Unit 2 Pumps and Actuators

Marks Distribution for this Unit

Unit No	Unit Title	Teaching Hours	R Level	U Level	A Level	Total Marks
II	Pumps and Actuators	08	04	04	04	**12**

R-Remember, U-Understand,A-Apply
* Refer syllabus for details about Bloom's taxonomy

Syllabus content

2.1 Classification of pumps-
Classification of pumps
2.2 Working of pumps
Construction and working of gear,vane,screw,piston pumps(axial and radial)
2.3 Performance characteristic
Performance characteristics and selection of pumps
2.4 Actuators
Classification of hydraulic and pneumatic actuators
2.5 Working of actuators
Construction and working of linear and rotary actuators(motors)

2.1 CLASSICICATION OF PUMPS

Q.1. Classify hydraulic pumps.

Ans : Hydraulic pumps are designed and manufactured over a wide range of constructions and capacities, to suit the particular requirement of the application. Pumps in general are classified on following basis,

1) Classifications based on principle of operation

Hydrostatic type pumps (Positive displacement).

Hydrodynamic type pumps (Non - Positive displacement type).

2) Classification based on displacement

Constant displacement pumps.

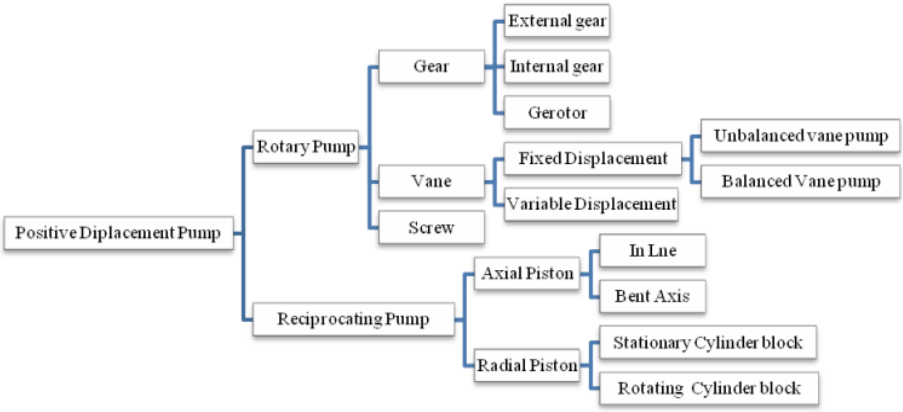
Variable displacement pumps.

3) Classification based on Constructions

1) Gear type Pumps - External gear pump.
- Internal gear pump.

2) Vane type pumps - Constant displacement vane pump.
- Variable displacement vane pump.

3) Piston type pumps - Radial piston pump.
- Axial piston pump. (Swash plate & bent axis)
-Screw type pumps.
- Ball piston type pumps.



Q.2. State the function of pump in a hydraulic system.

Ans : Hydraulic pump is the heart of a hydraulic system. Its function is to convert mechanical energy into hydraulic energy by pushing the hydraulic fluid into the system.

Pump is an energy conversion element, which receives energy from the prime mover (generally an electric motor or engine), and imparts it to fluid. Most of hydraulic pumps receive fluid form reservoir and pump it to loaded actuator to perform work.

It is worth noting that a pump dose not create the pressure, but load on the fluid (resistance to its free motion) creates the pressure.

Q.3. State the importance of pump used in hydraulic system

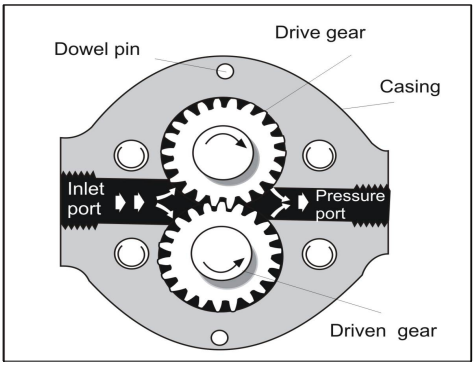
Ans :

1. They convert mechanical energy into hydraulic energy.
2. The Volumetric efficiency of pump is relatively high
3.They have high performance characteristics under varying speed and pressure requirements
4.Pumps used to generate high pressure in hydraulic system

2.2 WORKING OF PUMPS

Q.4. Explain the working of gear pump.

