



A T M E
College of Engineering



Hydraulics & Pneumatics BME-702

Module-2 PUMPS AND ACTUATORS

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MODULE 2: PUMPS AND ACTUATORS

PUMP

A pump, which is the heart of hydraulic system, converts mechanical energy into hydraulic energy. The mechanical energy is delivered to the pump using a prime mover such as an 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.

CLASSIFICATION OF PUMPS:

Pumps are broadly classified into two types

- 1) Dynamic (non-positive displacement) pumps
- 2) Positive displacement pumps

PUMPS

- 1) **Dynamic (non-positive displacement) pumps:** This type is generally used for low pressure, high-volume flow applications. Because they are not capable of withstanding high pressures, they are of little use in the fluid power field. Normally their maximum pressure capacity is limited to 250-300psi. This type of pump is primarily used for transporting fluids from one location to another. The two most common types of dynamic pumps are the centrifugal and axial flow propeller pumps.
- 2) **Positive displacement pumps:** This type is universally used for fluid power systems. As the name implies, a positive displacement pump ejects a fixed amount of fluid into the hydraulic system per revolution of pump shaft rotation. Such a pump can overcome the pressure resulting from the mechanical loads on the system as well as the resistance to flow due to friction.

Positive displacement pumps are further classified into:

- i) **Fixed displacement pumps:** It is the one in which the amount of fluid ejected per revolution (displacement) cannot be varied.
- ii) **Variable displacement pumps:** In this type of pumps, the displacement can be varied by changing the physical relationships of various pump elements. This change in pump displacement produces a change in pump flow output even though pump speed remains constant.

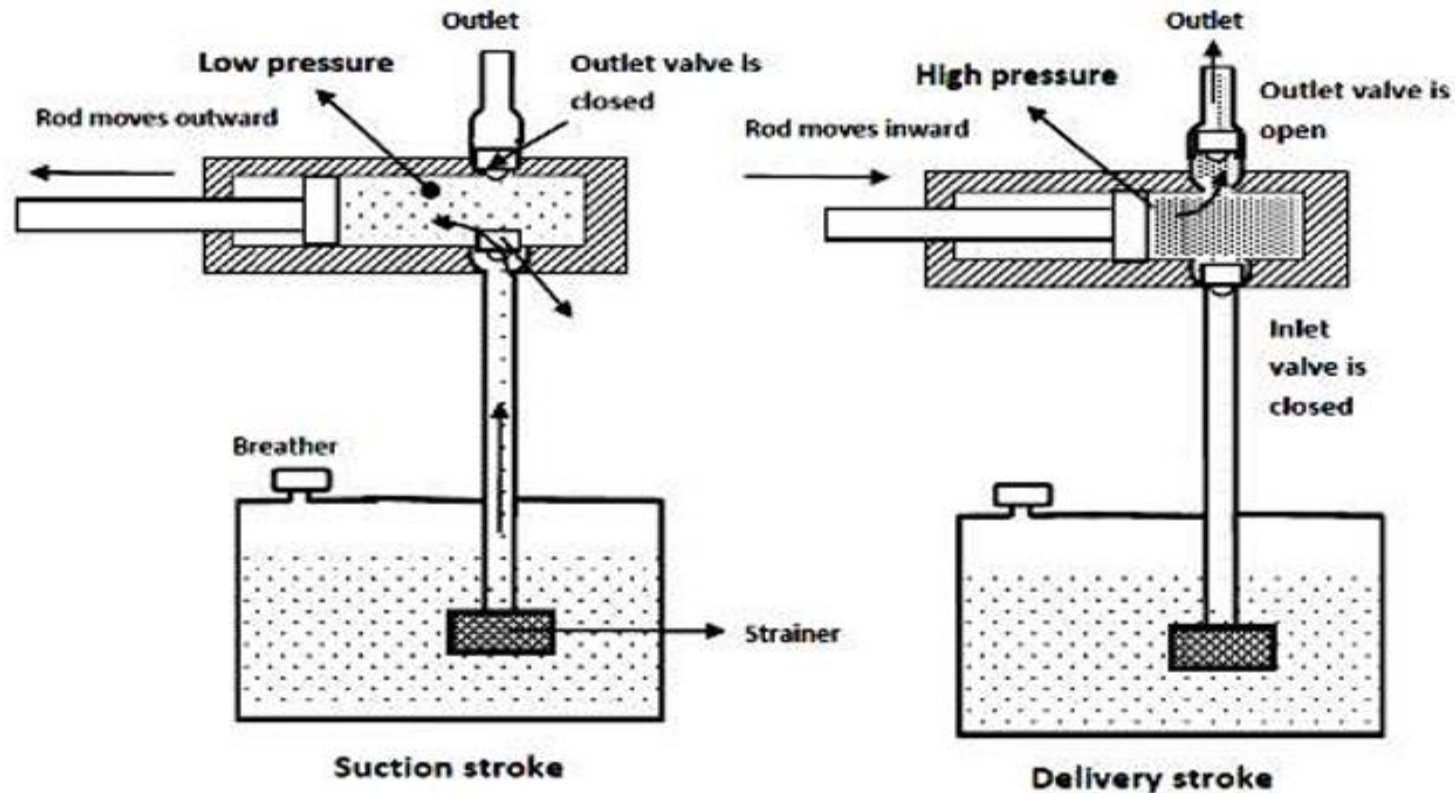
PUMPS

The advantages of positive displacement pumps over non-positive displacement pumps are as follows:

1. They can operate at very high pressures of up to 800 bar (used for lifting oils from very deep oil wells).
2. They can achieve a high volumetric efficiency of up to 98%.
3. They are highly efficient and almost constant throughout the designed pressure range.
4. They are a compact unit, having a high power-to-weight ratio.
5. They can obtain a smooth and precisely controlled motion.
6. By proper application and control, they produce only the amount of flow required to move the load at the desired velocity.
7. They have a great flexibility of performance. They can be made to operate over a wide range of pressures and speeds

PUMPING THEORY OF POSITIVE DISPLACEMENT PUMPS

Pumps operate on the principle whereby a partial vacuum is created at the pump inlet due to the internal operation of the pump. This allows atmospheric pressure to push the fluid out of oil tank (reservoir) and into the pump intake. The pump then mechanically pushes the fluid out the discharge line. This action can be best described by reference to a simple piston pump shown in Fig.



