UNIT II

HYDRAULIC SYSTEM AND COMPONENTS

Introduction:

A pump which is the heart of a hydraulic system converts mechanical energy into hydraulic energy. The mechanical energy is delivered to the pump via prime mover such as electric motor. Due to the mechanical action the pump creates a partial vacuum at its inlet. This permits atmospheric pressure to force the fluid through the inlet line and into the pump. The pump then pushes the fluid into the hydraulic system.

Pump Classifications:

1. **Non Positive Displacement Pumps:** The most common types of dynamic pumps are the centrifugal and axial pumps. Although these pumps provide smooth continuous flow, their flow output is reduced as circuit resistance is increased and thus are rarely used in fluid power systems. In dynamic pumps there is a great deal of clearance between the rotating impeller and the stationary housing. Thus as the resistance of the external system starts to increase, some of the fluid slips back into the clearance spaces, causing a reduction in the discharge flow rate. This slippage is due to the fact that the fluid follows the path of least resistance. When the resistance of the external system becomes infinitely large the pump will produce no flow. These pumps are typically used for low pressure, high volume flow applications. Also since there is a great deal of clearance between the rotating and stationary elements, dynamic pumps are not self priming unlike positive displacement pump.
2. **Positive Displacement Pump:** This type of pump ejects a fixed quantity of fluid per revolution of the pump shaft. As a result, pump output flow, neglecting changes in the small internal leakage is constant and not dependent on system pressure. This makes them particularly well suited for fluid power systems. However positive displacement pumps must be protected against overpressure if the resistance to flow becomes very large. This can happen if a valve is completely closed and there is no physical place for the fluid to go. The reason for this is that a positive displacement pump continues to eject fluid causing an extremely rapid buildup in pressure as the fluid compressed. A pressure relief valve is used to protect the pump against overpressure by diverting pump flow back to the hydraulic tank where the fluid is stored for system use.

Classification of Positive Displacement Pump:

1. Gear Pumps
    a. External Gear Pump
    b. Internal Gear Pump
    c. Lobe Pump
    d. Screw Pump

2. Vane Pumps
    a. Unbalanced Vane Pumps
    b. Balanced Vane Pumps
    c. Pressure Compensated Vane Pump
3. Piston pumps
    a. Axial Piston Pump
    b. Radial Piston Pump

GEAR PUMPS:

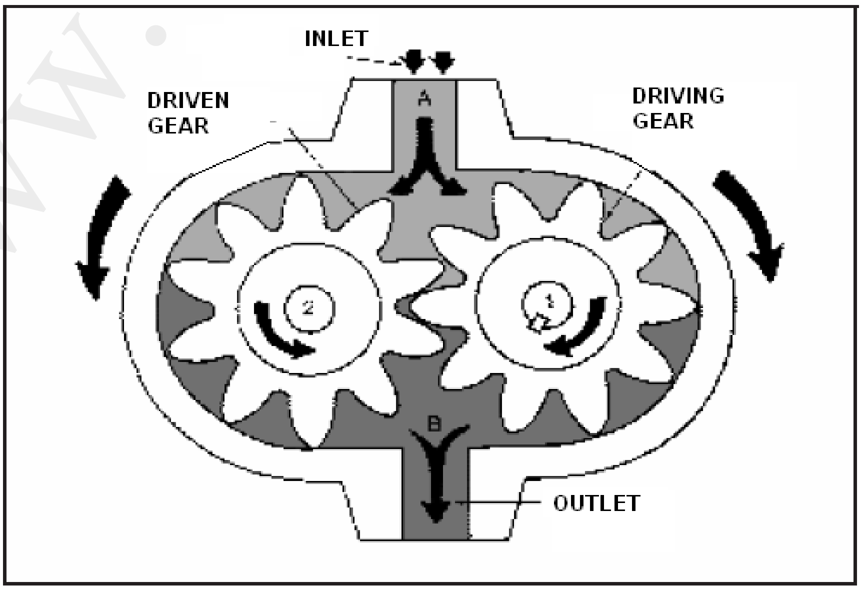
External Gear Pump:

The given figure shows the operation of an external gear pump, which develops flow by carrying fluid between the teeth of two meshing gears. One of the gears is connected to a drive shaft connected to the prime mover. The second gear is driven as it meshes with the driver gear. Oil chambers are formed between the gear teeth, the pump housing and the side wear plates. The suction side is where teeth come out of mesh and it is here that the volume expands bringing about a reduction in pressure to below atmospheric pressure. Fluid is pushed into this void by atmospheric pressure because the oil supply tank is vented to the atmosphere. The discharge side is where teeth go into mesh and it is here that the volume decreases between mating teeth. Since the pump has a positive internal seal against leakage the oil is positively ejected into the outlet port. The displacement of the gear pump is determined by volume of fluid between each pair of teeth, Number of teeth and speed of rotation.

$$Q_T = V_D \times N$$

$$V_D = \frac{\Pi}{4}(D_o^2 - D_i^2)\, L$$

Q_T – Theoretical Pump Flow Rate   L – Width Of Gear
VD – Displacement Volume of Pump   N – Speed of Pump
Do, Di – Outside and Inside Diameter of Gear Teeth



There must be a small clearance between the teeth tip and pump housing. As a result some of the oil at the discharge port can leak directly back toward the suction port. This means that the actual flow rate Q_A is less than the theoretical flow rate Q_T which is based on volumetric displacement and pump speed. This internal leakage called pump slippage is identified by the term volumetric efficiency.

$$\eta_v = \frac{Q_A}{Q_T}$$

Advantages

- High speed
- High pressure
- No overhung bearing loads
- Relatively quiet operation
- Design accommodates wide variety of materials

Disadvantages

- Four bushings in liquid area
- No solids allowed
- Fixed End Clearances

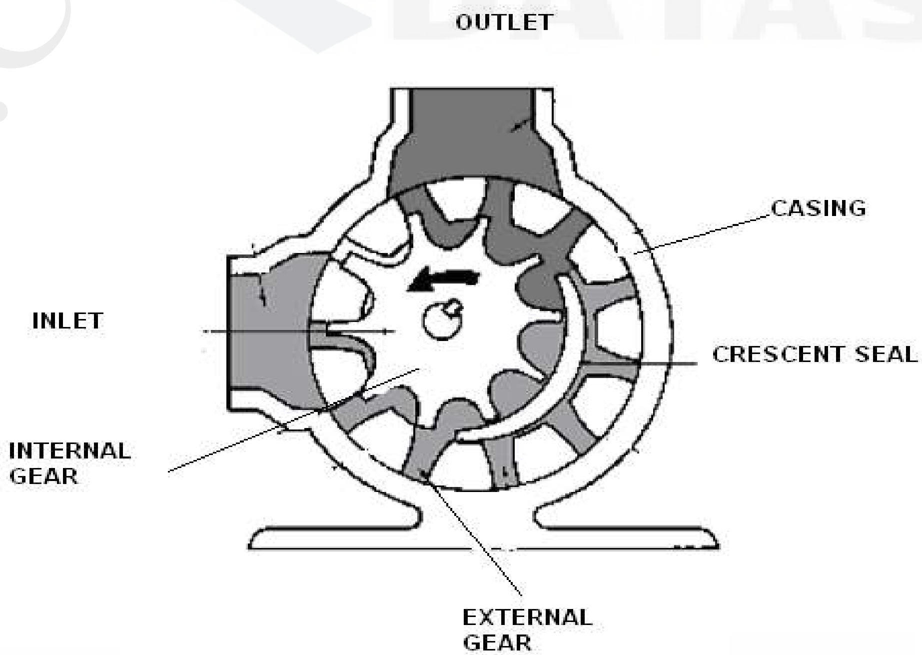
Applications

- Various fuel oils and lube oils
- Chemical additive and polymer metering
- Chemical mixing and blending (double pump)
- Industrial and mobile hydraulic applications splitters, lifts
- Acids and caustic (stainless steel or composite construction)

Low volume transfer or application

Internal Gear Pump:

The figure shows the operation of the internal gear pump. This design consists of an internal gear, a regular spur gear, a crescent shaped seal and an external housing. As power is applied to either gear the motion of the gears draws fluid from the reservoir and forces it around both sides of the crescent seal which 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 to enter the discharge port of the pump.