Ans :



Gear pumps are positive displacement pumps. A partial vacuum is created as the internal gears go through their cycle, and oil is forced up into the pump due to atmospheric pressure on the oil surface. This oil is then carried to the delivery port by teeth and finally forced out to the actuator.

Constructional details:

As shown in the diagram besides the pump consists of two intermeshing gears (machined to close tolerance)

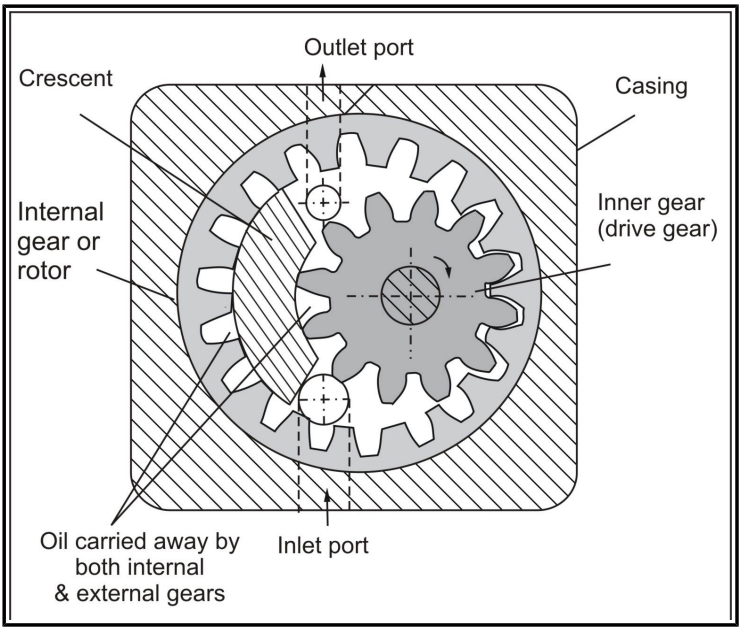
which are situated in four bearing blocks with axially lobed seals, housing with front and back cover. The input shaft rests on the casing fixed in front cover and sealed with seal ring. The material from which pump housing is made is rolled aluminum of extremely high endurance or cast iron. The two covers are made up of gray cast iron. The gears have 12- teeth, which reduces the variation of output flow rate and noise level respectively.

Operation :

When the pump is started working liquid is trapped in the gaps between the gear teeth, and is propelled along the inside of the pump from the suction (inlet) port to the pressure (outlet) port. The partial vacuum needed to produce suction in the suction chamber is generated when the teeth take away liquid along with them from suction chamber; thus, reduction in the volume of suction chamber creates suction.The suction and delivery sides are constantly sealed due to continuous meshing of gears.

Q.5. Explain the working of EXTERNAL gear pump.

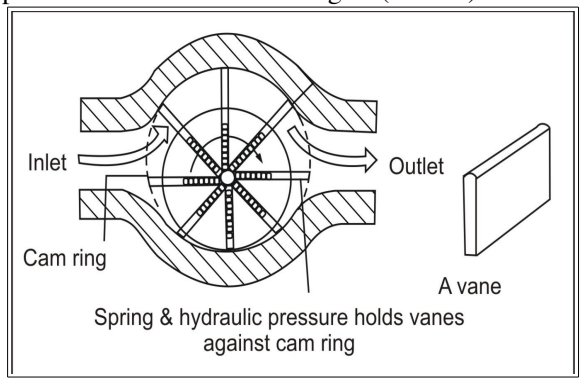
Ans :



It consists of one external and one internal meshing gear pair. External gear is connected to electric motor and hence is driving gear. Internal gear or ring gear is driven gear which rotates in same direction as that of external gear. Between two gear a spacer called 'crescent' is located which is a stationary pieces connected to housing. Inlet and outlet ports are located in end plates. External gear (driving gear) drives the internal gear (Ring Gear). Portion where teeth start meshing, a tight seal is created near port the vacuum is created due to quick un-meshing and oil enters from oil tank through inlet port. Oil is trapped between the internal and external gear teeth on both sides of crescent (spacer) and is then carried from inlet to outlet port. Meshing of gear near outlet port reduces the volume or gap and oil gets pressurized. These pumps make very less noise.

Q.6. Explain the working of vane pump.

Ans :Vane type pumps operate on the principle of increasing and diminishing volume. The oil from suction port is confined into a chamber comprising sliding vanes and as the rotor proceeds the volume of this chamber goes on reducing resulting pressure in the fluid and in last the pressurized fluid is discharged (forced) into delivery chamber.



