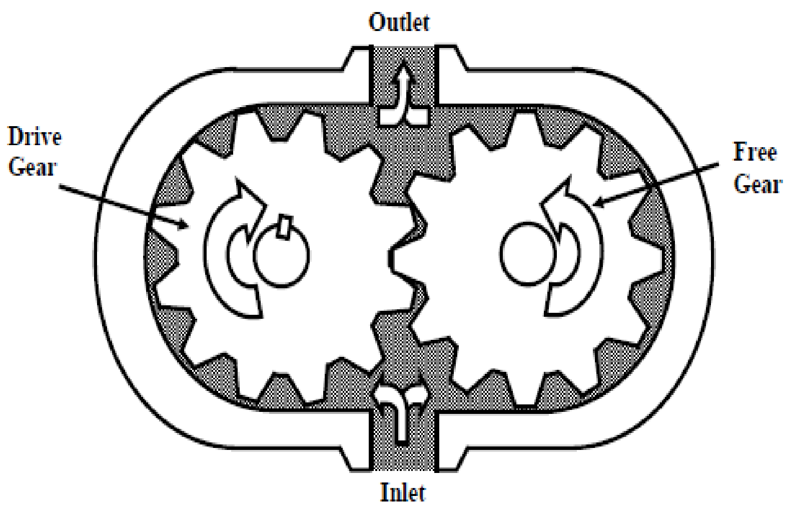


Figure 3.1 - External gear pump

(b) Lobe pumps

− Lobe pumps work on the similar principle of working as that of external gear pumps. However in Lobe pumps, the lobes do not make any contact like external gear pump (see Figure 3.2).

− Lobe contact is prevented by external timing gears located in the gearbox. Similar to the external gear pump, the lobes rotate to create expanding volume at the inlet.

− Now, the fluid flows into the cavity and is trapped by the lobes. Fluid travels around the interior of casing in the pockets between the lobes and the casing. Finally, the meshing of the lobes forces liquid to pass through the outlet port. The bearings are placed out of the pumped liquid. Therefore the pressure is limited by the bearing location and shaft deflection.

− Lobe pumps are widely used in industries such as pulp and paper, chemical, food, beverage, pharmaceutical and biotechnology etc.

− These pumps can handle solids (e.g., cherries and olives), slurries, pastes, and a variety of liquids. A gentle pumping action minimizes product degradation.

− Lobe pumps are frequently used in food applications because they handle solids without damaging the product. Large sized particles can be pumped much effectively than in other positive displacement types. As the lobes do not make any direct contact therefore, the clearance is not as close as in other Positive displacement pumps.

(c) Internal gear pumps

− Internal gear pumps are exceptionally versatile. They are often used for low or medium viscosity fluids such as solvents and fuel oil and wide range of temperature. This is non-pulsing, self-priming and can run dry for short periods. It is a variation of the basic gear pump.

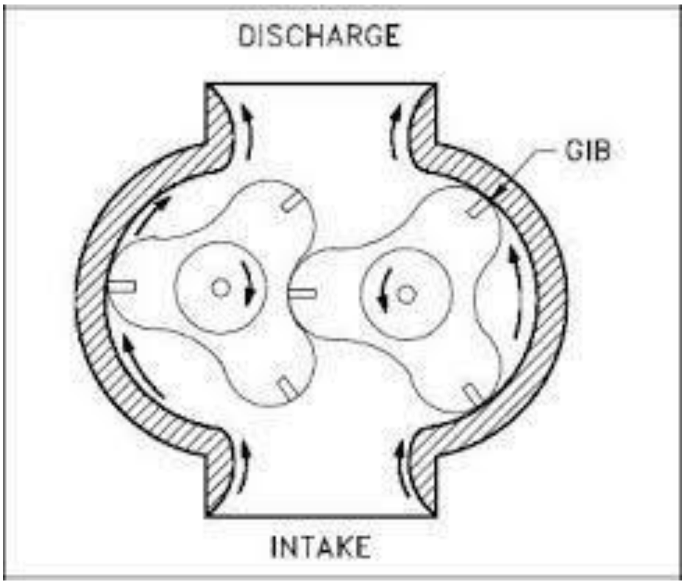


Figure 3.2 - Lobe pump

− It comprises of an internal gear, a regular spur gear, a crescent-shaped seal and an external housing. The schematic of internal gear pump is shown in Figure 3.3.

− Liquid enters the suction port between the rotor (large exterior gear) and idler (small interior gear) teeth. Liquid travels through the pump between the teeth and crescent. Crescent divides the liquid and acts as a seal between the suction and discharge ports.

− When the teeth mesh on the side opposite to the crescent seal, the fluid is forced out through the discharge port of the pump. This clearance between gears can be adjusted to accommodate high temperature, to handle high viscosity fluids and to accommodate the wear.

− However, these pumps are not suitable for high speed and high pressure applications. Only one bearing is used in the pump therefore overhung load on shaft bearing reduces the life of the bearing.

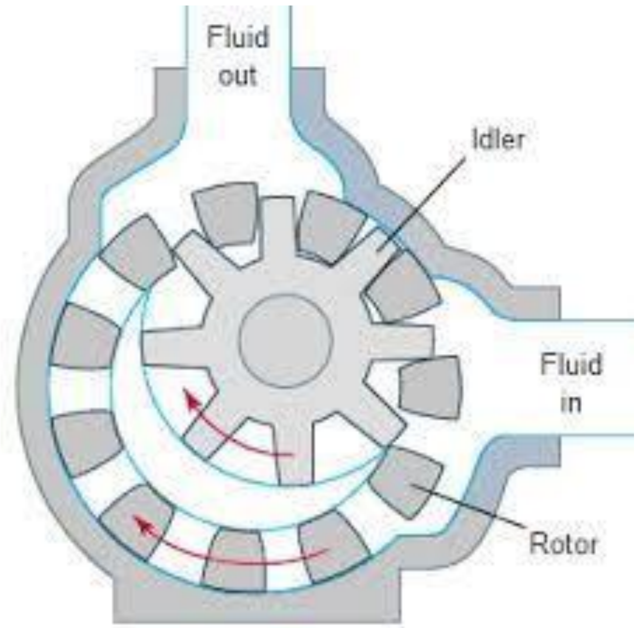


Figure 3.3 - Internal gear pump

3.1.2 Vane Pumps

− In the previous topic we have studied the gear pumps. These pumps have a disadvantage of small leakage due to gap between gear teeth and the pump housing. This limitation is overcome in vane pumps.

− The leakage is reduced by using spring or hydraulically loaded vanes placed in the slots of driven rotor.

− Vane pumps are available in a number of vane configurations including sliding vane, flexible vane, swinging vane, rolling vane, and external vane etc.

− The operating range of these pumps varies from -32 °C to 260 °C.

− The schematic of vane pump working principle is shown in figure 3.4 Vane pumps generate a pumping action by tracking of vanes along the casing wall.

− The vane pumps generally consist of a rotor, vanes, ring and a port plate with inlet and outlet ports.