Advantages

- Only two moving parts
- Non-pulsating discharge
- Excellent for high-viscosity liquids
- Constant and even discharge regardless of pressure conditions
- Operates well in either direction
- Single adjustable end clearance

Disadvantages

- Usually requires moderate speeds
- Medium pressure limitations
- One bearing runs in the product pumped
- Overhung load on shaft bearing

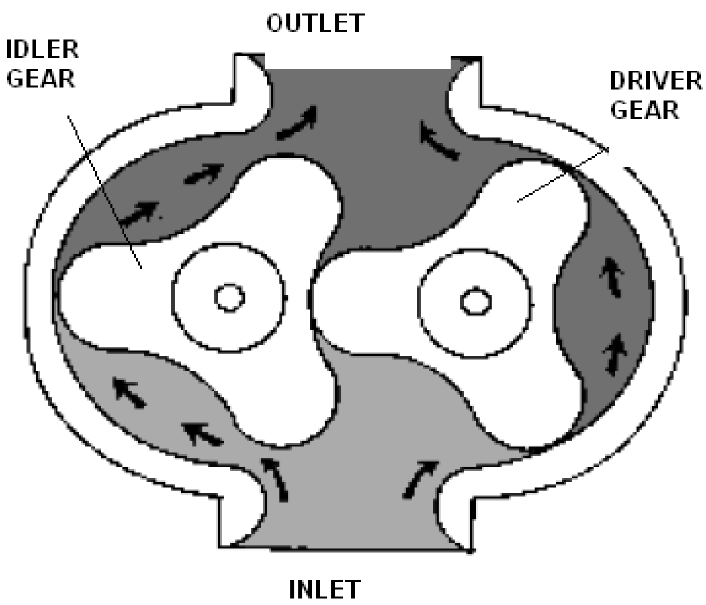
Applications

- All varieties of fuel oil and lube oil
- Resins and Polymers
- Alcohols and solvents
- Food products such as corn syrup, chocolate, and peanut butter
- Paint, inks, and pigments

Lobe Pump:

In this pump, the gears are replaced by the lobes. This pump operates in a similar fashion as that of external pump. But unlike the external gear pump, these both lobes are driven independently and they do not have actual contact with each other.

Lobe contact is prevented by external timing gears located in the gearbox. Pump shaft support bearings are located in the gearbox, and since the bearings are out of the pumped liquid, pressure is limited by bearing location and shaft deflection. As the lobes come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the lobes as they rotate. Liquid travels around the interior of the casing in the pockets between the lobes and the casing it does not pass between the lobes. Finally, the meshing of the lobes forces liquid through the outlet port under pressure. So, they are quieter than other types of gear pumps. Since the lobe pump has smaller number of mating elements, the lobe pump output will have a somewhat greater amount of pulsating, although its volumetric displacement is generally greater than that for other types of gear pumps.Lobe pumps are frequently used in food applications because they handle solids without damaging the product.



Advantages

- Pass medium solids
- No metal-to-metal contact
- Long term dry run (with lubrication to seals)

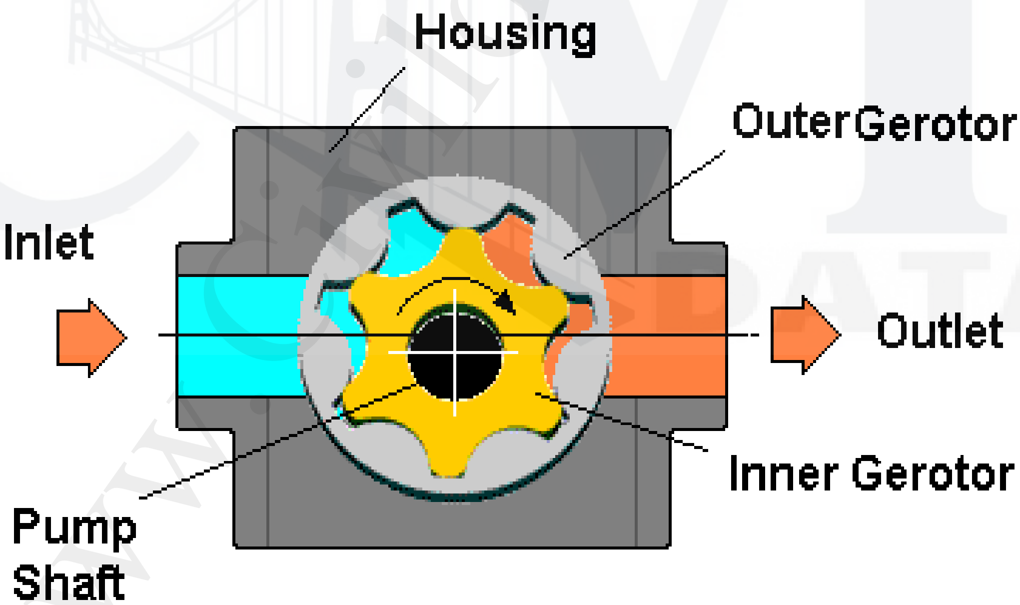
Disadvantages

- Requires timing gears
- Requires two seals
- Reduced lift with thin liquids

Applications

- Paper coatings
- Soaps and surfactants
- Paints, dyes, Rubber and adhesives
- Pharmaceuticals

Gerotor Pump: It is a positive displacement pumping unit. The name gerotor is derived from "Generated Rotor". A gerotor unit consists of an inner and outer rotor. The inner rotor has N teeth, and the outer rotor has N+1 teeth. The inner rotor is located off-center and both rotors rotate. During part of the assembly's rotation cycle, the area between the inner and outer rotor increases, creating a vacuum. This vacuum creates suction, and hence, this part of the cycle is where the intake is located. Then, the area between the rotors decreases, causing compression. During this compression period, fluids can be pumped, or compressed (if they are gaseous fluids).



Gerotor Pump

Gerotor pumps are generally designed using a trochoidal inner rotor and an outer rotor formed by a circle with intersecting circular arcs. A gerotor can also function as a motor. High pressure gas enters the intake area and pushes against the inner and outer rotors, causing both to rotate as the area between the inner and outer rotor increases. During the compression period, the exhaust is pumped out.

Advantages

- High Speed
- Only two moving parts
- Constant and even discharge regardless of pressure conditions
- Operates well in either direction
- Quiet operation

Disadvantages

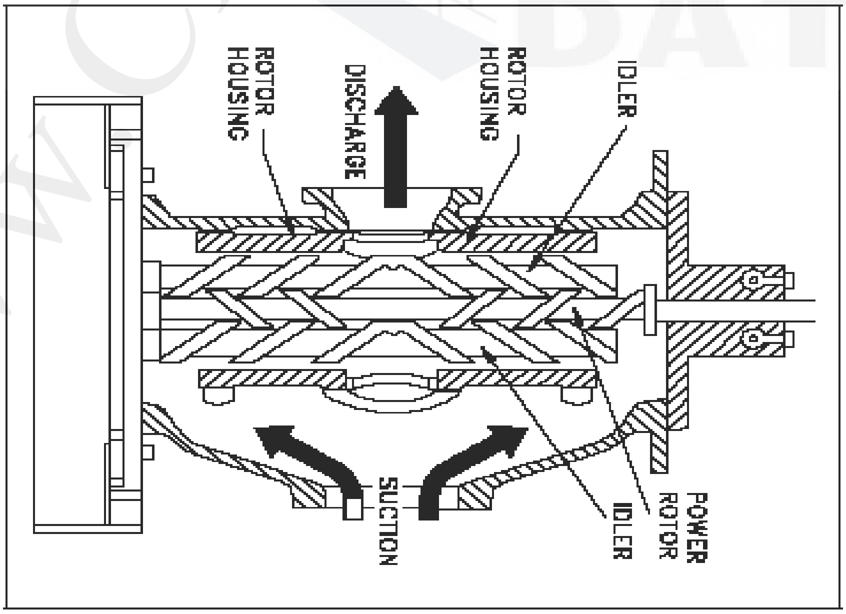
- Medium pressure limitations
- Fixed clearances
- No solids allowed
- One bearing runs in the product pumped
- Overhung load on shaft bearing

Applications

- Light fuel oils
- Lube oil
- Cooking oils
- Hydraulic fluid

Screw Pump:

It is an axial flow positive displacement unit. Three precision ground screws, meshing within a close fitting housing, deliver non pulsating flow quietly and efficiently. The two symmetrically opposed idler rotors act as rotating seals, confining the fluid in a succession of closures or stages. The idler rotor are in rolling contact with the central power rotor and are free to float in their respective housing bores on a hydrodynamic oil film. There are no radial bending loads. Axial hydraulic forces on the rotor set are balanced, eliminating any need for thrust bearings. The liquid is introduced at the two ends and discharged at the centre. The pumping action comes from the sealed chamber. The sealed chamber formed by the contact of the two gears at the intersection of their addenda and by the small clearance between the screws and the pump housing. This working is similar to a nut moving along a thread rod when the rod rotated. In these pumps, it should be noted that the liquid does not rotate but moves linearly. Thus the liquid moves forward along the axis with the rotation of the screw and is discharged to the outlet port.



Screw Pump

Advantages:

1. Give uniform pressure with negligible pulsations.
2. Very quiet, because of rolling action of the screw spindles.
3. Can handle liquids containing vapour and gases

Disadvantages:

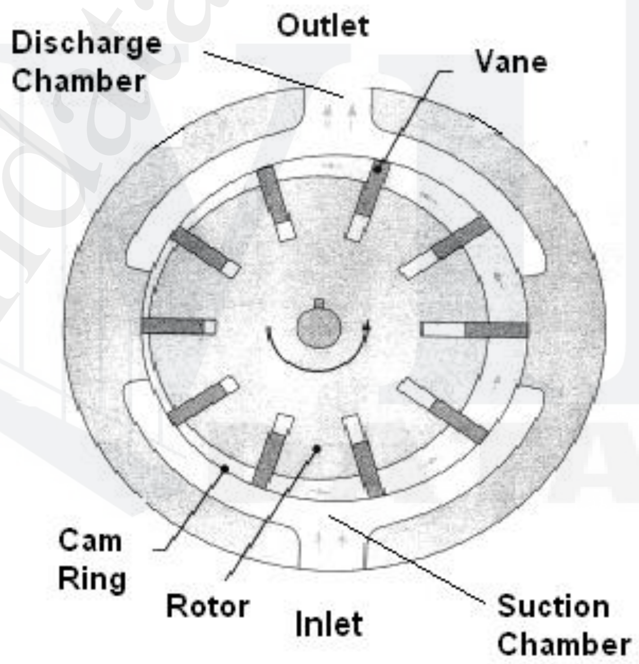
1. It is difficult to manufacture the screw profile to maintain close tolerance.
2. Overall volumetric and mechanical efficiency is relatively low.