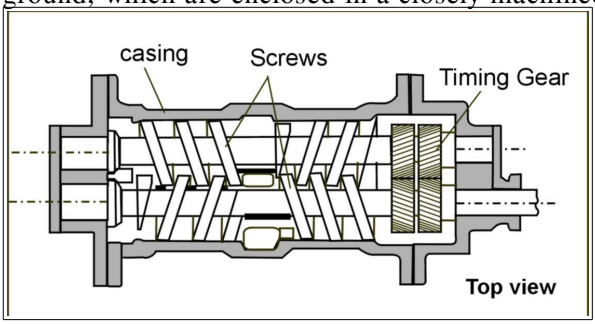
As shown in fig. in its simplest version, it consists of a rotor in which vanes are held in a series of slots around the rotor. The rotor is off set within the housing, and the vanes are constrained by the cam ring as they cross inlet and outlet ports.

Operation :As the rotor rotates in clockwise direction, the area between the two vanes is sealed as the vane uncovers suction port, this creates partial vacuum in suction chamber and results in suction of hydraulic fluid into suction chamber. Further, the fluid confined between two vanes is carried away to the outlet chamber, forcing the fluid into the delivery port.

Q.7. Explain the working of Screw pump. State its advantages and limitations

Ans : These pumps use screws to transmit fluid from suction to delivery port. The fluid is carried foreword to the discharge by the screw, very much similar a nut moves along a screw. The helical grooves on the screws serves as the path for fluid from suction chamber to delivery chamber.

Constructional details : The figure below illustrates the construction details of a screw type pump. The screws are hardened and precision ground, which are enclosed in a closely machined casing. Each of the two screws have half part right hand threading and other half part left hand threading. These screws mesh to from a fluid tight seal between the screws and the screw and casing. Out of two screws, one is connected to power source and another is driven through gears.



Operation

As the screw rotates it draws oil from the suction chamber, enfold it into the helical grooves. As the screw further rotates the fluid gets transferred along the screw and finally forced into delivery chamber. Thus oil is sucked continuously from four points and finally discharged into delivery chamber.

Advantages and limitations of screw type pumps

Advantages :

1) They provide continuous (non - pulsating) flow.

2) Few moving parts and rolling action of rotors make them quite in operation and more reliable.

Limitations :

1) Screw pumps are available with operating pressure upto 200 bar.

2) Fixed displacement :Screw type pumps are fixed displacement pumps; this characteristic limits their application where variable displacement is required.

Q.8. Explain the working of radial type piston pump.

Ans :As shown in the diagram a typical radial piston pump has a fixed casing

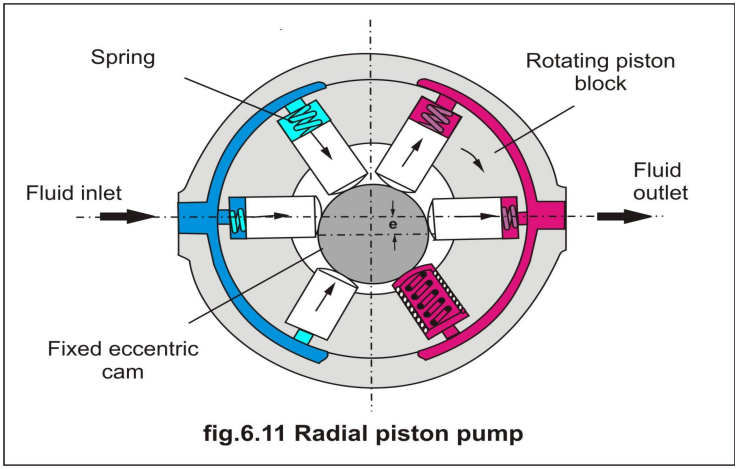


fig.6.11 Radial piston pump

incorporating suction and delivery ports in it. Inside the fixed casing there is a rotating piston block (which carries pistons in it), and at the center there is a fixed eccentric cam, whose center and the center of rotation of the block are offset by an amount equal to 'e' (as shown).