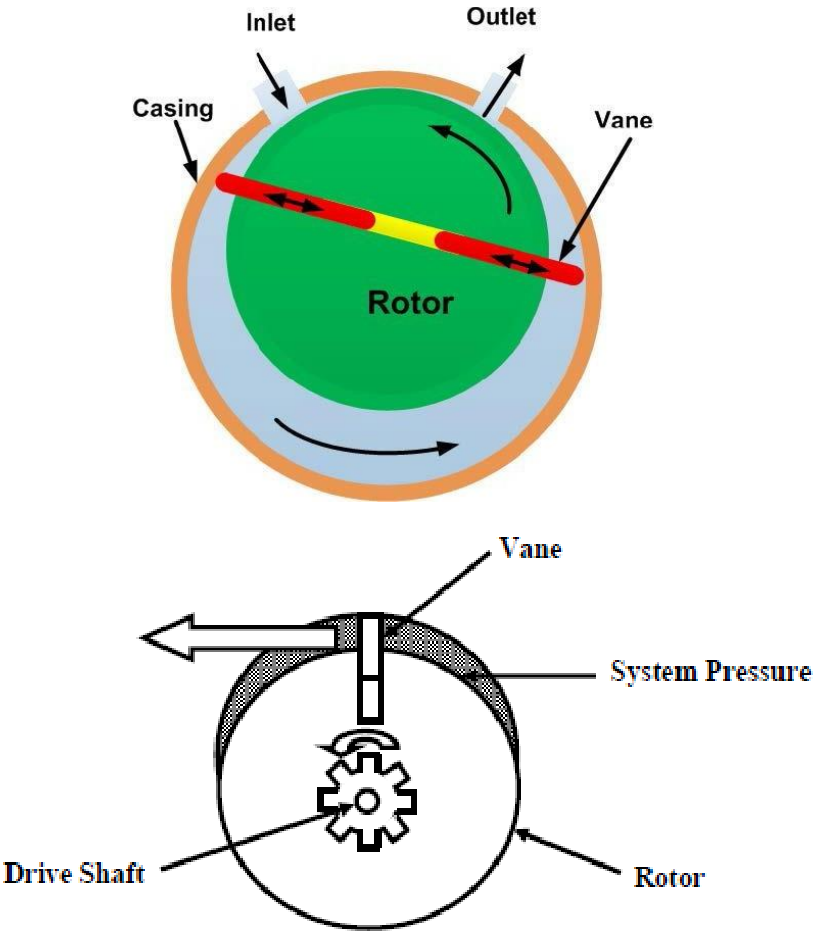


Figure 3.4 - Schematic of working principle of vane pump

− The rotor in a vane pump is connected to the prime mover through a shaft. The vanes are located on the slotted rotor.

− The rotor is eccentrically placed inside a cam ring as shown in the figure. The rotor is sealed into the cam by two side plates.

− When the prime mover rotates the rotor, the vanes are thrown outward due to centrifugal force. The vanes track along the ring.

− It provides a tight hydraulic seal to the fluid which is more at the higher rotation speed due to higher centrifugal force. This produces a suction cavity in the ring as the rotor rotates. It creates vacuum at the inlet and therefore, the fluid is pushed into the pump through the inlet. The fluid is carried around to the outlet by the vanes whose retraction causes the fluid to be expelled.

− The capacity of the pump depends upon the eccentricity, expansion of vanes, and width of vanes and speed of the rotor. It can be noted that the fluid flow will not occur when the eccentricity is zero.

− These pumps can handle thin liquids (low viscosity) at relatively higher pressure.

− However, these pumps are not suitable for high speed applications and for the high viscosity fluids or fluids carrying some abrasive particles.

− The maintenance cost is also higher due to many moving parts. These pumps have various applications for the pumping of following fluids:

- Aerosol and Propellants
- Aviation Service - Fuel Transfer, Deicing
- Auto Industry - Fuels, Lubes, Refrigeration Coolants
- Bulk Transfer of LPG and NH3
- LPG Cylinder Filling
- Alcohols
- Refrigeration - Freons, Ammonia
- Solvents

Unbalanced Vane pump

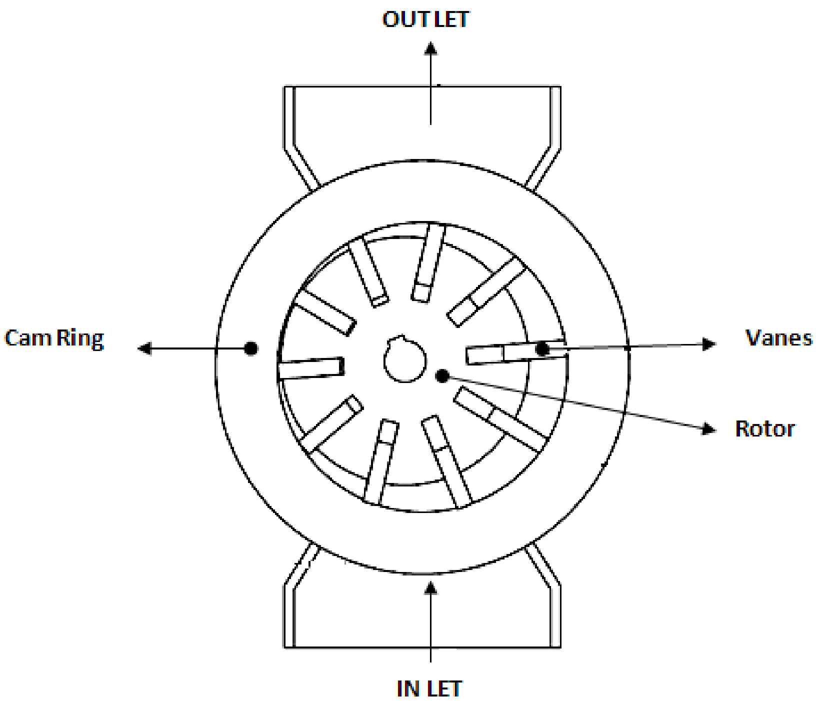


Figure 3.5 - Unbalanced vane pump

− In practice, the vane pumps have more than one vane as shown in figure 3.5. The rotor is offset within the housing, and the vanes are constrained by a cam ring as they cross inlet and outlet ports.

− Although the vane tips are held against the housing, still a small amount of leakage exists between rotor faces and body sides.

− Also, the vanes compensate to a large degree for wear at the vane tips or in the housing itself. The pressure difference between outlet and inlet ports creates a large amount of load on the vanes and a significant amount of side load on the rotor shaft which can lead to bearing failure. This type of pump is called as unbalanced vane pump.

Adjustable vane pump

− The proper design of pump is important and a challenging task. In ideal condition, the capacity of a pump should be exactly same to load requirements. A pump with larger capacity wastes energy as the excess fluid will pass through the pressure relief valve.

− It also leads to a rise in fluid temperature due to energy conversion to the heat instead of useful work and therefore it needs some external cooling arrangement. Therefore, the higher capacity pump increases the power consumption and makes the system bulky and costly.

− Pumps are generally available with certain standard capacities and the user has to choose the next available capacity of the pump. Also, the flow rate from the pump in most hydraulic applications needs to be varying as per the requirements.

− Therefore, some vane pumps are also available with adjustable capacity as shown in figure 3.6. This can be achieved by adjusting a positional relationship between rotor and the inner casing by the help of an external controlling screw.

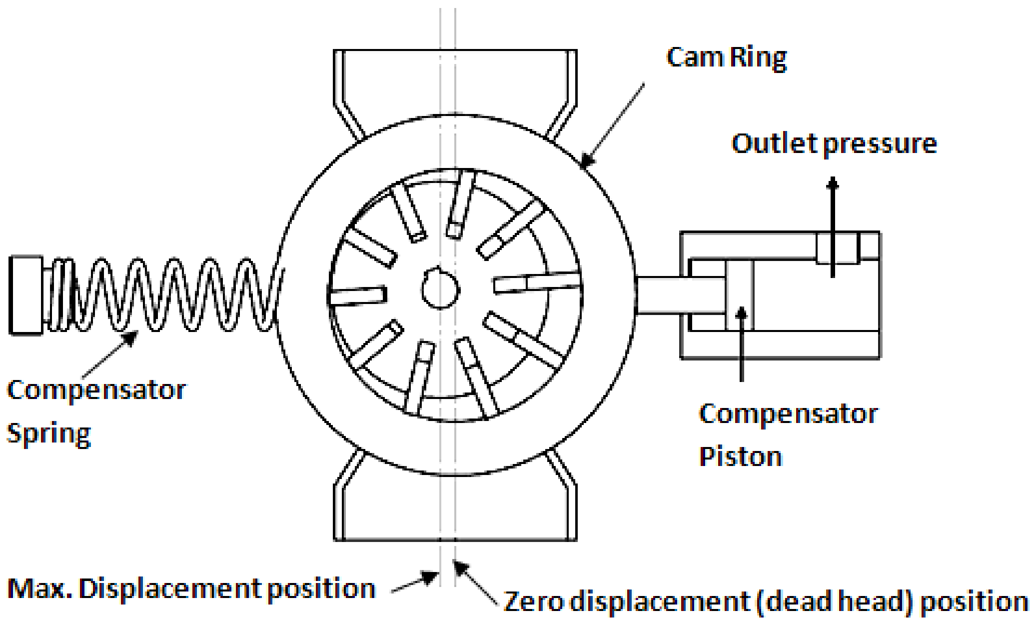


Figure 3.6 - Adjustable vane pump

− These pumps basically consist of a rotor, vanes, cam ring, port plate, thrust bearing for guiding the cam ring and a discharge control screw by which the position of the cam ring relative to the rotor can be varied. In general, the adjustable vane pumps are unbalanced pump type.