Types of Vane Pumps:

1. Unbalanced Vane Pumps
   a. Fixed displacement unbalanced pumps
   b. Variable displacement unbalanced pumps
2. Balanced Vane Pumps

Unbalanced Vane Pump:

The pump consists of a rotor which contains radial slots splined to the drive shaft. The rotor rotates inside a cam ring. Each slot contains a vane which is free to slide in or out of the slots in the pump rotor. The vane is designed to mate with the surface of the cam ring as the rotor turns. The cam ring axis is offset to the drive shaft axis. As the rotor rotates, the centrifugal force pushes the vanes out against the surface of the cam ring. The vanes divide the space between the rotor and the cam ring into a series of small chambers. During the first half of rotor rotation, the volume of these chambers increase, thereby causing a reduction of pressure. This is the suction process which causes the fluid to flow through the inlet port and fill the void.



Unbalanced Vane Pump

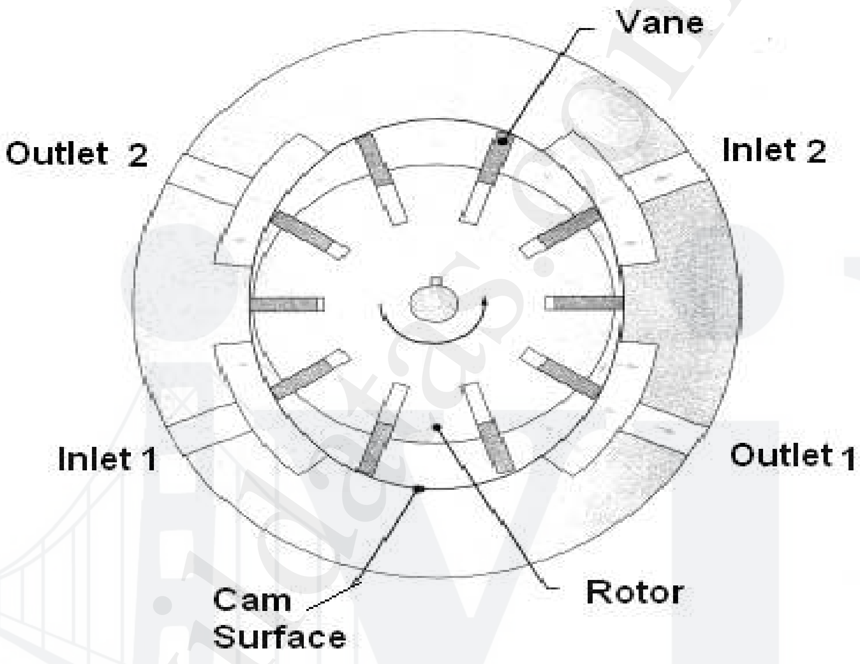
As the rotor rotates through the second half, the cam ring pushes the vane back into their slots and the trapped volume is reduced. This positively ejects the trapped fluid through the outlet port. In this pump, all the pumping action takes place in the chambers located on the one side of the rotor and shaft. So the pump is of an unbalanced design.

Fixed Displacement Unbalanced Vane Pumps: In this type rotor housing eccentricity is constant. Hence the displacement volume is fixed. A constant volume of fluid is discharged during each revolution of the rotor.

Variable Displacement Unbalanced Vane Pump: Variable displacement can be provided if the housing can be moved with respect to the rotor. This movement changes the eccentricity and hence the displacement. Usually a hand wheel or pressure compensator can be used to move the cam ring to change the eccentricity.

Balanced vane pump:

In balanced vane pump, the rotor rotates inside a cam ring of elliptical shape. It has two inlet and outlet ports which are diametrically opposite each other. Movement of the vanes in and out causes the chamber between them to increase and decrease. When these chambers are increasing in size, the fluid is being sucked into the pump through the inlet ports. The two inlet ports are connected to a common inlet passage. When the chambers are decreasing in size, the fluid starts being delivered into the system through the outlet ports which are connected to a common outlet passage. Because the pressure ports are opposite to each other, a complete hydraulic balance can be achieved. One disadvantage of balanced vane pump is that it cannot be designed as a variable displacement pump.



Balanced Vane Pump

Advantages:

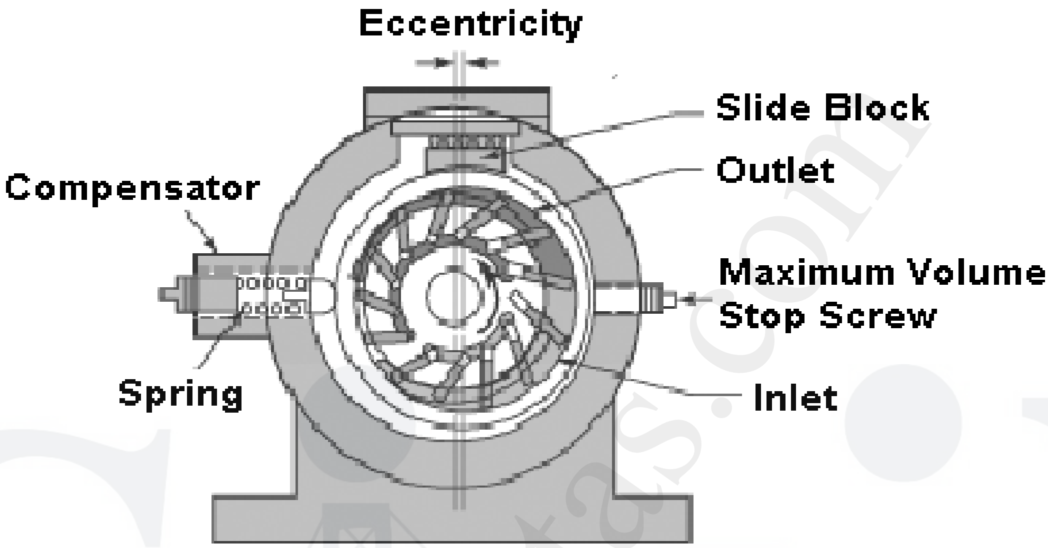
1. Volumetric and overall efficiencies are high.
2. only small changes in capacity occur with variations in viscosity and discharge pressure
3. Their vanes are self compensating for wear and also vanes can be easily replaced.
4. They are self priming, robust and give constant delivery for a set rotor speed.

Disadvantages:

1. They cannot handle abrasive liquids
2. They require seals and foreign bodies can damage the pump
3. They cannot be operated against a closed discharge without damage to the pump. Hence relief valves are required

Pressure Compensated Variable Delivery Pump:

In this system pressure acts directly via a hydraulic piston on the right side. This forces the cam ring against a spring loaded piston on the left side. If the discharge pressure is large enough, it overcomes the compensator spring force and shifts the cam ring to the left. This reduces the eccentricity and decreases the flow. If the pressure continues to increase, there is no eccentricity and pump flows becomes zero.



Pressure Compensated Vane Pump

Piston Pumps:

In piston pumps, the pumping action is affected by a piston that moves in a reciprocating cycle through a cylinder. The basic operations of piston pumps are very similar to that of the reciprocating engines. These pumps are classified as

1. Axial Piston Pumps
    a. Swash plate axial piston pump
    b. Bent axis Axial piston pump
2. Radial Piston Pumps

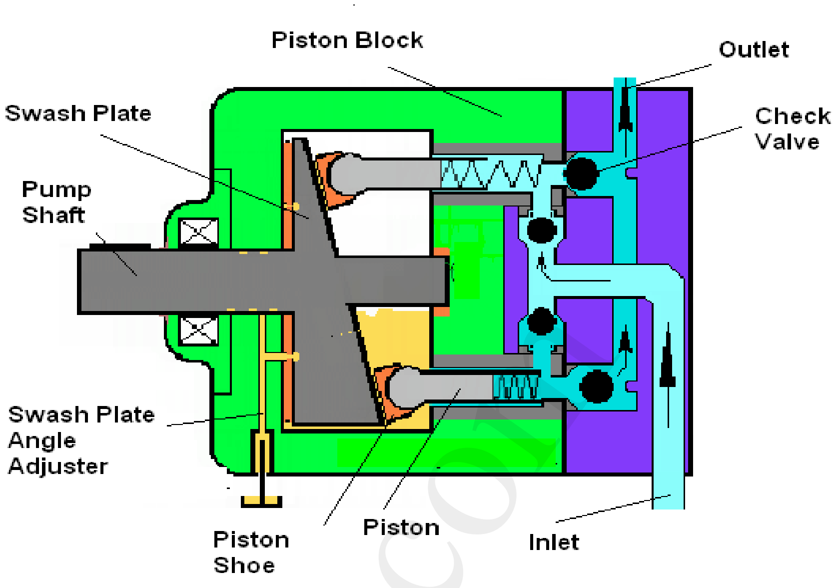
In axial piston pumps, a number of pistons and cylinders are located in a parallel position with respect to the drive shaft, while in the radial type they are arranged radially around the rotor hub.