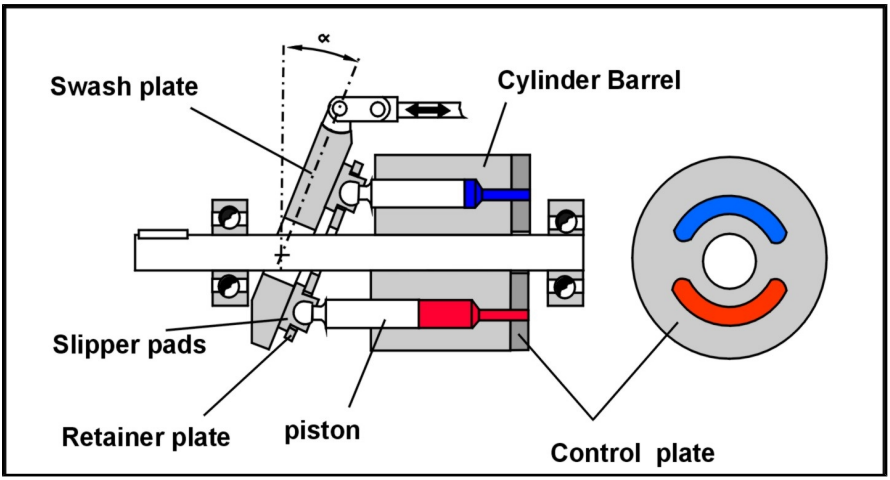
Operation :As the piston block rotates in clockwise direction, the eccentricity causes the piston on the suction side to move inwards, towards center (due to spring force) and pistons on delivery side to move outwards (due to reducing eccentricity). This motion of pistons causes suction and delivery of the fluid. Radial piston pumps are also available in constructions, which provide variable displacement. In such designs, the eccentricity of the pump is changed manually or hydraulically with load dependent sensing.

The flow direction of the pumps is determined by the direction of rotation and by adjusting range of the stroke ring, displacement can also be varied.

Q.9. Explain the working of Swash Plate type Axial piston Pump.

Ans :Swash plate type axial piston pumps, as shown in diagram consists of rotating cylinder barrel, which consists piston arranged on it axially. The piston ends are connected to an inclined swash plate.

The direction of piston movement (forward or backward i.e. suction



or delivery) is decided by its peripheral position on swash plate. The rotating piston travels along an elliptical line on the stationary swash plate. The friction between piston ends and stationary swash plate is kept intact with swash plate by retaining ring. The suction and delivery chambers are shown in cross-section.

Operation :

As the shaft rotates, it imparts motion to pistons, but since piston ends are connected to an inclined swash plate the pistons start reciprocating (with a stroke length as determined by inclination of swash plate α). The reciprocating motion of piston causes suction and delivery of fluid as the respective pistons uncover the suction and delivery ports. The delivery (discharge) of this type of pump can be varied or even reversed by changing the swash plate angle.

Following are the various positions indicating maximum forward flow, neutral position (no flow) and maximum reverse flow (suction and delivery ports get interchanged).

Q.10.What is swash plate? What is its use? What will happen if we change the angle of swash plate? Explain with sketch.

Swash Plate – It's an inclined plate in axial piston pump on which all pistons are connected through piston rod. This swash plate is usually inclined.

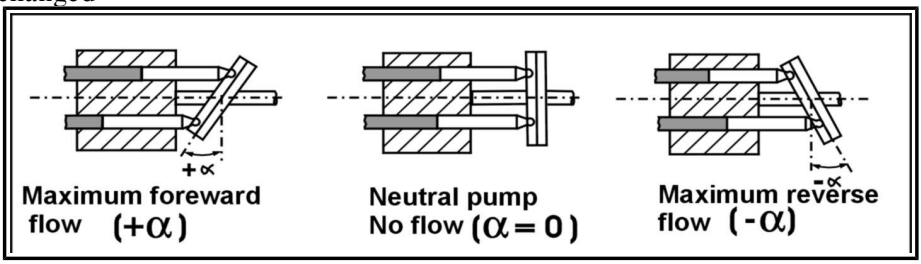
Use – It is helps to reciprocate the piston of axial piston pump while the cylinder block is rotating Working: Motor drives the shaft, which in turn rotates the entire cylinder block. The pistons are connected to inclined swash plate through piston rod. Now since swash plate is inclined and block is rotating, the piston reciprocates inside the barrel. The reciprocating motion of piston causes suction and delivery of fluid through inlet and outlet ports which come infront of outlet of piston.

If we change the angle of swash plate i.e. θ if ,

a) θ = 0 then no flow of oil, because pistons are at same level. When θ = 0 swash plate is vertical. No reciprocation of piston, hence no flow.