− The amount of fluid that is displaced by a vane pump running at a constant speed is determined by the maximum extension of the vanes and the vanes width.

− However, for a pump running in operation, the width of vanes cannot be changed but the distance by which the vanes are extended can be varied. This is possible by making a provision for changing the position of the cam ring (adjustable inner casing) relative to the rotor as shown in figure.

− The eccentricity of rotor with respect to the cam ring is adjusted by the movement of the screw. The delivery volume increases with increase in the eccentricity. This kind of arrangement can be used to achieve a variable volume from the pump and is known as variable displacement vane pump.

Balanced vane pump

− Figure 3.7 shows the schematic of a balanced vane pump.

− This pump has an elliptical cam ring with two inlet and two outlet ports. Pressure loading still occurs in the vanes but the two identical pump halves create equal but opposite forces on the rotor. It leads to the zero net force on the shaft and bearings. Thus, lives of pump and bearing increase significantly. Also the sounds and vibrations decrease in the running mode of the pump.

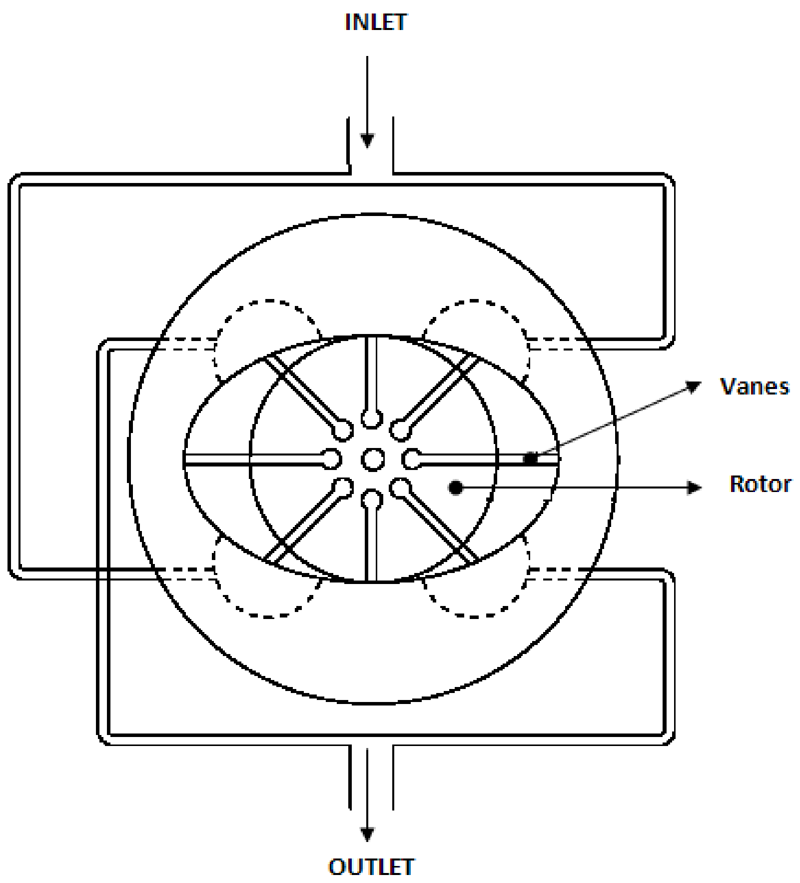


Figure 3.7 - Balanced Vane Pump

3.1.3 Piston Pumps

− Piston pumps are meant for the high-pressure applications. These pumps have high-efficiency and simple design and needs lower maintenance. These pumps convert the rotary motion of the input shaft to the reciprocating motion of the piston. These pumps work similar to the four stroke engines.

− They work on the principle that a reciprocating piston draws fluid inside the cylinder when the piston retracts in a cylinder bore and discharge the fluid when it extends. These pumps are positive displacement pump and can be used for both liquids and gases. Piston pumps are basically of two types:

(a) Axial piston pumps

(b) Radial piston pumps

(a) Axial piston pumps

− Axial piston pumps are positive displacement pumps which converts rotary motion of the input shaft into an axial reciprocating motion of the pistons. These pumps have a number of pistons (usually an odd number) in a circular array within a housing which is commonly referred to as a cylinder block, rotor or barrel. These pumps are used in jet aircraft.

− These pumps have sub-types as:

1. Bent axis piston pump
2. Swash plate axial piston pump

1. Bent axis piston pump

− Figure 3.8 shows the schematic of bent axis piston pump. In these pumps, the reciprocating action of the pistons is obtained by bending the axis of the cylinder block.

− The cylinder block rotates at an angle which is inclined to the drive shaft. The cylinder block is turned by the drive shaft through a universal link.

− The cylinder block is set at an offset angle with the drive shaft. The cylinder block contains a number of pistons along its periphery. These piston rods are connected with the drive shaft flange by ball-and-socket joints.

− The volumetric displacement (discharge) of the pump is controlled by changing the offset angle. It makes the system simple and inexpensive.

− These pistons are forced in and out of their bores as the distance between the drive shaft flange and the cylinder block changes. A universal link connects the block to the drive shaft, to provide alignment and a positive drive.

− The discharge does not occur when the cylinder block is parallel to the drive shaft. The offset angle can vary from 0° to 40°.

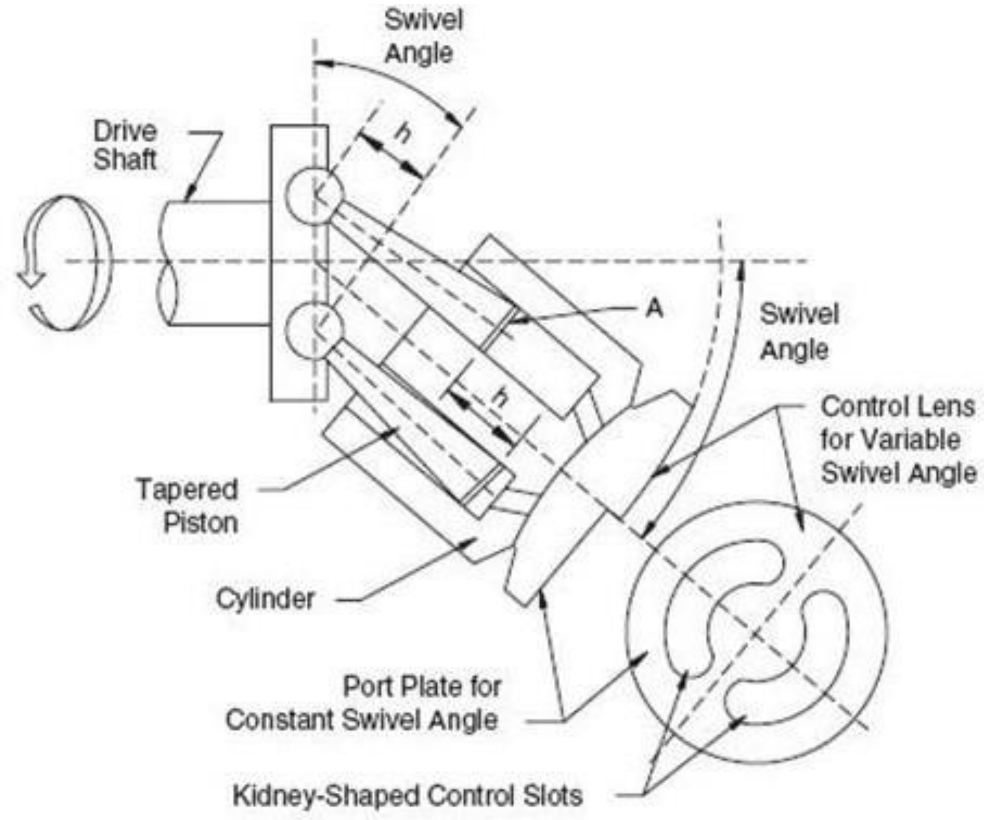


Figure 3.8 - Bent axis piston pump

2. Swash plate axial piston pump

− A swash plate is a device that translates the rotary motion of a shaft into the reciprocating motion. It consists of a disk attached to a shaft as shown in Figure 3.9. If the disk is aligned perpendicular to the shaft; the disk will turn along with the rotating shaft without any reciprocating effect.