CLASSIFICATION OF POSITIVE DISPLACEMENT PUMPS

1. Gear Pumps

- i) External Gear pump
- ii) Internal Gear pump

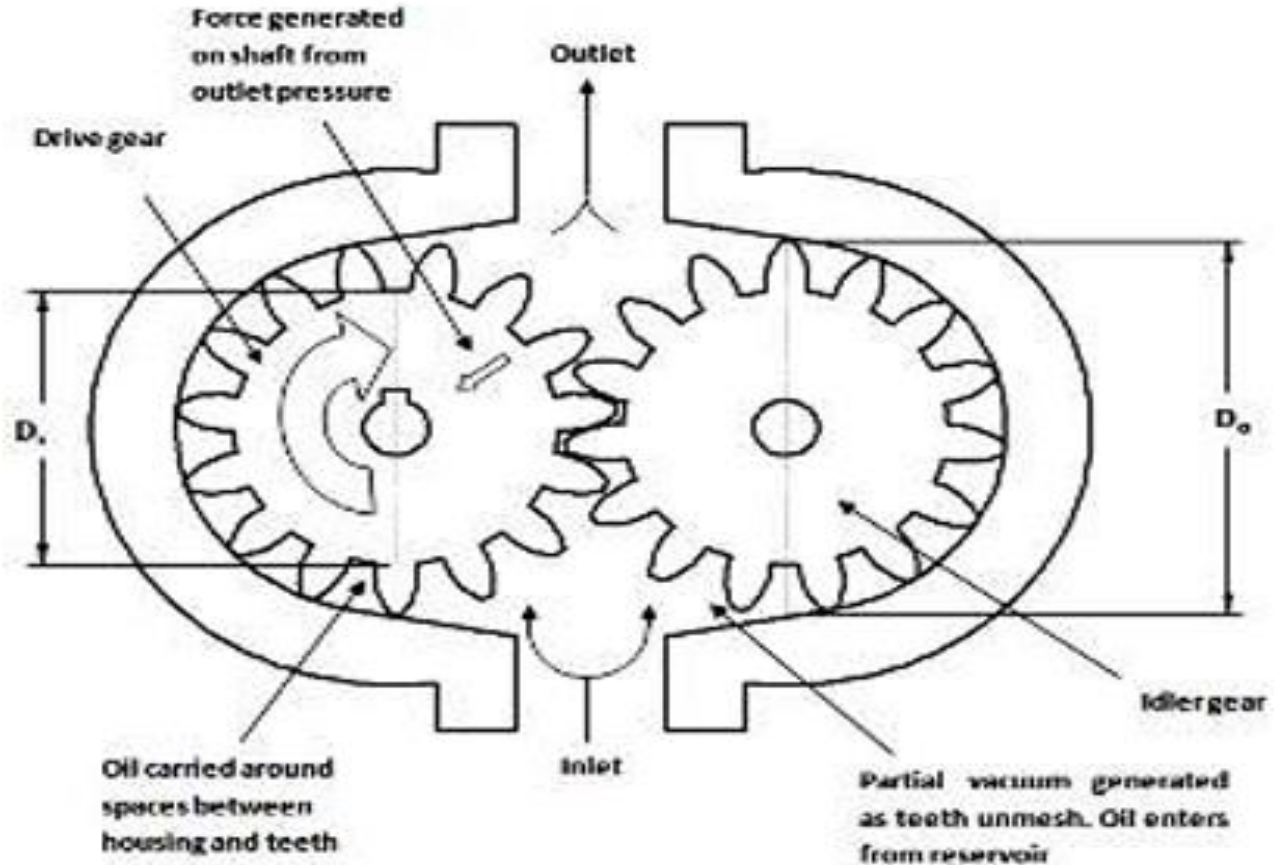
2. Vane Pumps

- i) Balanced vane pump
- ii) Unbalanced vane pump

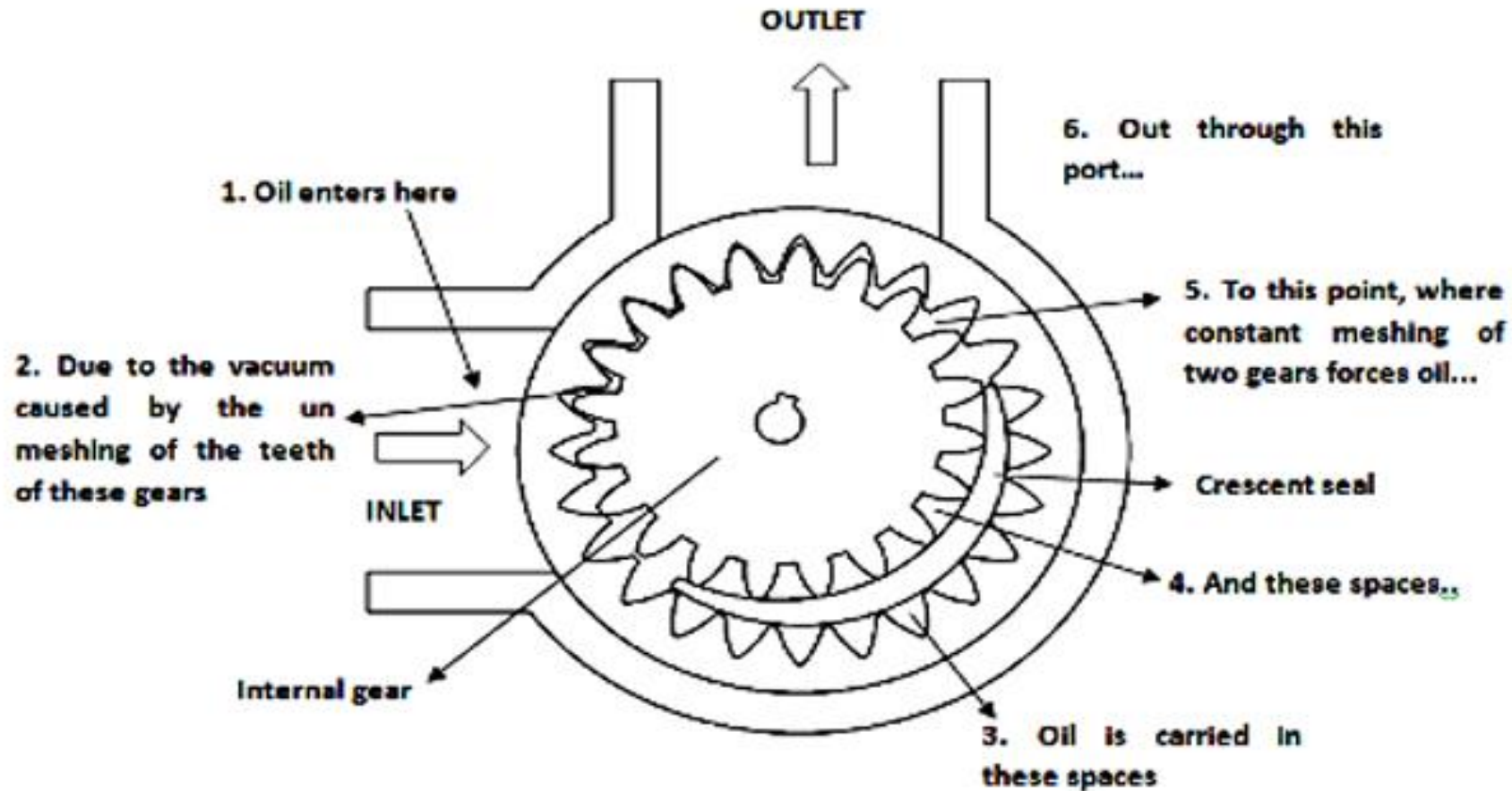
3. Piston Pumps

- i) Axial type
- ii) Radial type

EXTERNAL GEAR PUMPS:



INTERNAL GEAR PUMPS



ADVANTAGES AND . DISADVANTAGES OF GEAR PUMPS

ADVANTAGES OF GEAR PUMPS:

- 1.They are self-priming.
- 2.They give constant delivery for a given speed.
3. They are compact and light in weight.

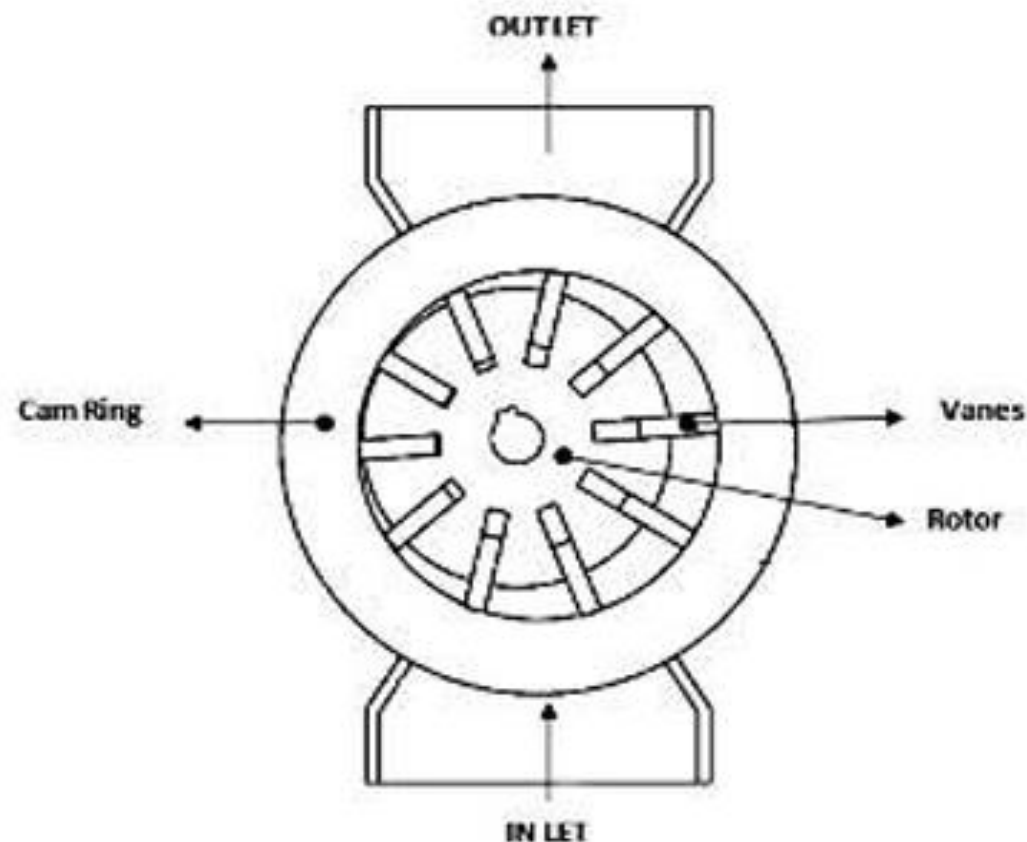
DISADVANTAGES OF GEAR PUMPS:

1. The liquid to be pumped must be clean, otherwise it will damage pump.
2. . Variable speed drives are required to change the delivery.
3. If they run dry, parts can be damaged because the fluid to be pumped is used as lubricant.