Axial Piston Pump:

In this type rotary shaft motion is converted to axial reciprocating motion which drives the piston. Most axial piston pumps are multi piston designs and utilize check valves or port plates to direct liquid flow from inlet to discharge. Output can be controlled by manual, mechanical or pressure compensated controls.

Swash Plate (In line) axial Piston Pump:

In this pump rotary drive motion is converted to reciprocating, axial piston motion by means of the swash plate, mounted on the drive shaft. Thus the rotation of the swash plate produces in and out motion of the piston in their cylinders and hence the fluid is discharged.

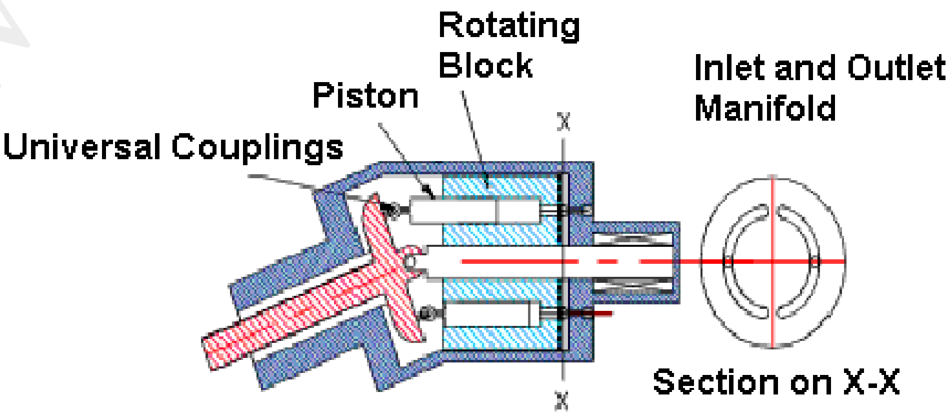


Swash Plate Piston Pump

This type of pumps can also be designed to have variable displacement capability. This can be achieved by altering the angle of the swash plate. Because in the swash plate axial pump, the angle of tilt of the swash plate determines the piston stroke and hence the pump displacement. The increase in the swash plate angle will increase the piston stroke and hence the fluid displacement. When the swash plate is vertical, then the displacement is zero. Even one can reverse the flow direction by changing the angle of swash plate. However, the maximum swash plate angle is generally limited to 17.5°, due to various design considerations.

Bent Axis Axial Piston Pump:

This type of pump contains a cylinder block rotating with the drive shaft. As shown the centerline of the cylinder block is sent at an offset angle relative to the centerline of the drive shaft. The cylinder has a number of pistons and cylinders arranged along a circle. The ball and socket joints connect the piston rods with the drive shaft flange. When the distance between the drive shaft flange and cylinder block changes, the piston move in and out of



Bent Axis Type Piston Pump

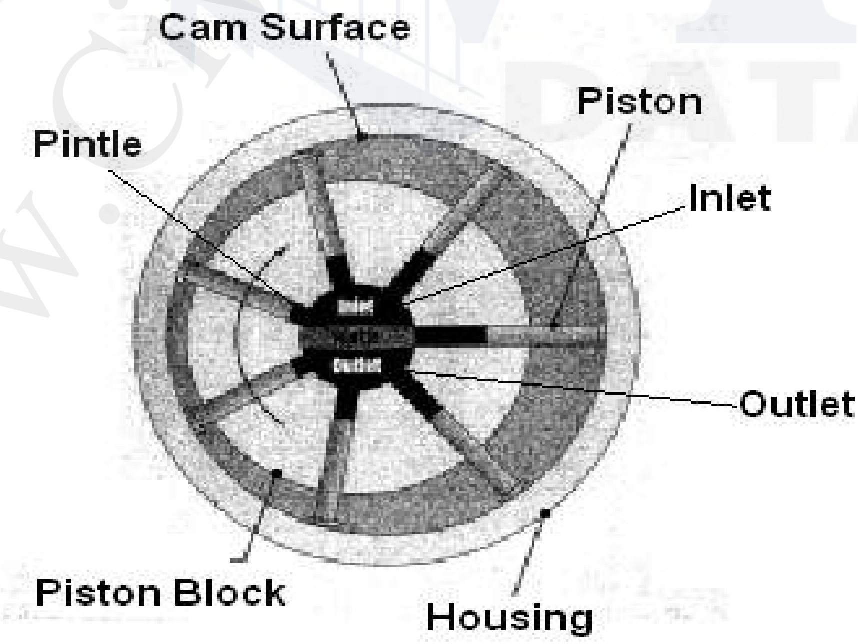
the cylinder. In order to provide alignment and positive drive, a universal link is used to connect the block to the drive shaft. When the piston carrying body turns, the exit passage in the cylinder bores move along the control slots of a firmly positioned control plate and are thus connected alternatively to suction or discharge pipelines.

In the fixed displacement pumps, the pumps are mounted in a fixed casing so that swing angle cannot be adjusted. So the fixed displacement of the piston and hence the constant discharge of fluid are achieved. In variable displacement pumps, the swing angle can be varied. Because the volumetric displacement of the pump varies with the offset angle. When the offset angle is zero, then the displacement will be zero. However, the angle will vary from 0 º to 30º.

Radial Piston Pump:

The radial piston pump has a number of radial pistons in a cylinder block which revolves around a stationary pintle or valve. The pistons remain in contact with the reaction ring due to centrifugal force and back pressure on the pistons. A drive shaft is attached to the end of cylinder block and provides the power needed to the pump. The reaction ring is moved eccentrically with respect to the pintle axis.

If the cylinder block is rotated in a clockwise direction, the pistons on one side travel outward and sucks the fluid when it passes the suction port of the pintle. When the piston passes the maximum point eccentricity, it is forced inward by the reaction ring. This force the fluid to enter into the discharge port. The displacement can be varied by moving the reaction ring to change the piston stroke.



Radial Piston Pump

Important Formulas:

1. Theoretical Discharge for Gear Pump: $Q_T = \frac{\pi}{4}(D_o^2 - D_i^2)\ b\ N$	D_o – Outer Diameter of Gear D_i – Inner Diameter of Gear b - Width of Gear N – Speed of Pump
2. Theoretical Discharge for Vane Pump: $Q_T = \frac{\pi}{4}(D_c + D_R)\ 2\ e\ L\ N$	D_c – Diameter of Cam Ring D_R – Diameter of Rotor e – Eccentricity L – Width of Rotor
3. Bent Axial Piston Pump $Q_T = DANY \sin\theta$; $\sin\theta = \frac{S}{D}$	D- Piston circle Diameter A – Area of Piston Y – Number of pistons θ - Offset angle S – Piston stroke
4. Swash Plate Pump: $Q_T = DANY \tan\theta$	θ - Offset angle of Swash Plate
5. Radial Piston Pump $Q_T = 0.5\ e\ Y\ \pi\ D^2\ N$	

Volumetric Efficiency: It indicates the amount of leakage within the pump. This involves considerations such as manufacturing tolerances and flexing of the pump casing under the design pressure operating conditions.

$$\eta_v = \frac{\text{Actual Flow rate produced by pump}}{\text{Theoretical flow rate the pump should produce}} \text{ X } 100$$

$$\eta_v = \frac{Q_A}{Q_T}$$

Mechanical Efficiency: It indicates the amount of energy losses that occur due to reasons other than leakages. This includes friction in bearings and between other mating parts. It also includes energy losses due to fluid turbulence.

$$\eta_m = \frac{\text{Theoretical Power required to operate the pump}}{\text{Actual power delivered to the pump}} \text{ x } 100$$

$$\eta_m = \frac{PQ_T}{2\pi NT}$$

Overall Efficiency:

$$\eta_o = \eta_v \times \eta_m$$

HYDRAULIC ACTUATORS

ACTUATORS:

It is a device used for converting hydraulic energy into mechanical energy. The pressurized hydraulic fluid delivered by the hydraulic pump is supplied to the actuators, which converts the energy of the fluid into mechanical energy. This mechanical energy is used to get the work done.

TYPES OF ACTUATORS:

1. Linear Actuators (Hydraulic cylinders)
2. Rotary Actuators (Hydraulic motors)
   a. Continuous rotary actuators
   b. Semi rotary actuators

HYDRAULIC CYLINDERS:

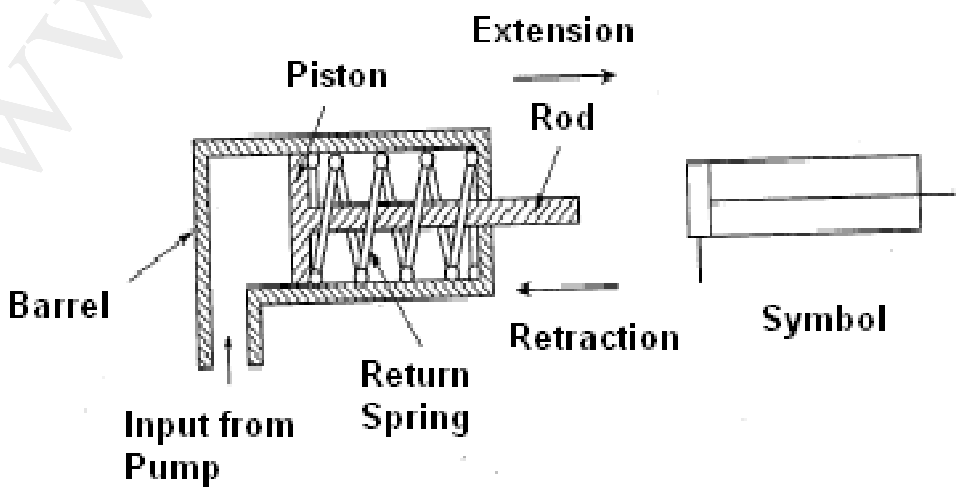
A hydraulic cylinder is a device, which converts fluid power into linear mechanical force and motion. It usually consists of a movable element, a piston and a piston rod operating within a cylinder bore.