− Similarly, the edge of the inclined shaft will appear to oscillate along the shaft's length. This apparent linear motion increases with increase in the angle between disk and the shaft (offset angle). The apparent linear motion can be converted into an actual reciprocating motion by means of a follower that does not turn with the swash plate.

− In swash plate axial piston pump a series of pistons are aligned coaxially with a shaft through a swash plate to pump a fluid. The schematic of swash plate piston pump is shown in Figure 3.9. The axial reciprocating motion of pistons is obtained by a swash plate that is either fixed or has variable degree of angle.

− As the piston barrel assembly rotates, the piston rotates around the shaft with the piston shoes in contact with the swash plate. The piston shoes follow the angled surface of the swash plate and the rotational motion of the shaft is converted into the reciprocating motion of the pistons.

− This reciprocating motion of the piston results in the drawing in and pumping out of the fluid. Pump capacity can be controlled by varying the swash plate angle with the help of a separate hydraulic cylinder. The pump capacity (discharge) increases with increase in the swash plate angle and vice-versa.

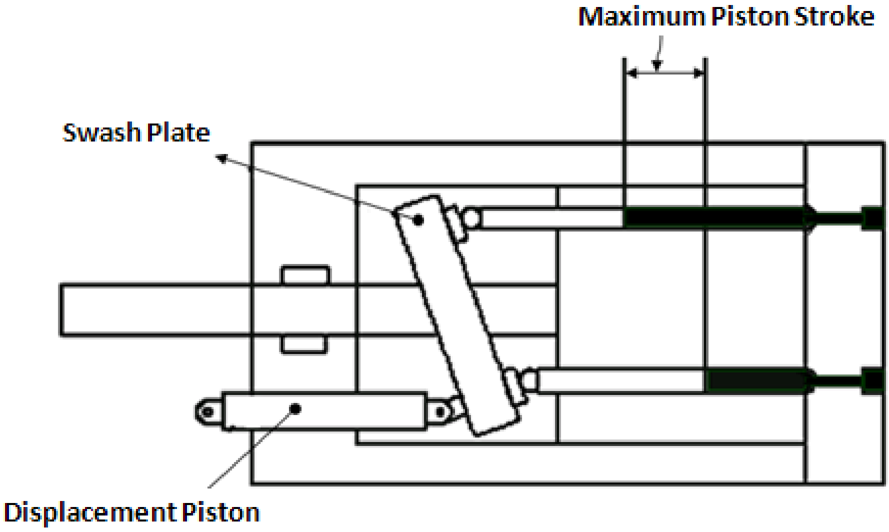


Figure 3.9 - Swash plate axial piston pump

(b) Radial piston pumps

− The typical construction of radial piston pump is shown in Figure 3.10. The piston pump has pistons aligned radially in a cylindrical block. It consists of a pintle, a cylinder barrel with pistons and a rotor containing a reaction ring. The pintle directs the fluid in and out of the cylinder. Pistons are placed in radial bores around the rotor.

− The piston shoes ride on an eccentric ring which causes them to reciprocate as they rotate. The eccentricity determines the stroke of the pumping piston. Each piston is connected to inlet port when it starts extending while it is connected to the outlet port when start retracting. This connection to the inlet and outlet port is performed by the timed porting arrangement in the pintle.

− As the cylinder barrel rotates, the pistons on one side travel outward. This draws the fluid in as the cylinder passes the suction port of the pintle. It is continued till the maximum eccentricity is reached. When the piston passes the maximum eccentricity, pintle is forced

inwards by the reaction ring. This forces the fluid to flow out of the cylinder and enter in the discharge (outlet) port of the pintle.

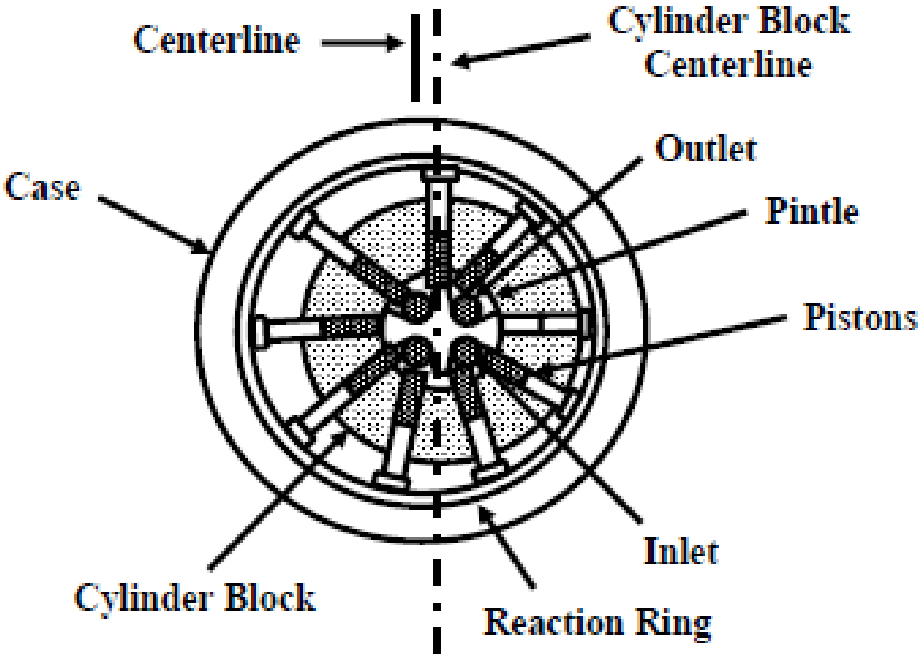


Figure 3.10 - Radial piston pump

3.2 LINEAR ACTUATORS

Reliability of hydraulic system not only depends on the system design but also on factors such as component design and manufacturing and their correct choice. This is also correct while selecting the cylinder.

A correct cylinder in a hydraulic system contributes to:

1. Optimize system maintainability
2. Ensure minimum down time
3. Ease the process of repairing and trouble shooting
4. Ensure maximum work accuracy
5. Maintain least economic liability and financial losses

3.3 TYPES OF CYLINDER

Functionally cylinders are classified as:

1. Single acting cylinders
2. Double acting cylinder
3. Telescopic cylinders
4. Tandem cylinders

1. Single-Acting Cylinders

− A single-acting cylinder is simplest in design and is shown schematically in Fig 3.11. It consists of a piston inside a cylindrical housing called barrel. On one end of the piston there is a rod, which can reciprocate**.** At the opposite end, there is a port for the entrance and exit of oil.

− Single-acting cylinders produce force in one direction by hydraulic pressure acting on the piston. (Single-acting cylinders can exert a force in the extending direction only.) The return of the piston is not done hydraulically. In single-acting cylinders, retraction is done either by gravity or by a spring.

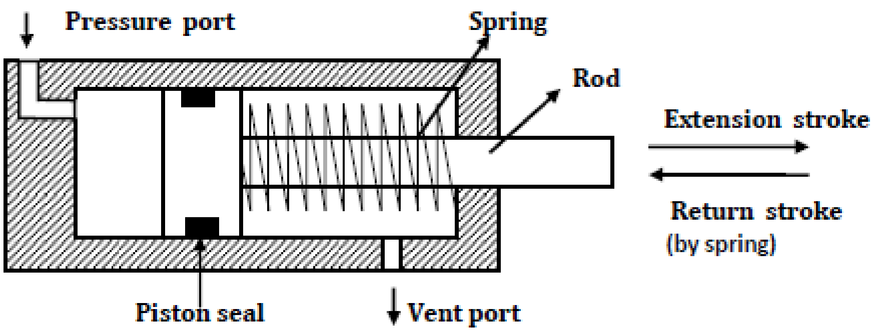


Figure 3.11 - Single-acting cylinders

According to the type of return, single-acting cylinders are classified as follows:

- Gravity-return single-acting cylinder
- Spring-return single-acting cylinder

Gravity-Return Single-Acting Cylinder

− Figure 3.12 shows gravity-return-type single-acting cylinders. In the push type [Fig. 3.12 (a)], the cylinder extends to lift a weight against the force of gravity by applying oil pressure at the blank end.