VANE PUMPS

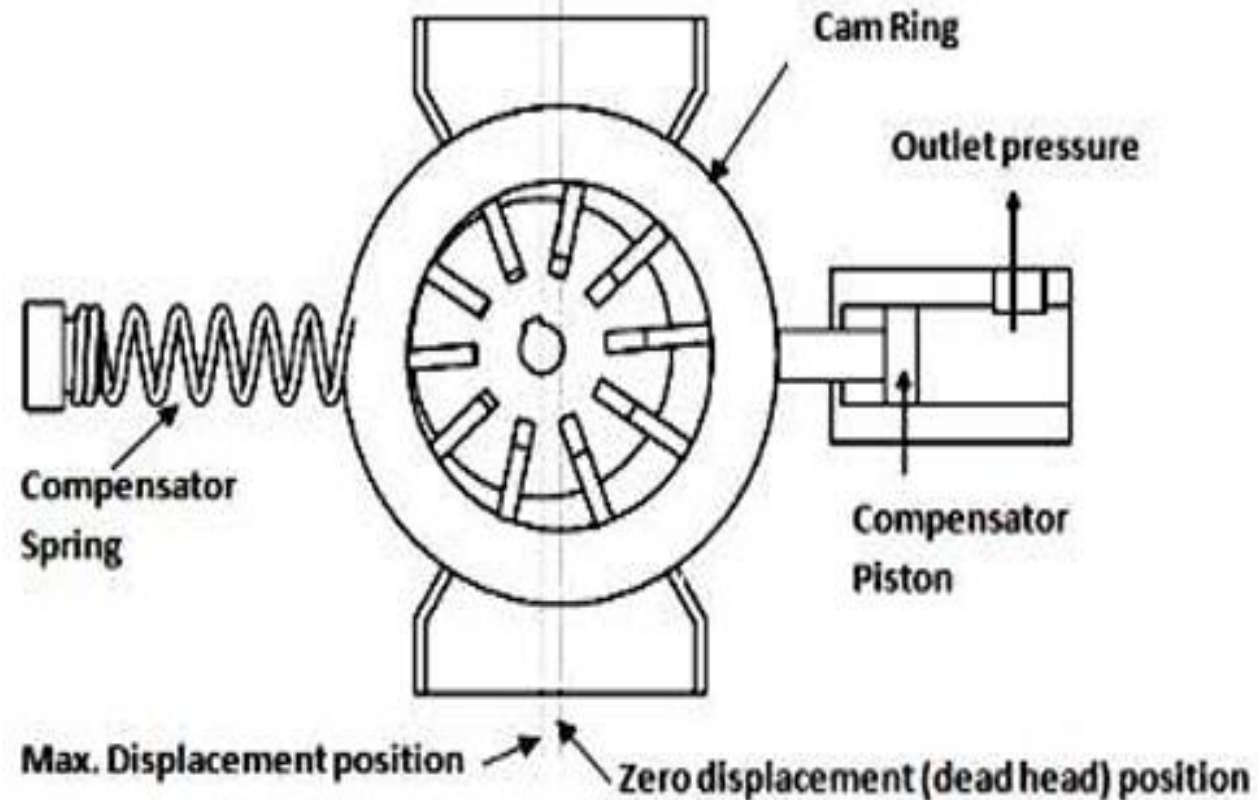
Vane Pumps are classified into

1. Unbalanced vane pump
 - i) Fixed displacement type
 - ii) Pressure compensated variable displacement type
2. Balanced vane pump