TYPES OF HYDRAULIC CYLINDERS:

1. Single acting cylinders
2. Double acting cylinders
3. Telescoping cylinders
4. Double rod cylinder
5. Tandem cylinder

SINGLE ACTING CYLINDER:

A single acting cylinder is designed to apply force in only one direction. It consists of a piston inside a cylindrical housing called barrel. Attached to end of the piston is a rod which extends outside. At the other end (Blank end) is a port for the entrance and the exit of oil. A single acting cylinder can exert a force only in the extending direction, as fluid from the pump enters through the blank end of the cylinder. Single acting cylinders do not hydraulically retract. Retraction is accomplished by using gravity or by the inclusion of a compression spring at the rod end.

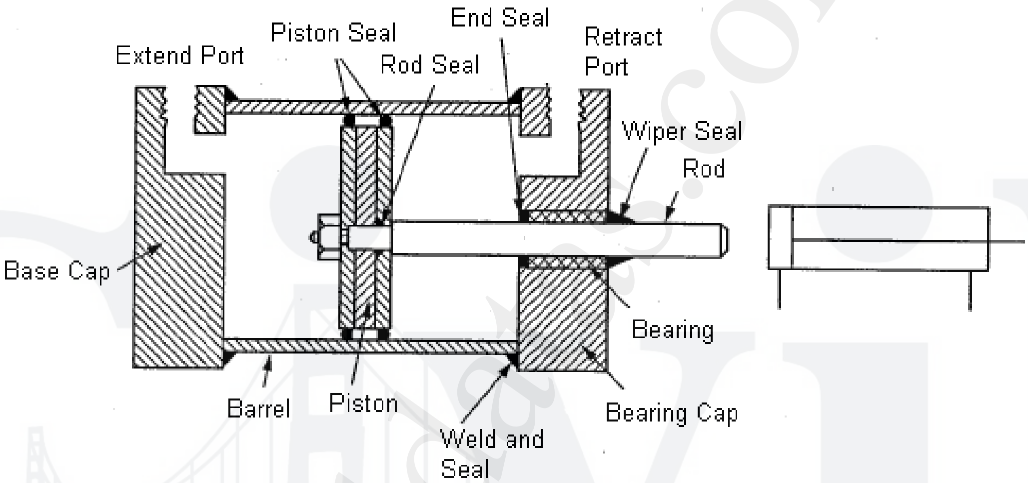


Advantages and Disadvantages:

1. The single acting cylinders are very simple to operate, and compact in size.
2. The single acting cylinders with spring return cannot be used for larger stroke length.

DOUBLE ACTING CYLINDER:

A double acting cylinder is capable of delivering forces in both directions. The barrel is made of seamless steel tubing, honed to affine finish on the inside surface. The piston which is made of ductile iron contains U cup packing to seal the leakage between the piston and the barrel. The ports are located in the end caps which are secured to the barrel by tie rods. The load of the piston rod at the neck is taken by a rod bearing, which is generally made of brass or bronze.

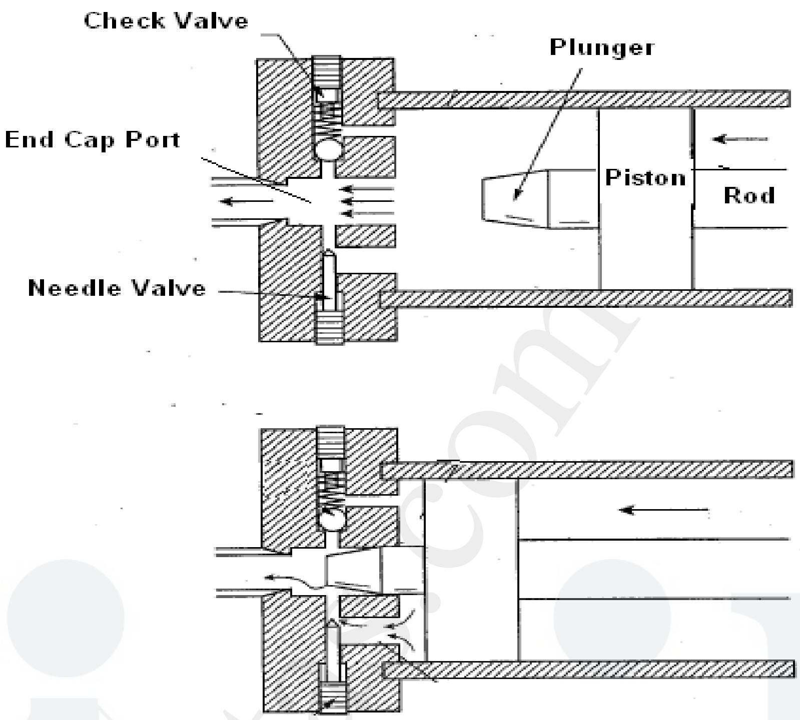


A rod wiper is provided at the end of the neck to prevent foreign particles and dust from entering into the cylinder along with the piston rod. When the fluid from the pump enters the cylinder through port 1, the piston moves forward and the fluid return to the reservoir from the cylinder through port 2. During the return stroke the fluid is allowed to enter the cylinder through port 2 and fluid from the other side of the piston goes back to the reservoir through port 1.

CYLINDER CUSHIONING:

As long as the piston is moving in the middle range of the cylinder, nothing will hit the piston head. But, due to the inertia forces of the moving parts at the end of the piston travel, the piston will hit the cylinder head at full speed. To overcome this, the designers provide a cushioning arrangement by which the hydraulic cylinder can be slowly retarded or cushioned, during the last portion of the stroke. The figure shows the position of the piston at the start of the cushioning action. In this position, the fluid from the pump enters into the rod end of the cylinder moving the piston towards the left. The fluid from the head end of the cylinder flows freely to the reservoir through the fluid port.

As the stroke nears completion, the cushion nose starts entering in the space of the cylinder head. Due to the taper front of the cushion nose, the fluid port path is gradually closed. So the fluid cannot flow through the port or through the passage of check valve. Now entrapped fluid can escape only through the passage controlled by the needle valve. Thus due to the restricted outflow during the last portion of the stroke, the piston decelerates slowly. By adjusting the needle valve,



rate of deceleration is controlled. For starting the forward stroke of the piston, the fluid is allowed to enter the fluid port. The fluid will now flow from all passages. Thus the full piston area will be subjected to the system pressure.

During deceleration of the load, extremely high pressures will develop within the cylinder cushion. Ideally, the back pressure will be constant over the entire cushioning length. But in practice, the cushion pressure is higher when the piston rod has just entered the cushion.

SPEED OF A HYDRAULIC CYLINDER:

Every hydraulic cylinder has its own economical and practicable range of speeds. If the speed of the cylinder is increased beyond this limit, the sudden stoppage of the piston will create shock load on the piston head, piston rod and other mechanical parts causing serious damages. The high speed will also create difficulty in the accurate positioning of the movable parts. So at the time of deciding the speed of a hydraulic cylinder, proper care is to be taken in the design stage itself.

The maximum speed of the piston rod is limited by the rate of fluid flow in and out of the cylinder and the ability of the cylinder to withstand the impact forces which occur when the piston movement is arrested. In an un-cushioned cylinder it is normal to limit the maximum piston movement is arrested. In an un-cushioned cylinder it is normal to limit the maximum piston velocity to 8m/min. This value is increased to 12m/min for a cushioned cylinder and 45m/min is permissible with high speed cylinders. Oversized ports are necessary in cylinders that are used in high speed applications.

Velocity equations:

Consider a double acting cylinder

D – Diameter of the piston

d – Diameter of piston rod

A – Area of Blank end - $\frac{\pi D^2}{4}$

a- Piston rod area - $\frac{\pi d^2}{4}$

Q – Input flow rate

q_E – Flow rate from rod end of the cylinder when extending

q_R – Flow rate from blank end of cylinder when retracting

Rod End Area – (A-a) = $\frac{\pi}{4}$ (D^2-d^2)

1. **When Piston rod is extending:**

Piston velocity $V_E = \frac{Q}{A} = \frac{q_E}{(A-a)}$

Thus $q_E = Q\,\frac{(A-a)}{A} = Q\,\frac{(D^2-d^2)}{D^2}$

Thus as the piston rod is extending, the flow rate of the fluid leaving the cylinder is less than the flow rate of fluid entering the cylinder.