− The oil is passed through the blank-end port or pressure port. The rod-end port or vent port is open to atmosphere so that air can flow freely in and out of the rod end of the cylinder.

− To retract the cylinder, the pressure is simply removed from the piston by connecting the pressure port to the tank. This allows the weight of the load to push the fluid out of the cylinder back to the tank. In pull-type gravity-return-type single-acting cylinder, the cylinder [Fig.3.12 (b)] lifts the weight by retracting.

− The blank-end port is the pressure port and blind-end port is now the vent port. This cylinder automatically extends whenever the pressure port is connected to the tank.

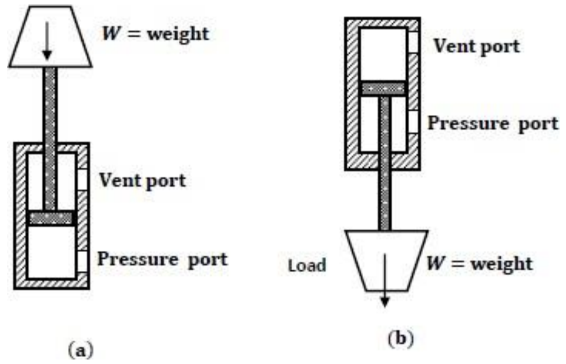


Figure 3.12 - Gravity-return single-acting cylinder: (a) Push type; (b) pull type

Spring-Return Single-Acting Cylinder

− A spring-return single-acting cylinder is shown in Fig.3.13.In push type [Fig. 3.13 (a)], the pressure is sent through the pressure port situated at the blank end of the cylinder.

− When the pressure is released, the spring automatically returns the cylinder to the fully retracted position. The vent port is open to atmosphere so that air can flow freely in and out of the rod end of the cylinder.

− Figure 3.13 (b) shows a spring-return single-acting cylinder. In this design, the cylinder retracts when the pressure port is connected to the pump flow and extends whenever the pressure port is connected to the tank. Here the pressure port is situated at the rod end of the cylinder.

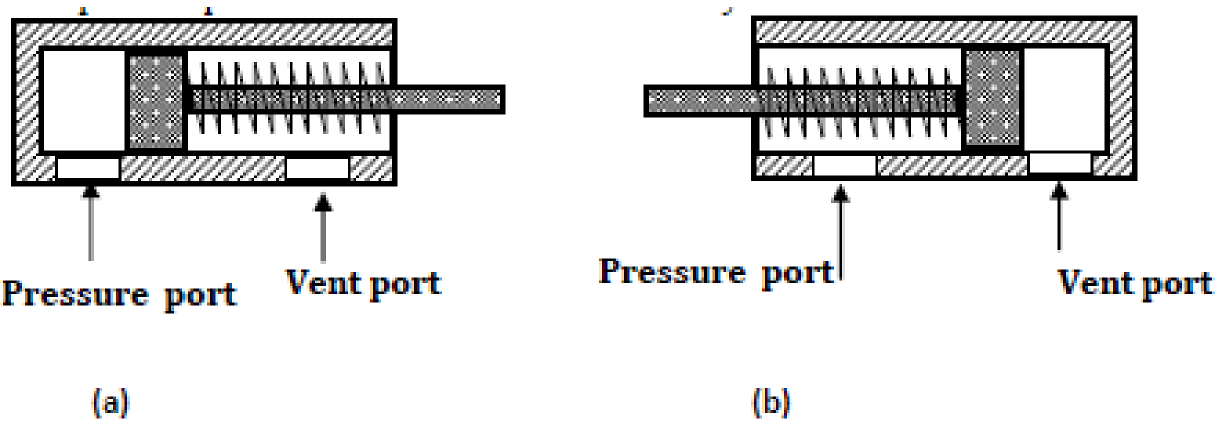


Figure 3.13 - (a) Push- and (b) pull-type single-acting cylinders

2. Double-Acting Cylinder

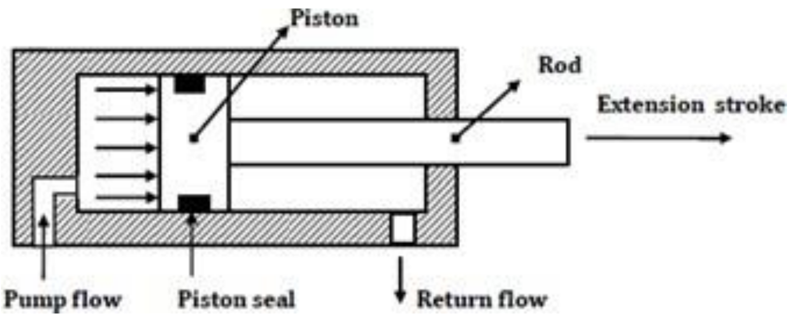
There are two types of double-acting cylinders:

- Double-acting cylinder with a piston rod on one side.
- Double-acting cylinder with a piston rod on both sides.

Double-Acting Cylinder with a Piston Rod on One Side

− Figure 3.14 shows the operation of a double-acting cylinder with a piston rod on one side. To extend the cylinder, the pump flow is sent to the blank-end port as in Fig. 3.14 (a). The fluid from the rod-end port returns to the reservoir.

− To retract the cylinder, the pump flow is sent to the rod-end port and the fluid from the blank-end port returns to the tank as in Fig. 3.14 (b).



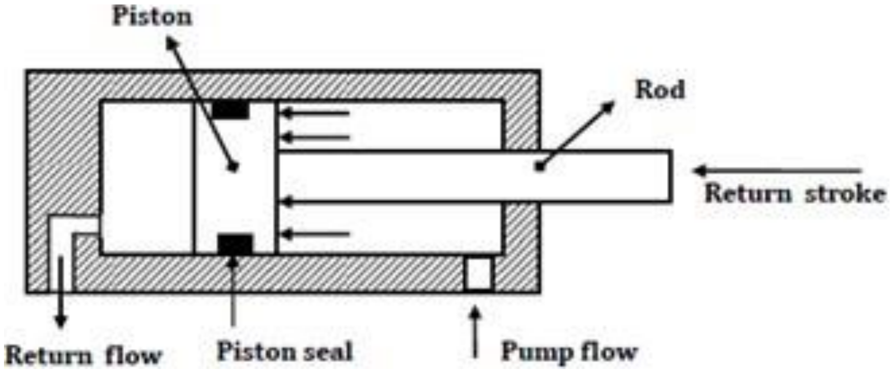


Figure 3.14 - Double-acting cylinder with a piston rod on one side

Double-Acting Cylinder with a Piston Rod on Both Sides

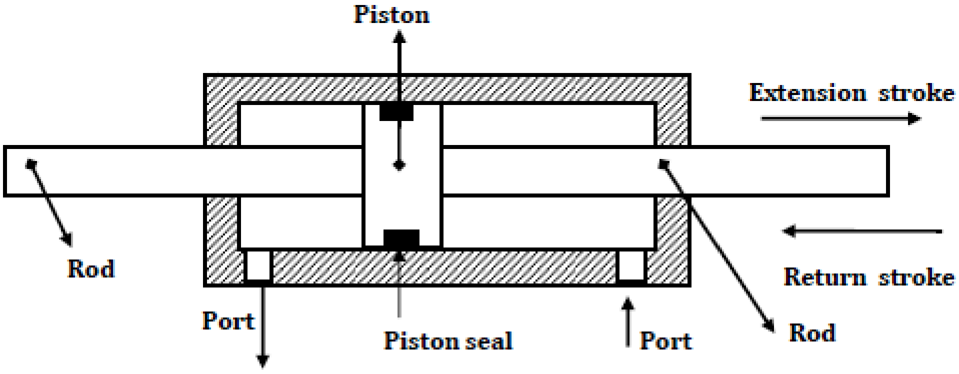


Figure 3.15 - Double-acting cylinder with a piston rod on one side

− A double-acting cylinder with a piston rod on both sides (Fig. 3.15) is a cylinder with a rod extending from both ends. This cylinder can be used in an application where work can be done by both ends of the cylinder, thereby making the cylinder more productive.