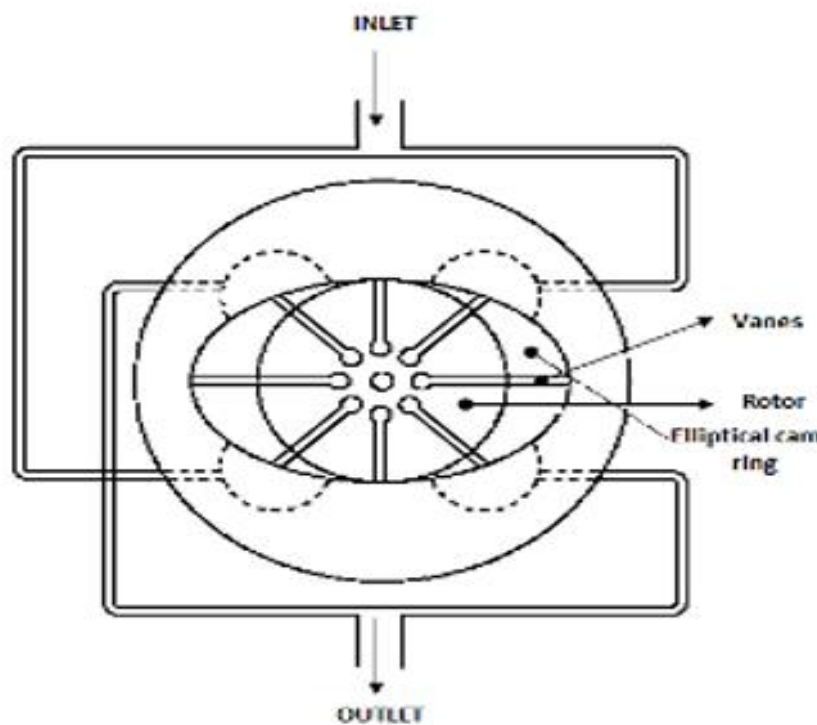


UNBALANCED FIXED DISPLACEMENT VANE PUMP

UNBALANCED PRESSURE COMPENSATED VARIABLE DISPLACEMENT VANE PUMP



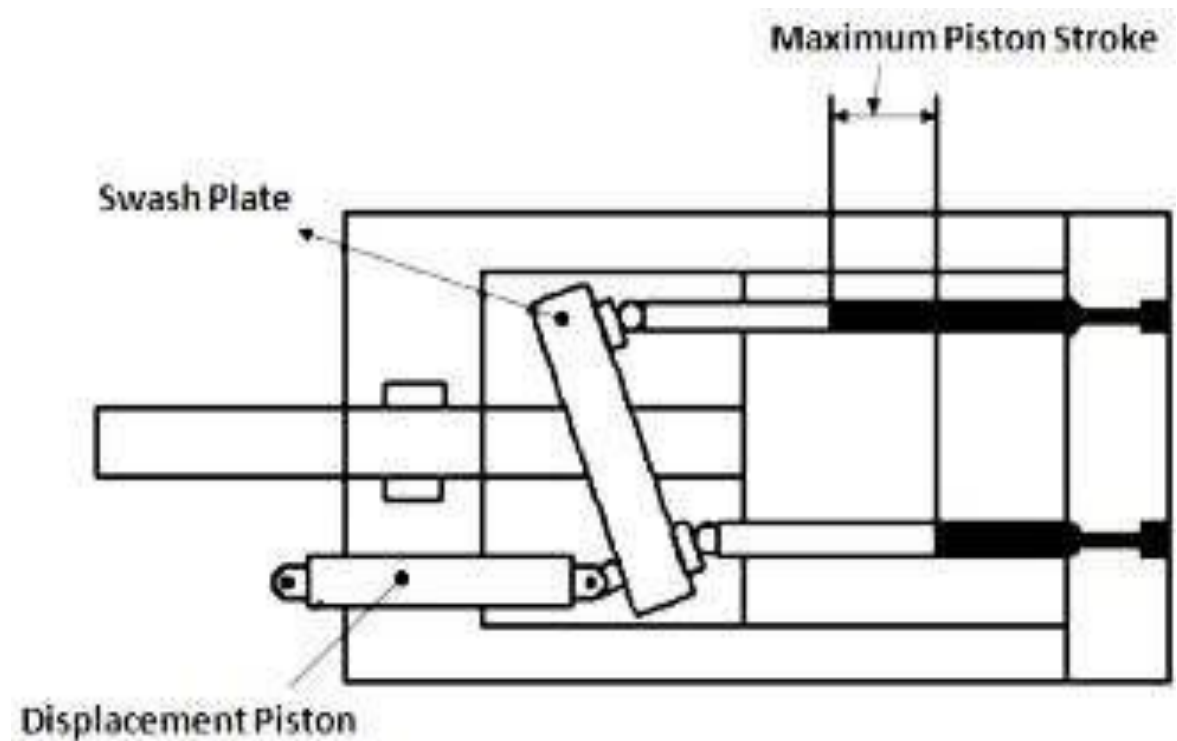
BALANCED VANE PUMP



The constructional features of a balanced vane pump is as shown in the fig. The rotor and the casing are on the same center line. Vanes are provided in the slots of the rotor. There are two inlet and outlet chambers around the elliptical cam ring surface. The inlet and outlet chambers are positioned diagonally opposite to each other. The cam ring is elliptical in shape, so that the vanes stroke twice per revolution of the pump shaft. Thus, the volume increase and decrease at the inlet and outlet chambers also occur twice per revolution. In fact, the inlet and outlet ports are connected to a common inlet and outlet within the pump housing. In operation, due to the elliptical shape of the cam ring, the oil suction at the inlets and the pumping at the outlets occurs simultaneously. This situation results in equal pressure on the opposite sides of the pump shaft, and the net force acting on bearing will be zero. Thus, it is termed the balanced vane pump.

PISTON PUMPS

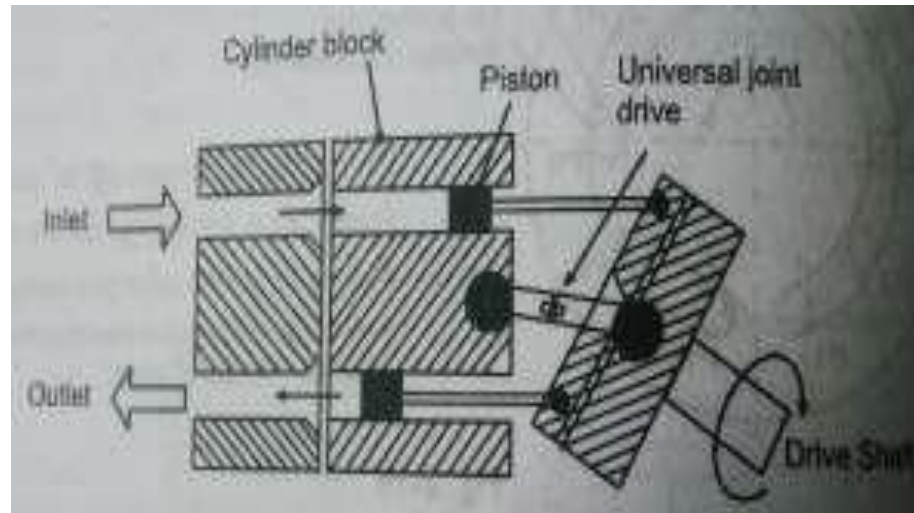
- Piston pumps are of following types
- Axial Piston Pump
 - Swash plate type piston pump
 - Bent axis type piston pump
- Radial Piston Pump



SWASH PLATE TYPE PISTON PUMP

BENT AXIS TYPE PISTON PUMP

In construction it consists of a cylinder block with arrayed cylindrical openings, housing, pistons and drive shaft. The housing design is such that it creates an offset angle between the centerline of the drive shaft and the center line of the cylinder block. The pistons are connected to the drive plate with ball and socket joints. The drive plate and the cylinder block relate to a universal joint, so that the motion is transmitted through the bent axis. The bent axis of the drive shaft leads to the reciprocating motion of the pistons in the cylinder block. The housing end at the cylinder block is sealed with an end cap, having inlet and outlet ports with feed grooves.