2. **When piston rod is retracting:**

Piston velocity $V_R = \frac{Q}{A-a} = \frac{q_R}{A}$

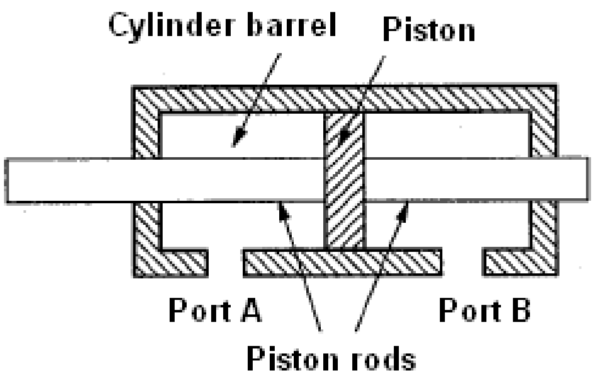
Thus $q_R = Q\,\frac{A}{(A-a)} = Q\,\frac{D^2}{(D^2-d^2)}$

Thus when the piston rod is retracting, the rate of fluid leaving the cylinder is greater than the flow rate of fluid entering the cylinder.

SPECIAL TYPE CYLINDERS:

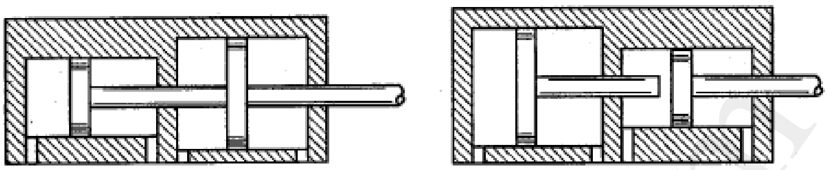
DOUBLE ROD CYLINDER:

It is a cylinder with single piston and a piston rod extending from each end. This cylinder allows work to be performed at either or both ends. It may be desirable where operating speed and return speed are equal.



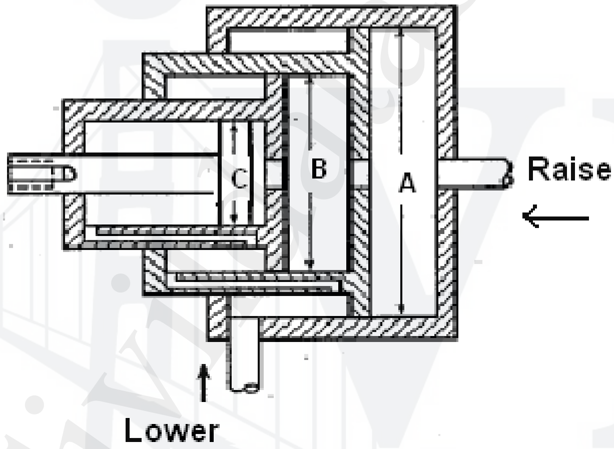
TANDEM CYLINDER:

It design has two cylinders mounted in line with pistons connected by a common piston rod. These cylinders provide increased output force when the bore size of a cylinder is limited. But the length of the cylinder is more than a standard cylinder and also requires a larger flow rate to achieve a speed because flow must go to both pistons.



TELESCOPING CYLINDER:

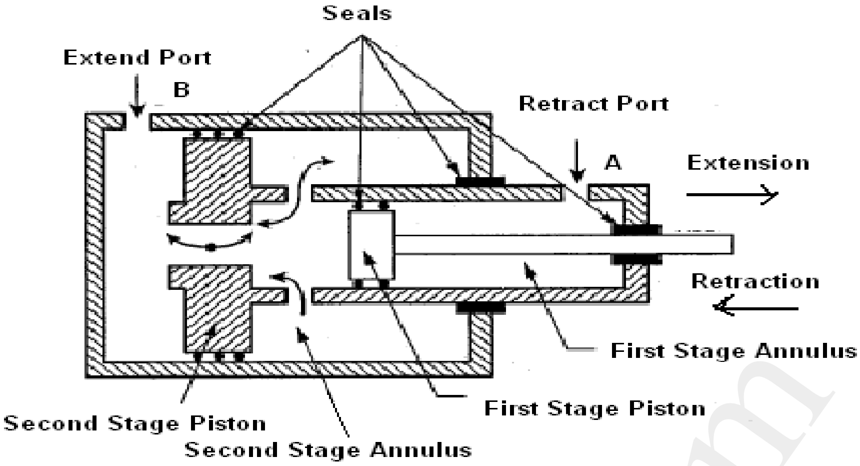
They are used where long work strokes are needed. A telescoping cylinder provides a relatively long working stroke for an overall reduced length by employing several pistons which telescope into each other.



Since the diameter A of the ram is relatively large, this ram produces a large force for the beginning of the lift of the load. When ram A reaches the end of the stroke, ram B begins to move. Now ram B provides the required smaller force to continue raising the load. When ram B reaches the end of its stroke, then ram C moves outwards to complete the lifting operation. These three rams can be retracted by gravity acting on the load or by pressurized fluid acting on the lip of each ram.

TWO STAGE DOUBLE ACTING TELESCOPING CYLINDER:

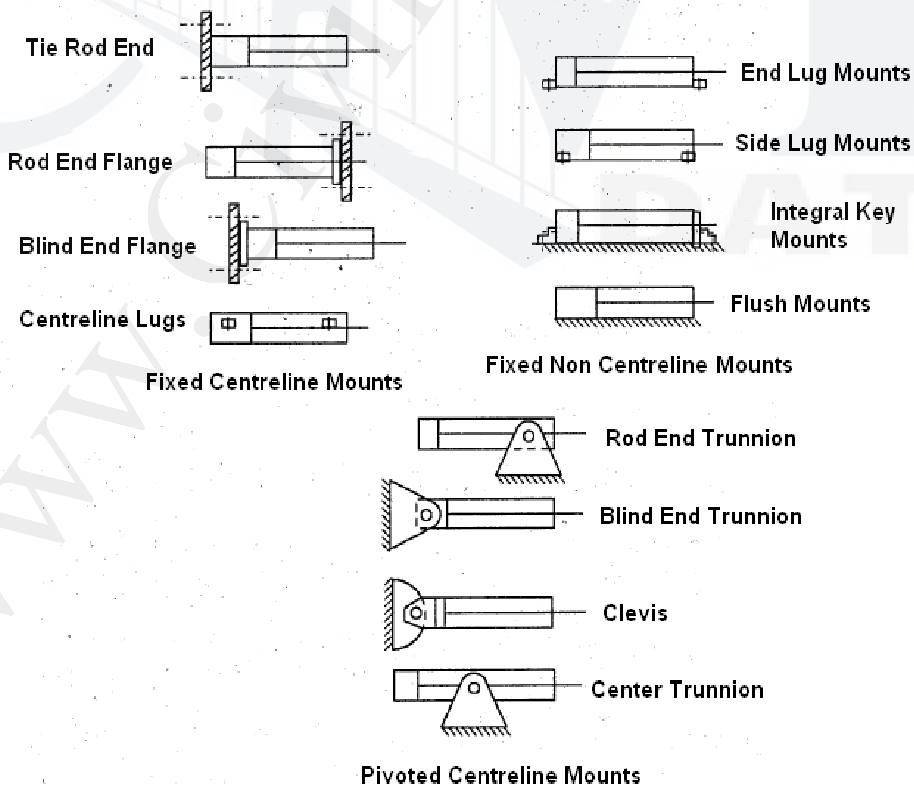
Retraction stroke: During the retraction stroke, the fluid is fed into the first stage annulus via retract port A. therefore the first stage piston is forced to the left until it uncovers the fluid ports connecting this with the second stage annulus. This, in turn, moves the larger piston to the left until both the pistons are fully retracted into the body of the cylinder.



Extension Stroke: During the extension stroke, the fluid is fed through the extend port B. Now the fluid forces both pistons to the right until the cylinder is fully extended.

MOUNTING CONFIGURATIONS:

The type of mountings on cylinder is numerous, and they can accommodate a wide variety of applications. The most common mountings are lugs, flange, trunnion, clevis and extended tie rods. One of the important considerations in selecting a particular mounting style is whether the major force applied to the load will result in tension or compression of the piston rod. The ratio of rod length to diameter should not exceed 6:1 proportion at full extension. This helps to prevent the rod from buckling due to compression or tensile shock forces.



Alignment of the rod with the resistive load is another important consideration while selecting cylinder mounts. Misalignment or non axial loading also tends to place unnecessary loads on the rod and the rod guides, bushes or bearings. Due to the immense loads and the extreme forces induced by the rod there are large stresses on the rod at full extension. Centre lugs, centre trunnions and clevis arrangements tend to help keep the rod or shaft in line with the load.

Fixed centerline mounts: These are used for thrust that occur linearly or in the centerline with the cylinder. Proper alignment is essential to prevent compound stresses that may cause excessive friction and bending as the piston rod extends. Additional holdings strength may be essential with long stroke cylinders.

Fixed non-centerline mounts: These are convenient where exceptionally heavy linear thrusts are encountered. Generally, integral keys or pins are used if excessive hydraulic shock is expected. This helps to relieve shear loads. Since the cylinder has to expand and contract with temperature changes, only one end should be keyed or pinned.