− Double-rod cylinders can withstand higher side loads because they have an extra bearing, one on each rod, to withstand the loading.

3. Telescopic Cylinder

− A telescopic cylinder (shown in Fig. 3.16) is used when a long stroke length and a short retracted length are required. The telescopic cylinder extends in stages, each stage consisting of a sleeve that fits inside the previous stage.

− One application for this type of cylinder is raising a dump truck bed. Telescopic cylinders are available in both single-acting and double-acting models. They are more expensive than standard cylinders due to their more complex construction.

− They generally consist of a nest of tubes and operate on the displacement principle. The tubes are supported by bearing rings, the innermost (rear) set of which have grooves or channels to allow fluid flow.

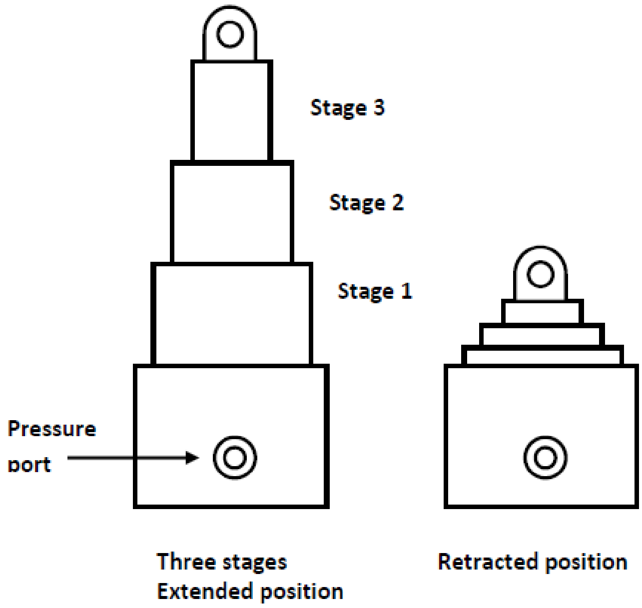


Figure 3.16 - Telescopic cylinder

− For a given input flow rate, the speed of operation increases in steps as each successive section reaches the end of its stroke. Similarly, for a specific pressure, the load-lifting capacity decreases for each successive section.

4. Tandem Cylinder

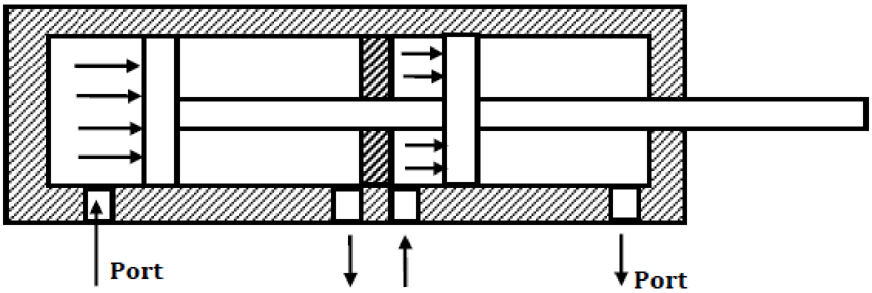


Figure 3.17 - Tandem cylinder

− A tandem cylinder, shown in Fig. 3.17, is used in applications where a large amount of force is required from a small-diameter cylinder. Pressure is applied to both pistons, resulting in increased force because of the larger area.

− The drawback is that these cylinders must be longer than a standard cylinder to achieve an equal speed because flow must go to both pistons.

5. Diaphragrn Cylinder

− These are used for very small displacements. There will be a diaphragm instead of piston inside the cylinder. The diaphragm deflects when working fluid is admitted into the cylinder.

− The diaphragm is fitted with a piston rod and hence the piston rod extends or retracts.

− Applications: Food industries, Milk dairies, Air brake etc.

3.4 ROTARY ACTUATORS

− Hydraulic motors are rotary actuators. However, the name rotary actuator is reserved for a particular type of unit that is limited in rotation to less than 360 degree.

− A hydraulic motor is a device which converts fluid power into rotary power or converts fluid pressure into torque.

− Torque is a function of pressure or, in other words, the motor input pressure level is determined by the resisting torque at the output shaft. A hydraulic pump is a device which converts mechanical force and motion into fluid power.

− A hydraulic motor is not a hydraulic pump when run backward. A design that is completely acceptable as a motor may operate very poorly as a pump in a certain applications.

Table 3.1 - Differences between a hydraulic motor and a hydraulic pump

Hydraulic Motor	**Hydraulic Pump**
It is a device for delivering torque at a given pressure. The main emphasis is on mechanical efficiency and torque that can be transmitted.	It is a device for delivering flow at a given pressure. The main emphasis is on volumetric efficiency and flow.
Motors usually operate over a wide range of speed, from a low RPM to high RPM.	Pumps usually operate at high RPM.
Most motors are designed for bidirectional applications such as braking loads, rotary tables.	In most situations, pumps usually operate in one direction.
Motors may be idle for long time (as in index table).	Pumps usually operate continuously.
Motors are subjected to high side loads (from gears, chains, belt-driven pulleys).	Majority of pumps are not subjected to side loads. Usually pumps are pad mounted on power pack top and shaft is connected to the prime mover directly.

3.3.1 Applications

− Hydraulic motors have become popular in industries. Hydraulic motors can be applied directly to the work. They provide excellent control for acceleration, operating speed, deceleration, smooth reversals and positioning.

− They also provide flexibility in design and eliminate much of bulk and weight of mechanical and electrical power transmission.

− The applications of hydraulic motors in their various combinations with pumping units are termed hydrostatic transmission.

− A hydrostatic transmission converts mechanical power into fluid power and then reconverts fluid power into shaft power. The advantages of hydrostatic transmissions include power transmission to remote areas, infinitely variable speed control, self-overload protection, reverse rotation capability, dynamic braking and a high power-to-weight ratio. Applications include material-handling equipment, farm tractors, railway locomotives, buses, lawn mowers and machine tools.

− New fields of applications are being discovered constantly for hydrostatic transmissions. Farm implements, road machinery, material-handling equipment, Numerical Control(NC) machines high-performance aircrafts, military uses and special machinery are only a few of new fields expanding through the use of fluid power transmission. Many automobiles, railway locomotives and buses use a hydrostatic transmission.

Table 3.2 - Comparison between a hydraulic motor and an electric motor

Electric Motor	Hydraulic Motor
Electric motors cannot be stopped instantly. Their direction of rotation cannot be reversed instantly. This is because of air gap between the rotor and stator and the weak magnetic field.	Hydraulic motors can be stalled for any length of time. Their direction of rotation can be instantly reversed and their rotational speed can be infinitely varied without affecting their torque. They can be braked instantly and have immense torque capacities.
Electric motors are heavy and bulky.	Hydraulic motors are very compact compared to electric motors. For the same power, they occupy about 25% of the space required by electric motors and weigh about 10% of electric motors.
Moment of inertia-to-torque ratio is nearly 100.	Moment of inertia-to-torque ratio is nearly 1.

3.5 CLASSIFICATION OF HYDRAULIC MOTORS

− There are two types of hydraulic motors: (a) High-speed low-torque motors and (b) low–speed high-torque motors. In high-speed low-torque motors, the shaft is driven directly from either the barrel or the cam plate, whereas in low-speed high-torque motors, the shaft is driven through a differential gear arrangement that reduces the speed and increases the torque.

− Depending upon the mechanism employed to provide shaft rotation, hydraulic motors can be classified as follows:

1. Gear motors.

2. Vane motors.

3. Piston motors:

- Axial piston-type motors.
- Radial piston-type motors.

− Gear motors are the least efficient, most dirt-tolerant and have the lowest pressure rating of 3. Piston motors are the most efficient, least dirt-tolerant and have high pressure ratings. Vane and piston motors can be fixed or variable displacement, but gear motors are available with only fixed displacement.

1. Gear Motors:

− A gear motor develops torque due to hydraulic pressure acting against the area of one tooth. There are two teeth trying to move the rotor in the proper direction, while one net tooth at the center mesh tries to move it in the opposite direction.

− In the design of a gear motor, one of the gears is keyed to an output shaft, while the other is simply an idler gear. Pressurized oil is sent to the inlet port of the motor. Pressure is then applied to the gear teeth, causing the gears and output shaft to rotate.

− The pressure builds until enough torque is generated to rotate the output shaft against the load. The side load on the motor bearing is quite high, because all the hydraulic pressure is on one side. This limits the bearing life of the motor. Schematic diagram of gear motor is shown in Fig.

− Gear motors are normally limited to 150 bar operating pressures and 2500 RPM operating speed. They are available with a maximum flow capacity of 600 LPM.

− The gear motors are simple in construction and have good dirt tolerance, but their efficiencies are lower than those of vane or piston pumps and they leak more than the piston units. Generally, they are not used as servo motors.

− Hydraulic motors can also be of internal gear design. These types can operate at higher pressures and speeds and also have greater displacements than external gear motors.

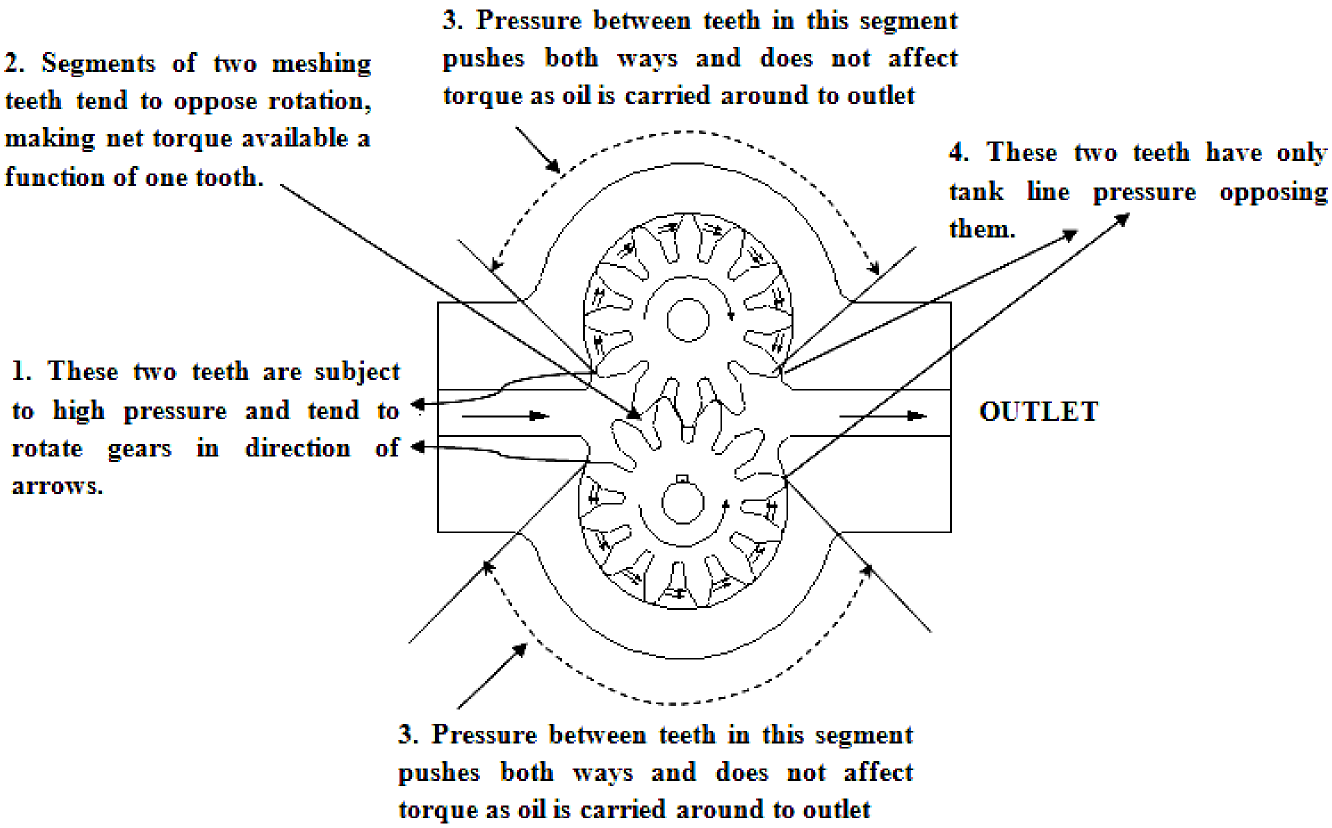


Figure 3.18 - Gear motor

2. Vane Motors

− Figure 3.19 shows an unbalanced vane motor consisting of a circular chamber in which there is an eccentric rotor carrying several spring or pressure-loaded vanes. Because the fluid flowing through the inlet port finds more area of vanes exposed in the upper half of the motor, it exerts more force on the upper vanes, and the rotor turns counter clockwise. Close tolerances are maintained between the vanes and ring to provide high efficiencies.

− The displacement of a vane hydraulic motor is a function of eccentricity. The radial load on the shaft bearing of an unbalanced vane motor is also large because all its inlet pressure is on one side of the rotor.

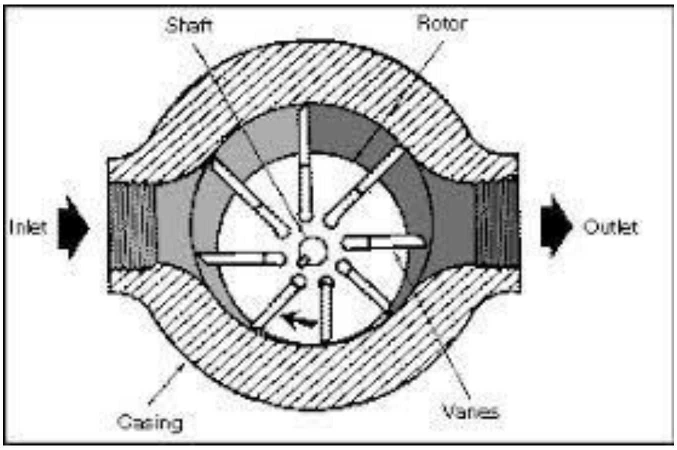


Figure 3.19 - Vane motor

3. Piston Motors

Piston motors are classified into the following types:

1. According to the piston of the cylinder block and the drive shaft, piston motors are classified as follows:

- Axial piston motors.
- Radial piston motors.

2. According to the basis of displacement, piston motors are classified as follows:

- Fixed-displacement piston motors.
- Variable-displacement piston motors

Axial Piston Motors

− In axial piston motors, the piston reciprocates parallel to the axis of the cylinder block. These motors are available with both fixed-and variable-displacement feature types. They generate torque by pressure acting on the ends of pistons reciprocating inside a cylinder block.

− Figure 3.20 illustrates the inline design in which the motor, drive shaft and cylinder block are centered on the same axis. Pressure acting on the ends of the piston generates a force against an angled swash plate. This causes the cylinder block to rotate with a torque that is proportional to the area of the pistons.

− The torque is also a function of the swash-plate angle. The inline piston motor is designed either as a fixed- or a variable-displacement unit.

− In variable-displacement units, the swash plate is mounted on the swinging yoke. The angle can be varied by various means such as a lever, hand wheel or servo control. If the offset angel is increased, the displacement and torque capacity increase but the speed of the drive shaft decreases. Conversely, reducing the angle reduces the torque capability but increases the drive shaft speed.

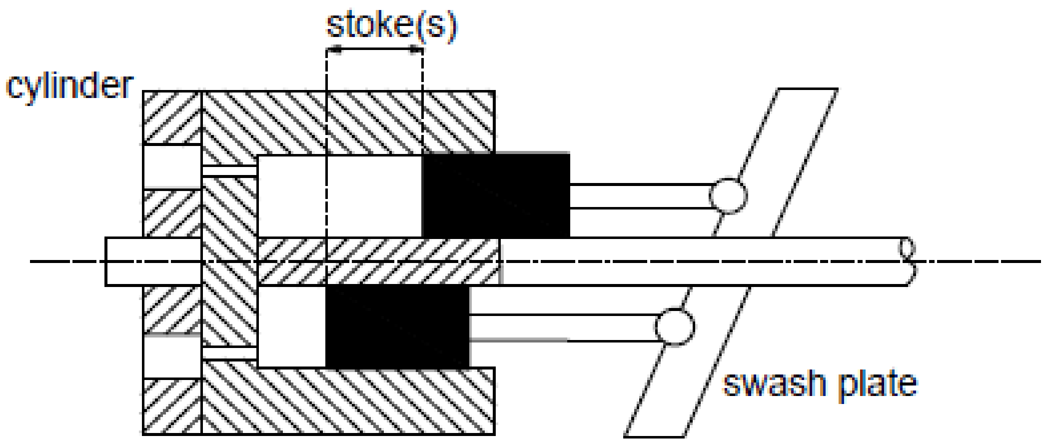


Figure 3.20 - Straight axis piston pump

Bent-Axis Piston Motors

− A bent-axis piston motor is shown in Fig 3.21. This type of motor develops torque due to pressure acting on the reciprocating piston. In this motor, the cylinder block and drive shaft mount at an angel to each other so that the force is exerted on the drive shaft flange.

− Speed and torque depend on the angle between the cylinder block and the drive shaft. The larger the angle, the greater the displacement and torque, and the smaller the speed. This angle varies from 7.5° (minimum) to 30° (maximum). This type of motor is available in two types, namely fixed-displacement type and variable-displacement type.

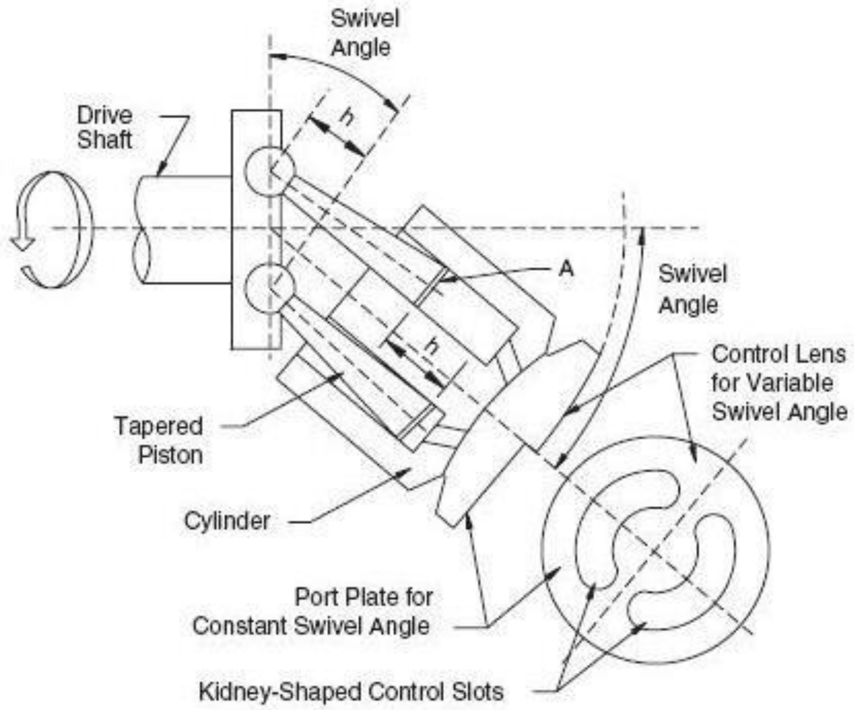


Figure 3.21 - Bent axis piston motor

3.6 HYDROSTATIC TRANSMISSION SYSTEM

In this type of drives a hydrostatic pump and a motor is used.

− The engine drives the pump and it generates hydrostatic pressure on the fluid.

− The pressurized fluid then fed to the motor and the motor drives the wheel.

− In these transmissions mechanical power is generated in the motor as a result of displacement under hydraulic pressure.

− The fluid, of course, also carries kinetic energy, but since it leaves the motor at the same velocity as that at which it enters, there is no change in its kinetic- energy content, and kinetic energy plays no part in the transmission of power.

− It consists of a pump, which converts torque and rotation of mechanical shaft into flow of pressurized fluid combined with a hydraulic motor, which converts fluid flow under pressure into rotating torque on the output shaft.

− The pump and motor are identical in construction but they may vary in size and displacement, particularly when torque multiplication is needed.

− By employing variable delivery of hydraulic units, it is possible to obtain a wide range of output ratios.

Various types of hydrostatic systems

1. Constant displacement pump and constant displacement motor
2. Variable displacement pump and constant displacement motor

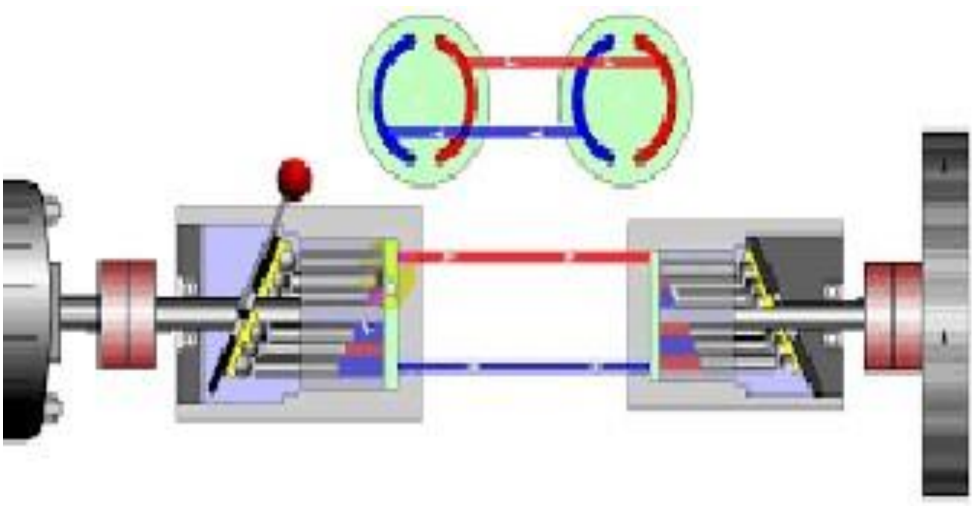


Figure 3.22 – Hydrostatic transmission system

3. Constant displacement pump and variable displacement motor
4. Variable displacement pump and variable displacement motor

Advantages of hydrostatic drive

− Hydrostatic drive eliminates the need for mechanical transmission components like clutch and gearbox as well as allied controls.

− It provides for smooth and precise control of vehicle speed and travel.

− This system ensures faster acceleration and deceleration of vehicle

− It offers better flexibility in vehicle installation because of wide range in choice of pumps and motors of different capacities and of fixed or variable displacement type. Besides hydraulic fluid pipes lines replace mechanical transmission drive line components

− The ease with which the reverse drive can be obtained makes the hydrostatic drive more attractive. This drive is fully reversible from maximum speed in one direction to zero speed and to maximum speed in the reverse direction.

Limitations of hydrostatic drive

− Noisy in operation

− Heavier in weight and larger in bulk

− Costlier when compared to other types of transmission

− Manufacturing of pump and motor requires high precision machining of components and skilled workmanship

− In view of high pressure employed in system, the working components are heavier.

− It also possesses problem of oil leakage through oil seals.

Applications of hydrostatic drive

− It is used to move the machine tools accurately.

− Used in steering gears of ship.

− Used in war ships to operate gun turrets.

− Used in road rollers, tractors, earth movers, heavy duty trucks.

Comparison of hydrostatic drive with hydrodynamic drives

− Torque ratio is lesser in hydrostatic drives for different speed ratios.

− Hydrostatic offers high efficiency over a wide range of speeds when compared to hydrodynamic drives.

− Vehicle with hydrostatic drive has no tendency to creep unlike hydrodynamic drive during idling.

− Dynamic braking of vehicle is an inherent feature of hydrostatic drive. This feature helps to eliminate conventional shoe or disc type of brakes. Creep is caused to drag torque, movement of vehicle during idling