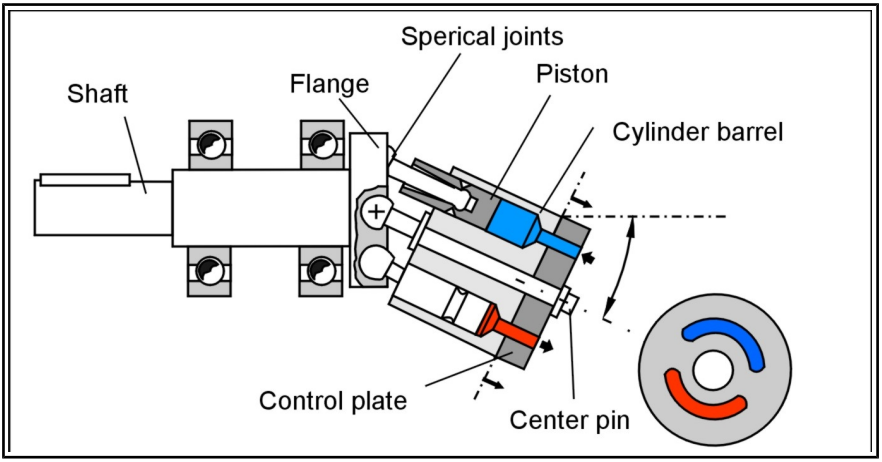
b) θ = max or +ve, then x will be stroke length which is maximum and there will be maximum forward flow.

c) θ = -ve, then 'x' i.e. stroke length will be maximum in reverse direction and hence there will be reverse flow. By changing the swash plate angle we can vary the stroke length of the piston. and also output flow can be changed



Q.11. Explain the working of bent axis type piston Pump.

Ans :As shown in the diagram, the pump consists of a cylinder barrel, which carries pistons arranged on it axially. The piston ends are connected to a flange by ball joints.



The cylinder barrel is inclined at an angle α with the axis of rotation of flange. Suction and pressure sides are split by control slots drilled in the control plate. As the shaft rotates the flange, the flange imparts rotary motion to cylinder barrel, which is turn rotates the pistons. Due to the inclination of barrel, the pistons in addition to rotating with cylindrical barrel start reciprocating. The reciprocating motion of piston causes suction and delivery of fluid as the respective pistons uncover the suction and delivery ports. Various designs of bent axis pump exist, where the cylinder barrel drive is obtained by bevel gear or cordon joint.

2.3 PERFORMANCE AND SELECTION

Q.12.List out any four criteria for selection of hydraulic pump in hydraulic system. Explain in brief.

Important criteria for selection of Hydraulic pump

1. Maximum operating pressure: This is determined by the power requirement of the circuit, the particular application, availability of components, type of fluid and to some extent the environment and level of labor both using and maintaining the equipment

2.Maximum delivery: The pump system selected must be capable of delivering the maximum flow rate demanded by the circuit. If the circuit demand is constant, a fixed displacement pump is chosen.

3. Type of control: Various types of pump controls are available such as

manual servo control, pressure compensated control, constant power control and constant flow control. The choice of control is dependent upon the circuit requirement such as complexity, accuracy of control, cost, type of machining operation, etc. The designer has to choose carefully the type of control after a detailed study of system characteristics.

4. Pump drive speed: The fluid delivery rate is proportional to the speed of rotation. Each design has a minimum and maximum operating speed: the faster the pump runs, the shorter its life

5. Type of fluid: Pumps are designed to operate within a particular range of fluid viscosity. Mineral oils of the correct viscosity work satisfactory with most pumps provided the oil is clean

6. Pump noise: The actual efficiency depends on design, operating pressure, speed and fluid viscosity

7. Cost: The initial cost of a pump is usually of secondary importance to running and maintenance costs. Gear pumps are cheaper, vane and piston pumps are expensive.

2.4 CLASSIFICATION OF ACTUATORS

Q.13.Classify hydraulic actuators in brief.