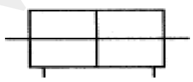
Pivoted centerline mounts: These are used to compensate for thrusts that occur in multiple planes or if the attached load travels in a curved path. Ball joints, trunnions and clevis mounts allow thrust to be taken up along the cylinder centerlines.

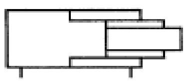
GRAPHIC SYMBOLS FOR LINEAR ACTUATORS:


Double Acting Cylinder


Single Acting Cylinder


Single Acting with Spring return


Double Rod Double Acting


Telescopic Double Acting


Telescopic Single Acting

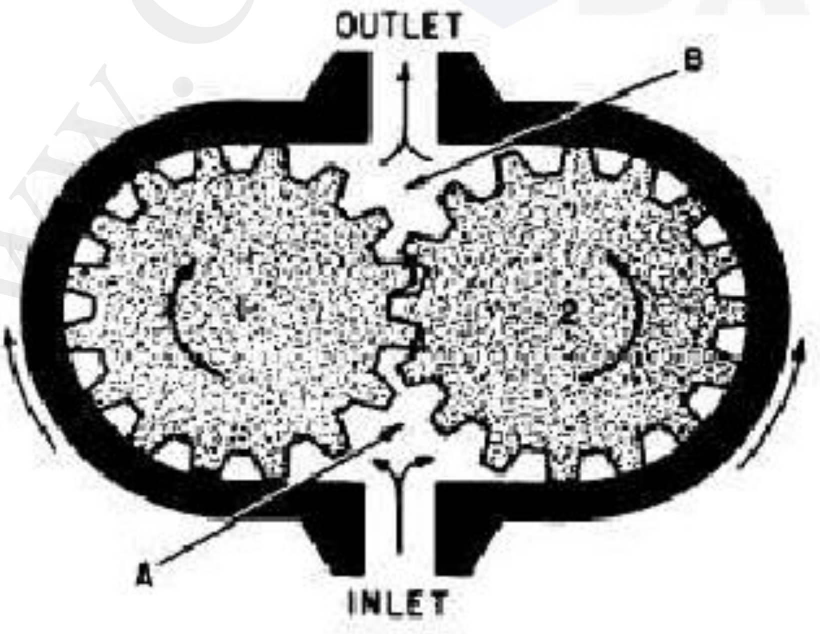
HYDRAULIC MOTORS:

A hydraulic motors converts fluid power into mechanical power in the form of rotational motion. Motors perform the opposite function of the pump, which converts mechanical power from an electric motor or engine into fluid power. Motors take pump flow and pressure as their input and output rotational motion and torque. Motor displacement is the volume. Pump displacement is the volume of the pump outputs per revolution of the pump shaft, a similar concept. Like pump motors can be fixed or variable displacement. Increasing the displacement of a motor decreases its speed because it requires more fluid to turn it each revolution. Increasing displacement increase torque output because more area within the motor is subjected to pressure. Decreasing motor displacement increases speed and decreases torque.

Hydraulic motors are most commonly gear, vane or piston type. All have a construction similar to the hydraulic pump of the same type. They also have similar properties. Gear motors are the least efficient, most dirt tolerant and have the lowest pressure ratings of the three. Piston motors are the most efficient, least dirt tolerant and have the highest pressure ratings. Vane and piston motors can be fixed or variable displacement like vane and piston pumps. Gear motors like gear pump are not available with variable displacement.

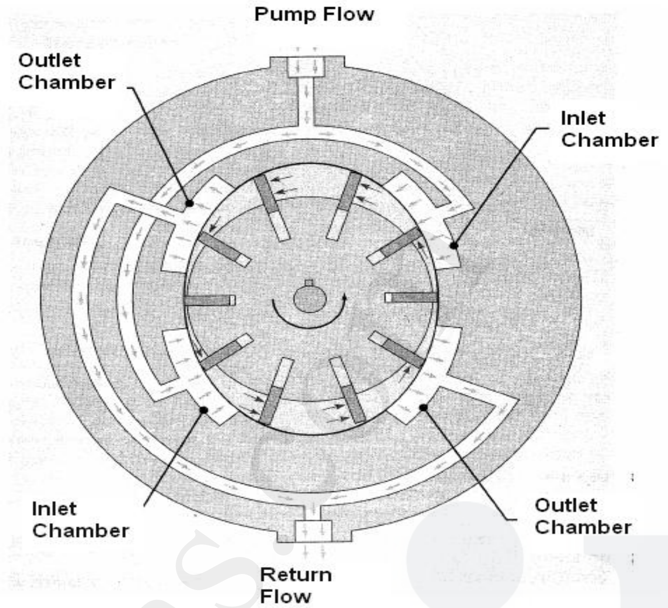
GEAR MOTOR:

The operation of gear motor is shown in the figure. One of the gears is keyed to an output shaft, while the other is simply an idler gear. Pump flow and pressure are sent to the inlet port of the motor. The pressure is then applied to the gear teeth, causing the gears and the output shaft to rotate. The pressure builds until enough torque is generated to rotate the output shaft against the load. Most gear motors are bi-directional the direction of rotation can be reversed by simply reversing the direction of flow.



VANE MOTORS:

In this type of motors the pump flow and pressure are applied to the vanes and the output shaft is rotated. The figure shows the balanced vane type motor. Recall from the discussion on vane pumps that balanced means that pressure is applied on both sides of the shaft resulting in no net force on the bearings.



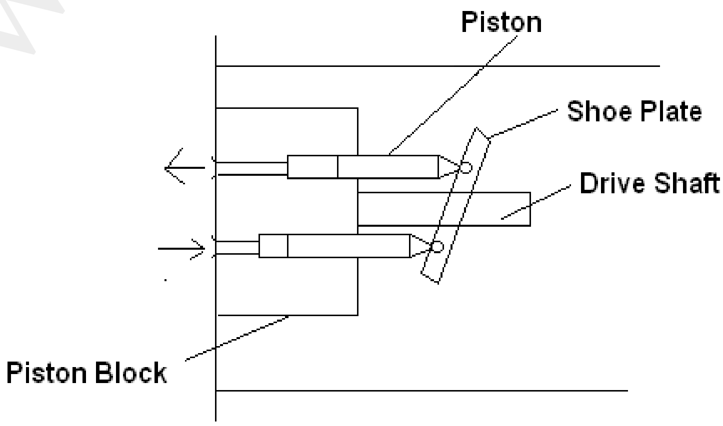
This increases the maximum operating pressure and drive speed at which the motor can operate. The vanes extent and retract twice per revolution of the rotor, which necessitates the use of two inlet and two outlet chambers. These chambers are combined into one common inlet and one common outlet within the motor housing. Most of the vane motors are bidirectional.

PISTON TYPE MOTORS:

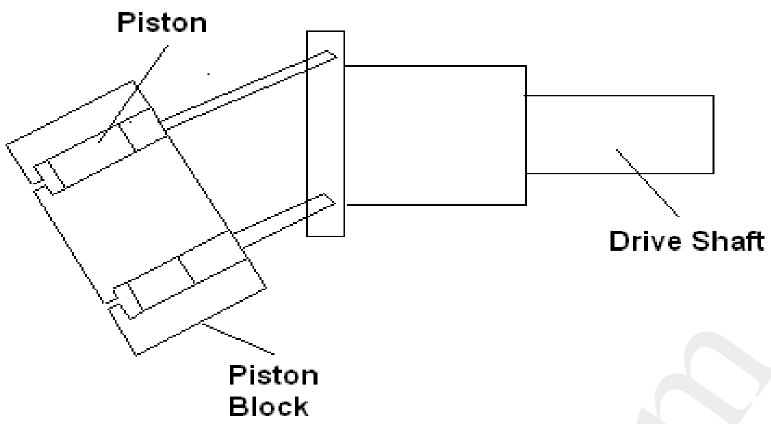
Piston motor develops an output torque at its shaft by allowing hydraulic pressure to act on pistons. Piston designs may be either axial piston type or radial piston type.

Axial piston motors:

Swash plate or bent axis type: It consists of a port plate, cylinder barrel, pistons, shoe plate, swash plate and a shaft. The arrangement is similar to a swash plate type pump. When fluid pressure acts on a piston, a force is developed which pushes the piston out and causes the piston shoe to slide across the swash plate surface. As the piston shoe slides, it develops a torque attached to the barrel.