PUMP PERFORMANCE

- The performance of a pump is determined by the following efficiencies:

- 1) **Volumetric efficiency (η_v)**: It is the ratio of actual flow rate of the pump to the theoretical flow rate of the pump.

$$\begin{aligned}\eta_v &= \frac{\text{Actual flow rate}}{\text{Theoretical flow rate}} \times 100 \\ &= \frac{Q_A}{Q_T} \times 100\end{aligned}$$

- 2) **Mechanical Efficiency (η_m)**: It refers to the efficiency of the pump due to energy losses other than due to leakages.

$$\begin{aligned}\eta_m &= \frac{\text{Pump output power (no leakage condition)}}{\text{Actual power input to pump}} \times 100 \\ &= \frac{P \times Q_T}{2\pi N T} \times 100\end{aligned}$$

Where, P = Pump discharge pressure, Pa

Q_T = Theoretical flow rate, m³/s

T = Torque input to pump, N.m

N = Pump speed, rpm

PUMP PERFORMANCE

- 3) **Overall Efficiency (η_o)**: Overall efficiency refers to the overall performance of the pump considering possible losses including the leakage loss, friction loss, etc. it is given by the relation:

$$\eta_o = \frac{\text{Actual power output by pump}}{\text{Actual power input to pump}} \times 100$$

It can also be given by,

$$\eta_o = \frac{\eta_v \times \eta_m}{100}$$
$$\eta_o = \frac{P \times Q_A}{2\pi NT} \times 100$$

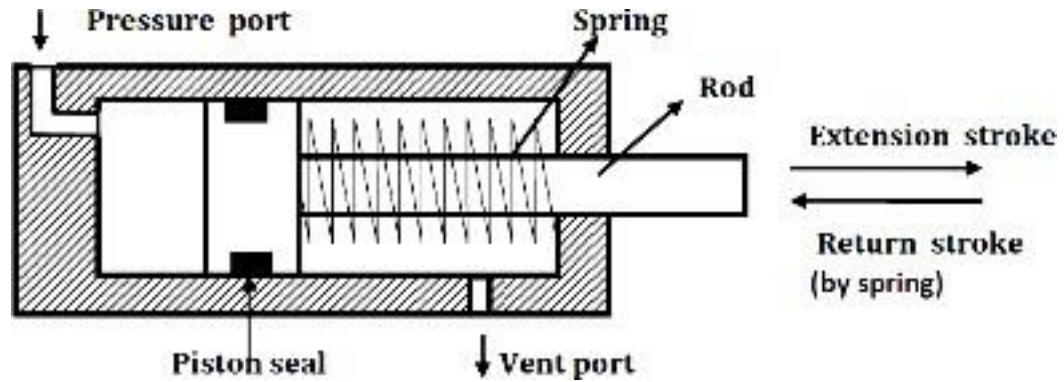
PUMP SELECTION FACTORS

- **The main parameters affecting the selection of a particular type of pump are as follows:**
- Maximum operating pressure.
- Maximum delivery.
- Type of control.
- Pump drive speed.
- Type of fluid.
- Pump contamination tolerance.
- Pump noise.
- Size and weight of a pump.
- Pump efficiency.
- Cost.
- Availability and interchangeability.
- Maintenance and Spares.

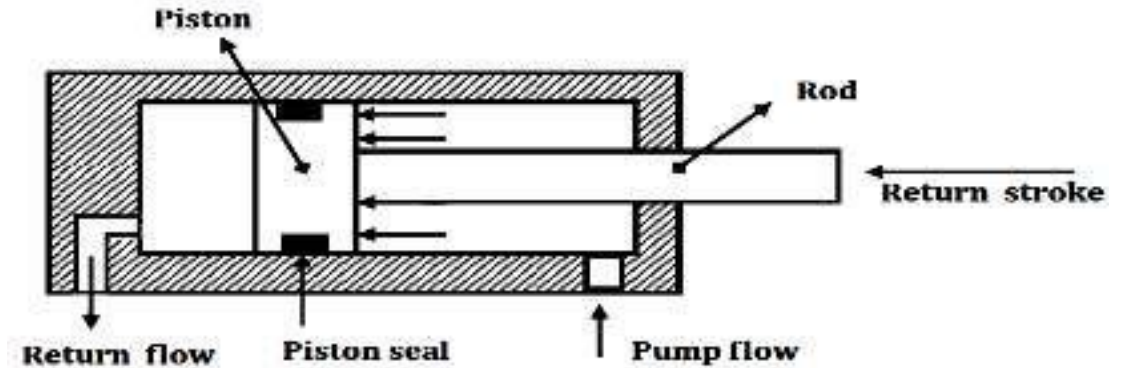
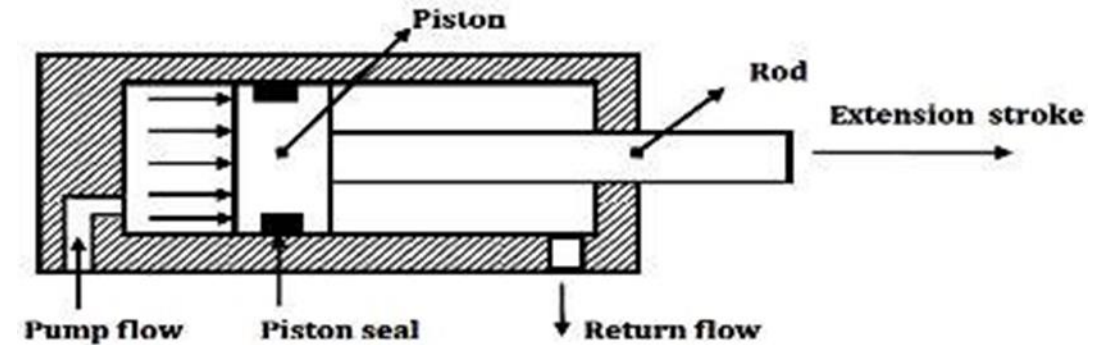
ACTUATORS

- An actuator is used to convert the energy of fluid back into the mechanical power. The amount of output power developed depends upon the flow rate, the pressure drops across the actuator and its overall efficiency. Thus, hydraulic actuators are devices used to convert pressure energy of the fluid into mechanical energy.
- Depending on the type of actuation, hydraulic actuators are classified as follows:
 - **Linear actuator:** For linear actuation (hydraulic cylinders)
 - **Rotary actuator:** For rotary actuation (hydraulic motor)
- **Hydraulic cylinders are of the following types:**
 - Single-acting cylinders
 - Double-acting cylinders
 - Double rod cylinders
 - Tandem cylinders
 - Telescopic cylinders

SINGLE AND DOUBLE ACTING CYLINDERS

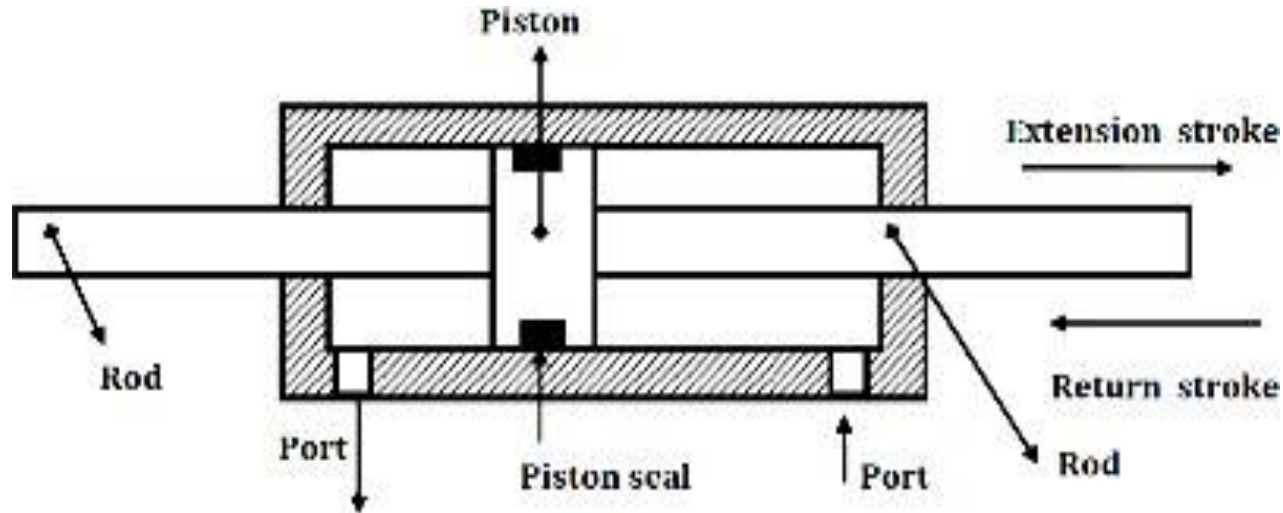


SINGLE-ACTING CYLINDERS



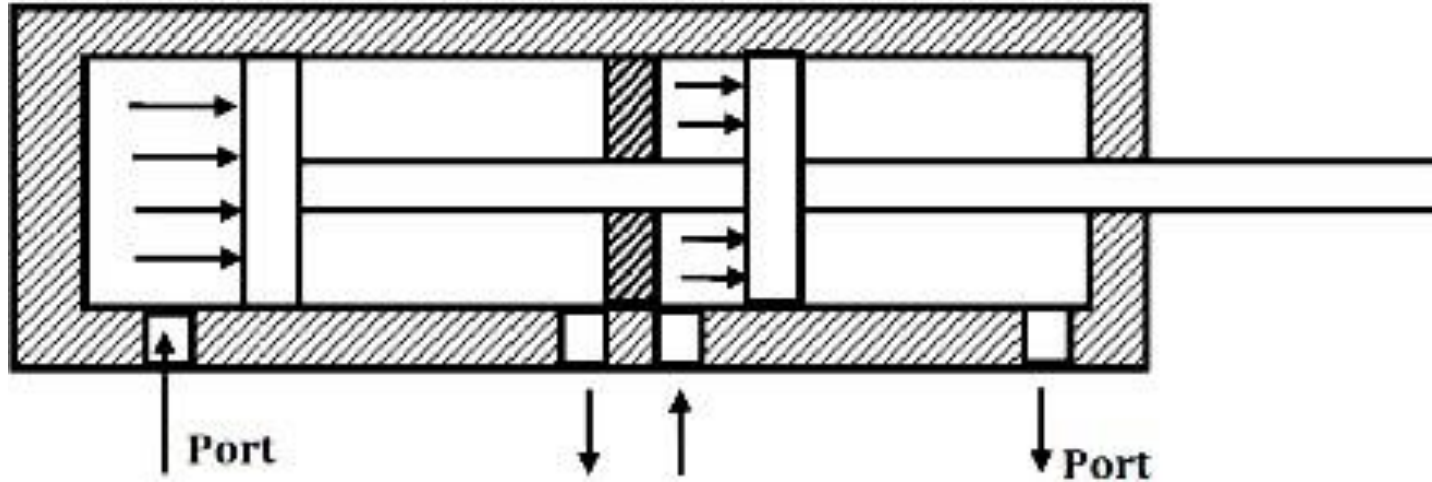
DOUBLE ACTING CYLINDERS

DOUBLE ROD CYLINDERS



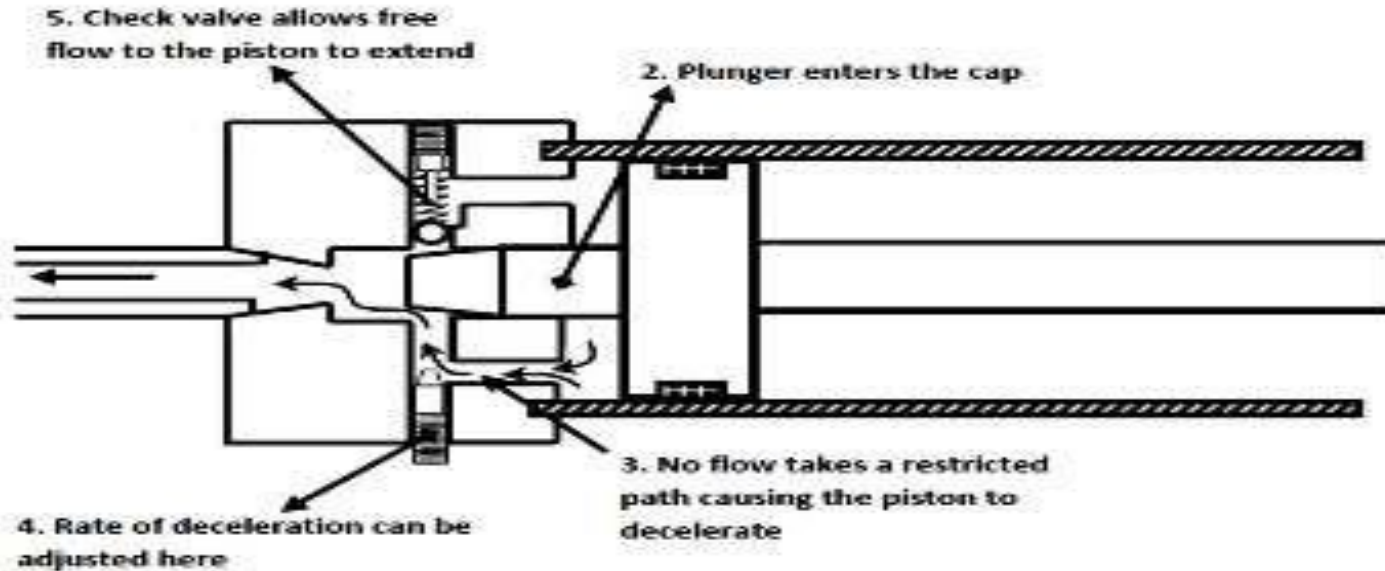
A double-acting cylinder with a piston rod on both sides is a cylinder with a rod extending from both ends. This cylinder can be used in an application where work can be done by both ends of the cylinder, thereby making the cylinder more productive. Double-rod cylinders can withstand higher side loads because they have an extra bearing, one on each rod, to withstand the loading.

TANDEM CYLINDERS



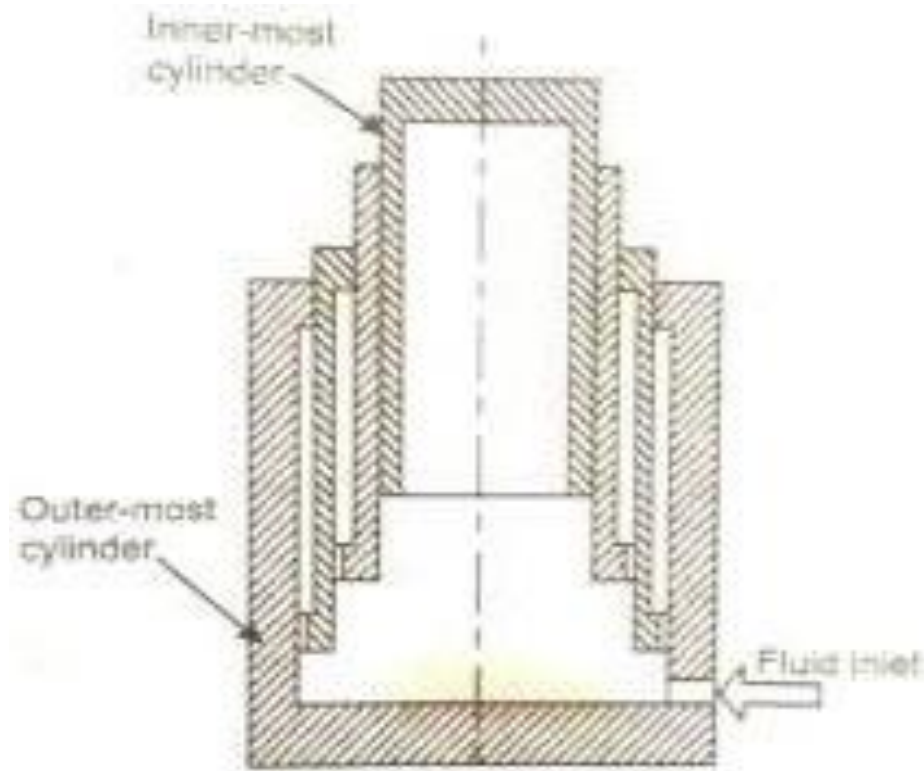
A tandem cylinder is used in applications where a large amount of force is required from a small-diameter cylinder. Pressure is applied to both pistons, resulting in increased force because of the larger area. The drawback is that these cylinders must be longer than a standard cylinder to achieve an equal speed because flow must go to both pistons.

CUSHIONED CYLINDERS



When the cylinder piston is actuated, the fluid enters the cylinder port and flows through the little check valve so that the entire piston area can be utilized to produce force and motion. For the prevention of shock due to stopping loads at the end of the piston stroke, cushion devices are used. Cushions may be applied at either end or both ends. They operate on the principle that as the cylinder piston approaches the end of the stroke, an exhaust fluid is forced to go through an adjustable needle valve that is set to control the escaping fluid at a given rate. This allows the deceleration characteristics to be adjusted for different loads.

TELESCOPIC CYINDERS



It has multiple cylinders that are mounted concentrically one within the other. The design is such that the innermost cylinder extends first, while the next cylinder extends after completion of the full stroke of the cylinder. Thus, each cylinder extends in stage, one after the other. Each stage of the cylinder has a sleeve that fits into the previous stage of the cylinder. The total stroke length achieved will be sum of the strokes of all the stages.