Hydraulic actuators also called consumers, are the elements of hydraulic system, which transform the hydraulic energy into useful work. Hydraulics in its applications is generally concerned with, moving gripping, lifting and rotating motions with force. Devices that actually achieve this objective are called actuators. Depending upon the motion they transmit, the actuators are classified as,

a) Linear actuators

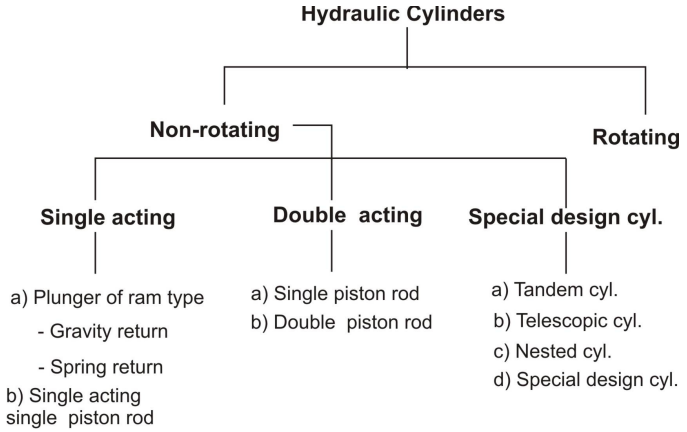
Linear actuators convert hydraulic energy into straight-line motion. They include various types of hydraulic cylinders.

b) Rotary actuators

Rotary actuators convert the hydraulic energy into rotational motion. They may further divided as limited rotation actuators and hydraulic motors. Limited rotary actuators transmit a part of full rotation, where as the hydraulic motors are the hydraulic equivalent of electric motors, which may be unidirectional or bi-directional.

Q.14.Classify hydraulic Cylinders.

Ans : The various designs of hydraulic cylinder covers such a wide range that it would be beyond the scope of this book to describe all of them. Broadly, they are classified as below,



Hydraulic Cylinder types

Q.15.Classify air (Pneumatic) Cylinders.

Ans:Air cylinder are classified as follows

a) Classification based on cylinder functioning
   1. Single acting cylinders
   2. Diaphragm cylinder.
   3.Rolling diaphragm cylinders
   4. Double acting cylinders
   5. Tandem cylinders
   6. Rotary type cylinder.

b) Classification based on cylinder movement
   1. Rotating cylinder
   2.Non rotating cylinder

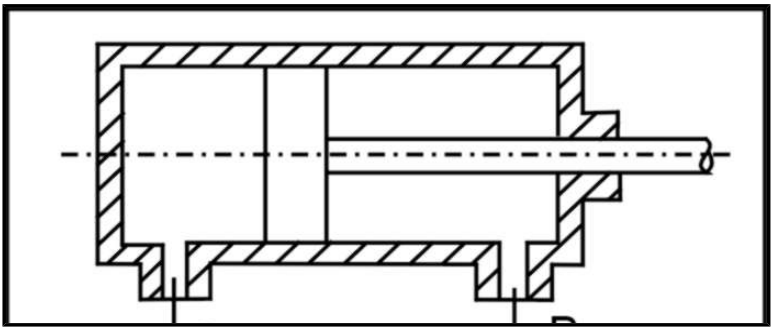
c) Classification based on type of application
   1. Light duty cylinders
   2. Medium duty cylinders

3. Heavy duty cylinders

2.5 WORKING OF ACTUATORS

Q.16. What are actuators ? Draw a double acting cylinder.

Ans: Actuator - Actuators are those components of hydraulic / pneumatic system, which produces mechanical work output. They develop force and displacement, which is required to perform any specific task. An actuator is used to convert the energy of the fluid back into mechanical power.

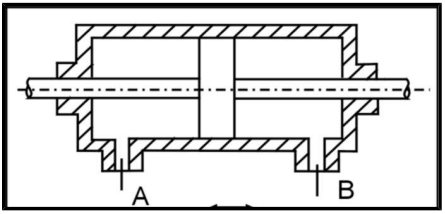


A double acting cylinder with single piston rod is shown in figure. The fluid pressure can be exerted on both sides of piston whenever required. This is the most common type of design and available in various sizes.

Here there are two different piston areas on both sides of piston, due to presence of piston rod on one side. Due to differential area, the retraction stroke is faster than extension stroke; as well, force obtained in extension stroke is more than that of in retraction stroke.

Q.17. Explain with sketch Double acting cylinder with double piston rod

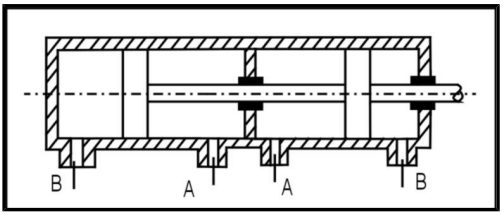
Certain applications such as feeding of machine table in machine tools, demands motion to be transmitted on both sides of cylinder. In such application double acting, double rod cylinders are used.



They have piston rods extending out from both ends of cylinder. Since the annular area is same on both sides, it has forward and reverse stroke of same speed and same force.

Q.18. What is Tandem cylinder? What is its beneficial property? Explain with sketch and draw its symbol.

A Tandem cylinder is the combination of two or more cylinders working in tandem i.e. coupled mechanically to each other. Each cylinder has its own inlet outlet ports, but can not operate independent of other cylinder.

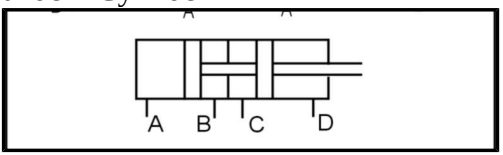


The advantage of tandeming the cylinder lies in forces addition, greater forces can be obtained at same pressure without increasing the piston sizes, but increasing the area on which the pressure acts by coupling the two or more cylinders. This finds application especially where high force requirement with limited space is required. Total force obtained at piston rod,

$$F = P \times A + P (A-a)$$

Where, P = Pressure in the cylinder , A = Cross sectional area of piston
a = Cross sectional area of piston rod

Symbol of Tandem Cylinder

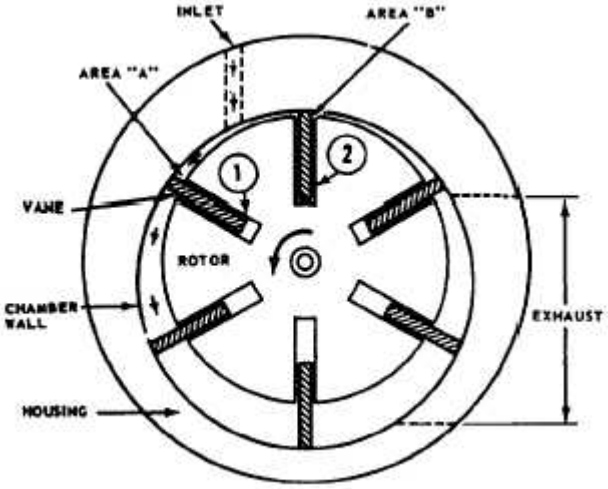


Q. 19.Enlist various types of air motors? Explain with sketch

Ans :

Various Types of Air Motors

1. Vane Motor
2. Ge-rotor Motor
3. Turbine Motor
4. Piston Motor



Construction: It consists of simple Vane rotor which is having slots in which vanes (flat piece of steel) slides freely. The rotor is eccentrically located inside the stator housing.

Working: When pressurized air comes in through inlet port, the pressure of air distributes equal in all directions. Since vane is sliding freely in slots of rotator, the vane comes in to way of pressurized air and air pushes the vanes so that rotor starts rotating with speed. The used low pressure air is exhausted through exhaust port. This is unidirectional motor. Since vanes are freely sliding in slots, there is possibility of leakage of air. With the help of these motors we can achieve the speeds up to 25000 r.p.m.

Q.20.Enlist advantages and limitations of air motor over electric motor and hydraulic motor.

Ans :

Advantages of air motor :

1) Low power to weight ratio : Air motor develops more kW/Kg of weight as compared to others hence, finds applications where lightness and compactness is required.

2) Shock and explosion proof : Air motors are inherently shock and explosion proof. This characteristic is increasing their application in the explosion prone areas, where using an electric motor needs very special and costlier construction.

3) No overheating : The air motors can be overloaded or stalled without hawing. On the other hand the harder an air motor works, the cooler it runs, because air creates a cooling effect while it expands in motor.

4) Faster acceleration and deceleration : Due to their low inertia it can accelerate and decelerate faster. As compared to the electrical motor (which has heavy shaft, windings etc. on it) the air motor does not have such loads on the shaft.

5) Clean in operation: As compared to hydraulic motor, the leaks from motor become quite messy and can result in damage to material, which is being processed. This is not the case with air motors, hence air motors are found widely applicable in food processing industry. As well, the at motor is comparatively easy to maintain due to cleanliness.

Limitation of Air Motor :

1) Noisy operation The air exhausting from the motor creates unpleasant sound, unless it is absorbed by use of mufflers.

2) Non precision motion In applications where high precision motion is required air motors are not suitable due to compressibility of air.