Swash Plate Type



Bent Axis Type

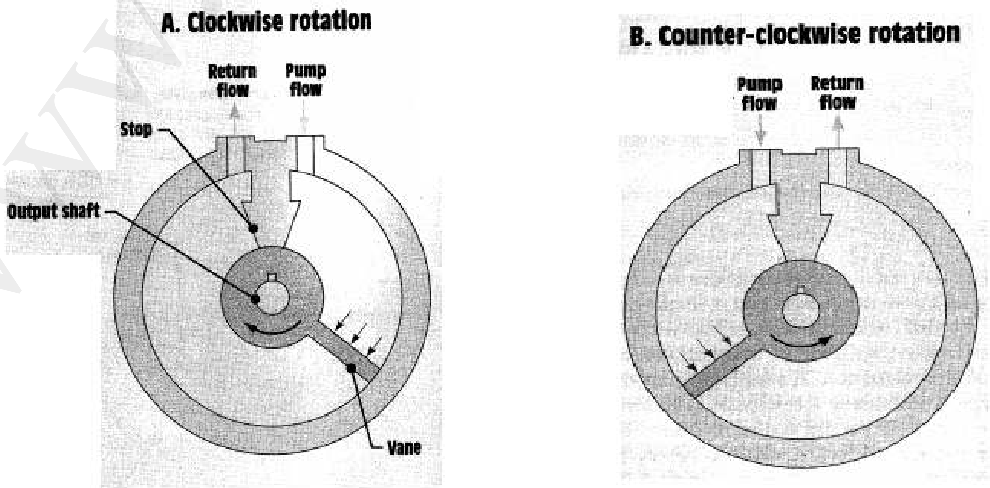
The amount of torque depends on the angle of slide caused by the swash plate and the pressure in the system. Since the swash plate angle controls the stroke in pistons of an axial piston motor, changing the angle will alter the stroke and motor displacement. The operating principle of an **bent axis motor** is similar to swash plate type. The angle of the cylinder block assembly with respect to drive shaft determines the stroke or motor displacement. Both these motors are used in high speed application only.

SEMI ROTARY ACTUATORS:

These are used to convert fluid pressure energy into torque which turns through an angle limited by the design of the actuator. With the majority of designs, the angle of rotation is within 360 degrees although it is possible to considerably exceed this when using piston operated actuators.

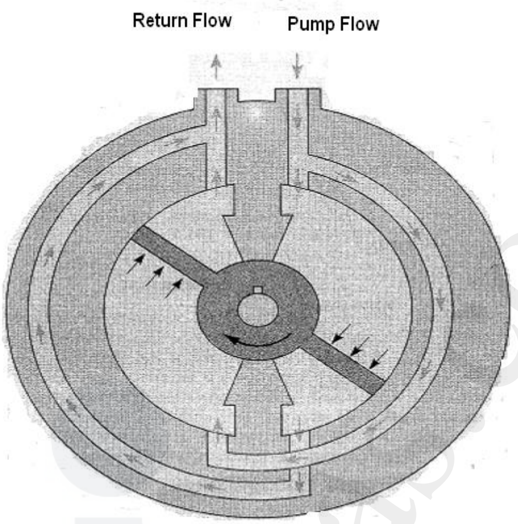
VANE TYPE ACTUATORS:

Vane type semi rotary actuator consists of one or two vanes connected to an output shaft which rotates when hydraulic pressure is applied to one side of the vanes. A single vane is limited to 280^{o} rotation and a double vane unit to approximately 100^{o}. Power in a two vane design is doubled.



Single Vane Semi Rotary Actuators

There will always be some internal fluid leakage across the vanes and these increases with the operating pressure as the viscosity of the working fluid decreases. This causes problems where a smooth speed control of the rotary motion is required. So, for the applications of vane type actuators, the manufacturer's recommendations regarding the operating pressure and type of fluid must be followed.



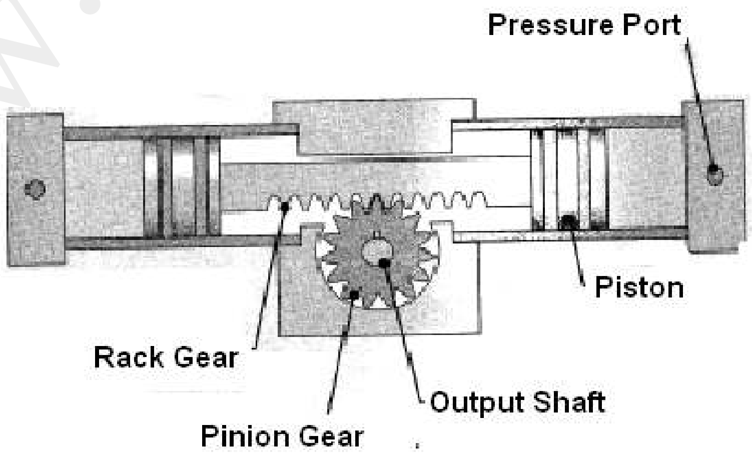
Double Vane Semi Rotary Actuators

The maximum torque obtainable from the currently available single vane unit is approximately 40X10^3 Nm and for double vane unit is 80X10^3 Nm.

PISTON TYPE SEMI ROTARY ACTUATORS:

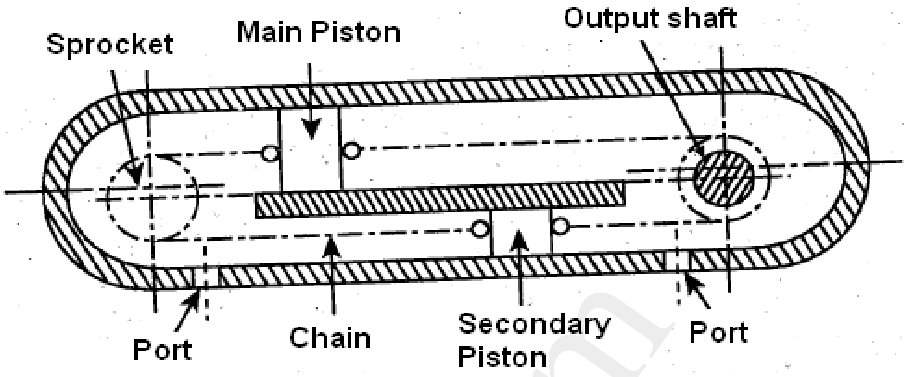
RACK AND PINION SEMI ROTARY ACTUATOR:

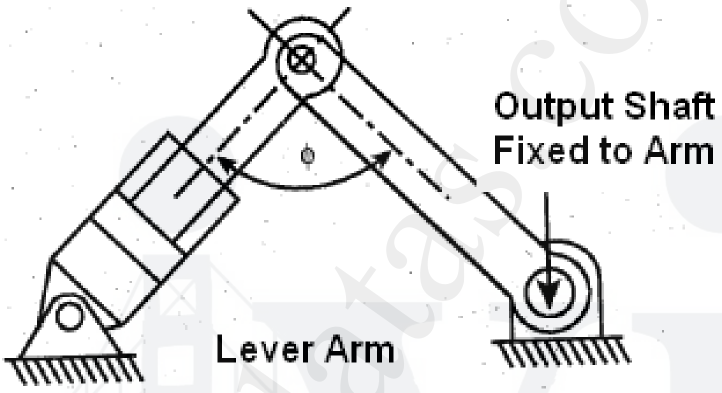
In this design, the cylinder drives a pinion gear and the rack is an integral part of the piston rod. The angle of rotation depends upon the stroke of the cylinder, rack and the pitch circle diameter of the pinion. The start and finish of the stroke is adjusted by means of an internal shop. The output torque available from the rack and pinion type is in an excess of 80X10^3 Nm at a pressure of 210 bar.



LEVER ARM SEMI ROTARY ACTUATOR:

A double acting cylinder can be made to generate rotary motion by using a lever arm. The angle of rotation will be less than 180o. The output is the product of {Piston trust x Sin φ x length of lever).





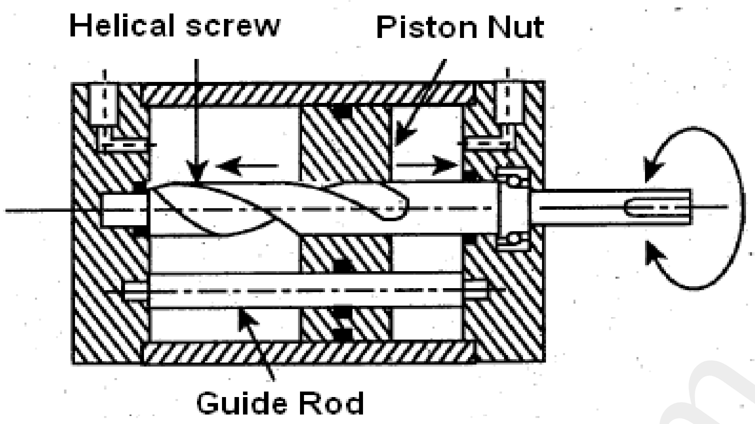
CHAIN AND SPROCKET SEMI ROTARY ACTUATOR:

In this design an endless chain and sprocket is used and it is suitable for multi revolution applications. The chain is anchored to two pistons, one large and the other small, which when in their respective bores, separate the halves of the unit. The large cylinder is the power cylinder and the small cylinder is the chain return or seal cylinder.

The idler is automatically a tensioned one, so a constant tension is maintained. Pressure is applied to one port of the actuator. The larger piston moves away from the port due to the differential area of the two pistons. Movement of the larger piston pulls the chain, causing the sprocket and output shaft to rotate.

HELICAL SCREW SEMI ROTARY ACTUATOR:

This type consists of a cylinder in which the piston is prevented from rotating by guide rods. The piston rod and the piston contain a helical groove and they mate together analogous to a screw and a nut. As the piston is driven along the barrel, it causes the rod to rotate.
Because of the difficulty in providing a hydraulic seal between the piston and rod, this design is limited to low pressure applications. The self locking helix angle of the piston and rod eliminate the possibility of external torque causing any rotary movement of the piston rod.



GRAPHIC SYMBOLS: