MODULE- 5 : INTRODUCTION TO HYDROSTATIC UNITS (PUMPS AND MOTORS)

LECTURE- 18 : BASIC FEATURES OF SOME Hydraulic Pumps & Motors

Introduction

In this section we shall discuss the working principles and fundamental calculations on input-output, sizes and capacities, of all three types basic unit.

Rotary Pumps and Motors

Vane pump

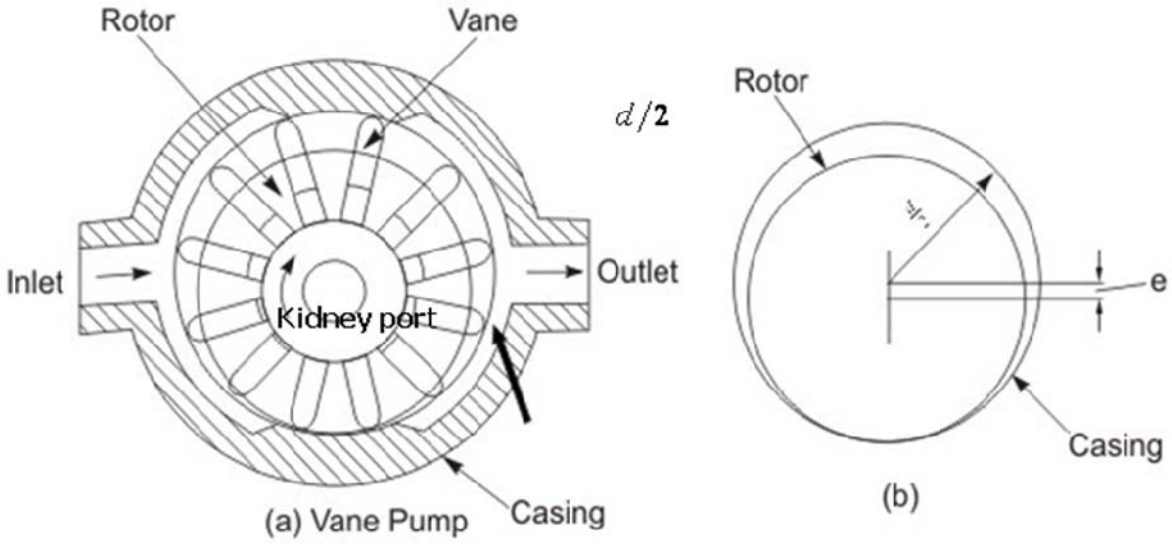


Fig. 5.18-1 : Vane type pump (or motor).

Referring to the Fig. 5.18-1 vane type a hydrostatic unit (pump or motor) consists of vanes located in radial slots of a cylindrical rotor. A shaft through the central axis of the rotor is mounted in a fixed cylindrical body with an eccentricity e (offset between two axes). The nominal widths of vanes, rotor and cylindrical body are equal. In pump model when the rotor rotates the vanes' tips touches the cylindrical casing due to centrifugal force action. As there is an eccentricity the space between two consecutive vanes is subjected to area volume change (in the figure area is subjected

to expand and contract during rotation). Usually kidney port type valve (which may also be used as one side plate) is used for flow inlet and outlet. In motor unit the process is reversed i.e. pressurized fluid in causes the rotation of rotor. The basic feature is same. However, there are difference in valve porting and may also in vanes.

The geometric displacement for a pump in a revolution (i.e., swept volume).

$$D_p = 2\pi ebd \qquad \ldots 5.18\text{-}1$$

Now if the thickness of the vane is considered

$$D_p = (\pi d - na)2eb. \qquad \ldots 5.18\text{-}2$$

Where b = Width of vanes
d = Internal diameter of housing
e = Eccentricity
n = Number of vanes
a = Thickness of a vane.

The vane type unit with single eccentricity, we have discussed so far is having the balancing problem and limited to 7 MPa usually. This unit can be made variable displacement by varying the eccentricity. Better performance is achieved using double eccentric rotor (Fig. 5.18-2). However, this balanced unit cannot be made variable displacement, although can be used for high pressure.

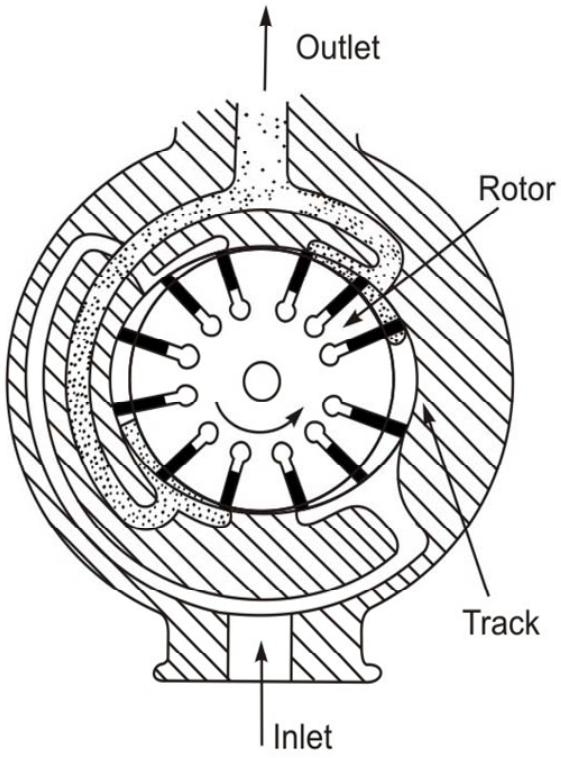


Fig. 5.18-2 : Balanced Vane type pump or motor
With Double Eccentric Rotor.

Gear Unit

Gear pumps and motors are fixed displacement type. Fig.5.18-3 shows such a unit. For the rotation shown the area within contacts at a, b and c is subjected to expand where as the area d, a and e is subjected to compression (and there by volume taking into account the width of the gear). It can be shown that such an expanding (or compressing) volume in each tooth contacting cycle, is equal to twice the volume between the two consecutive teeth. In pump model the volume after the full expansion is entrapped in the space between two consecutive teeth of both gears. They are carried out to other side to be compressed out to the outlet. Sealing at a, b, c, d and e are very important. Such metal to metal sealing, on which performance depends, is completely dependent on manufacturing accuracy. In high performance pumps and motors pressure balancing from suction to discharge sides is provided by internal grooving which connects high pressure entrapped volumes to low pressure entrapped volumes.

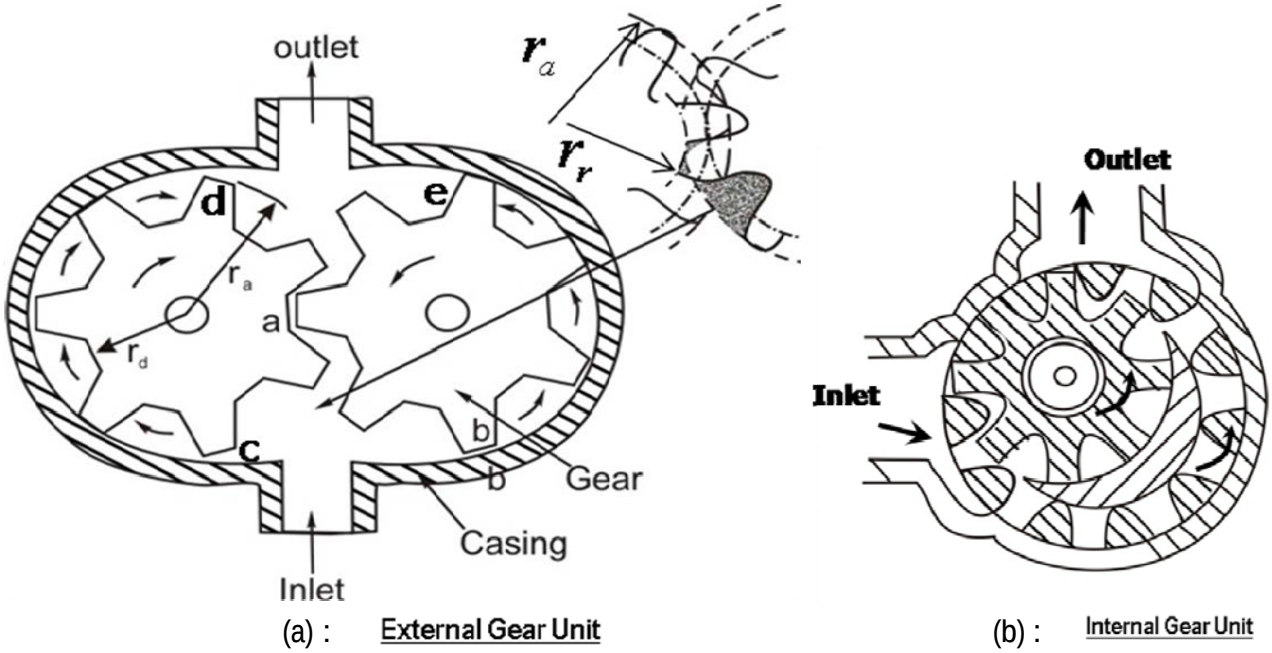


Fig. 5.18-3 : Gear Pump / Motor.

Involute straight tooth spur gears are widely used for gear pump and motor, However, helical & hearing bone gears are also used. Referring to Fig.-5.18-3 (a) the precise geometric displacement i.e., Swept Volume is expressed as:

$$D_p = \pi\left(r_a^2 - r_r^2\right)b \qquad \ldots 5.18\text{-}3$$

Internal gear pump. Internal gear pump (Fig.- 5.18-3 (b)) comprises of an external toothed pinion driving an internal gear. Both gears carry fluid around their periphery from suction to discharge (pump). A stationary crescent separates the suction to discharge side.

Piston unit :

Axial Piston Pumps :

Fig. 5.18-4 shows schematic view of an axial piston hydrostatic unit. In pump version the barrel with pistons, equispaced on a pitch circle, rotates on a central shaft housed in a casing, while the piston ends slides on a stationary inclined plate, called as *swash plate*. With a mechanism the piston ends are always kept in touch with the swash plate. As a result the pistons reciprocate generating suction and compression of volumes. The oil in and oil out are executed through the kidney port plate, fixed to the housing with a force contact to the barrel in opposite side of the swash plate. The unit can be made variable displacement by varying the swash plate angle α . As the radial reaction load acts on piston at piston-barrel interface α is usually kept within 25 degree.

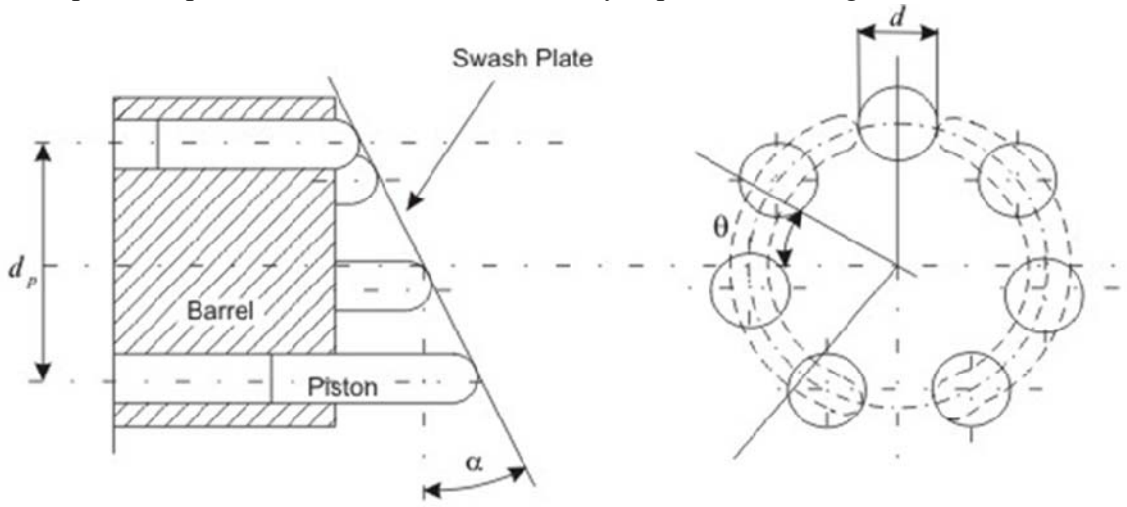


Fig. 5.18-4 : Axial Piston Pump/Motor (Schematic View).

The swept volume D_p (Geometric Displacement per revolution) can be expressed as:

$$D_p = n\frac{\pi d^2}{4} d_p \tan\alpha \qquad \ldots 5.18\text{-}4$$

where d_p the pitch circle diameter on which the piston are laid

d = diameter of the piston.
α = swash plate tilt angle
n = number of piston

Instantaneous volume of a piston.

$$V_p = \frac{\pi d^2}{4} d_p \tan\alpha . \sin\theta \qquad \ldots 5.18\text{-}5$$

$$\frac{dV_p}{dt} = Q_b = \frac{\pi d^2}{4} d_p \tan\alpha . \cos\theta \frac{d\theta}{dt} \qquad \ldots 5.18\text{-}6$$

Where θ degree is the position of a piston (in cw direction) as shown in figure 5.18-4. This means that for a piston we would add the angle of rotation of the barrel along with the initial position of the piston from that axis.

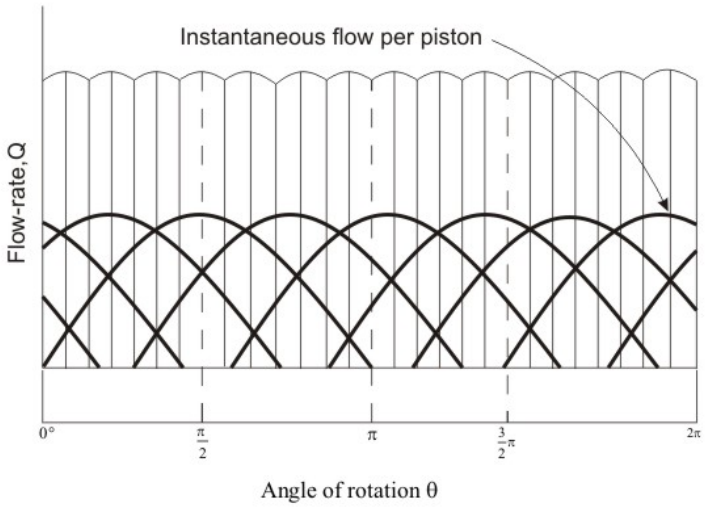


Fig. 5.18-5 : Plot of flow rate of 7 piston pump

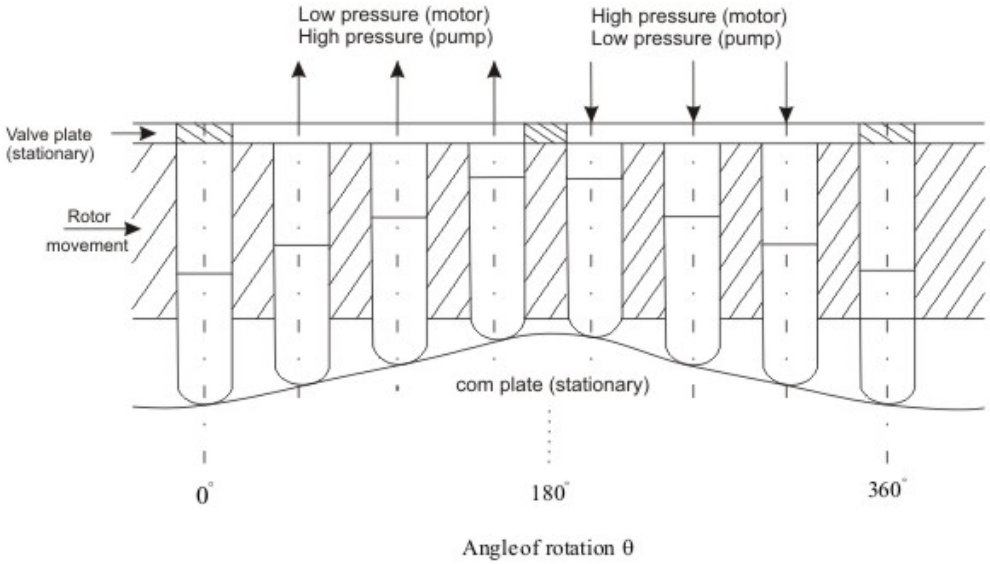


Fig. 5.18-6 : Development of the pitch circle along with all pistons showing the functions of valve plate and swash plate cam.

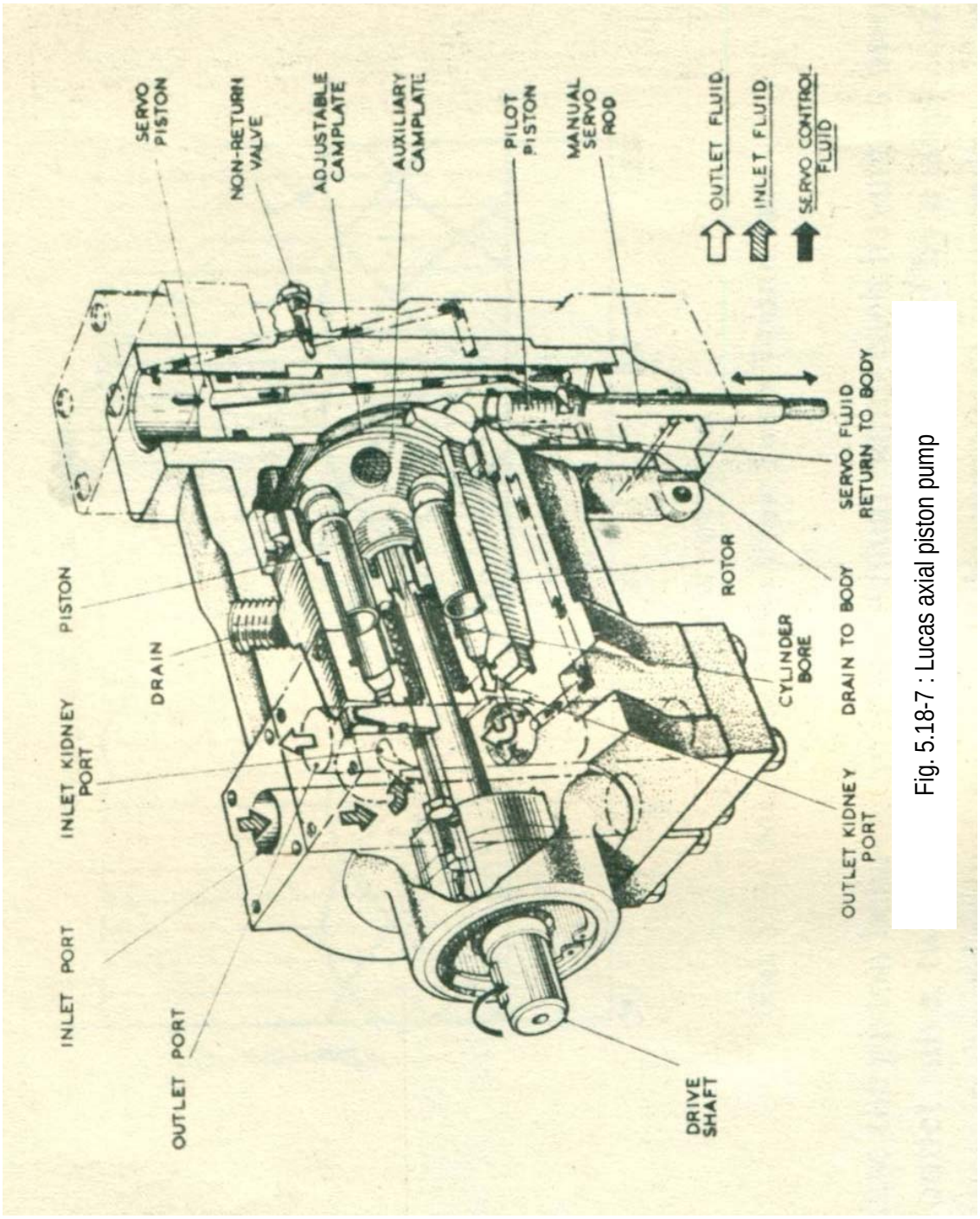


Fig. 5.18-7 : Lucas axial piston pump

Bend Axis Pumps

In bend axis units (pump or motor) the axis of the (rotating) barrel can be bent from the rotating shaft axis as shown in Fig. 5.18-8. Contrary to the swash plate type the angle α can be made as high as 45 degree, as no radial load acts on piston at piston barrel interface. Therefore, much more swept volume is available in comparison to axial swash plate type pump. However, valve plate and barrel bending arrangement needs more engineering complicacy, particularly to make this variety as a variable displacement unit.

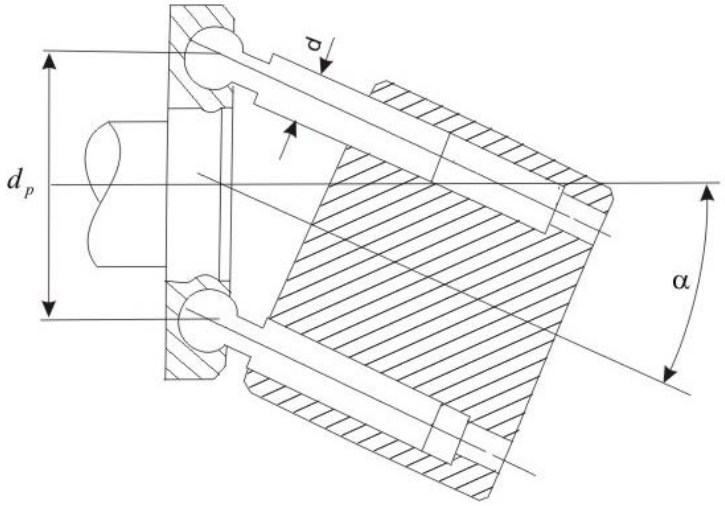


Fig. 5.18-8 : Bend Axis Pump (Schematic View).

The swept volume can be estimated as:

$$D_p = n\frac{\pi d^2}{4} d_p \sin\alpha \qquad \ldots 5.18\text{-}7$$

Radial Piston Pump/Motor

Referring to the Fig. 5.18-9, in radial piston unit a cylindrical block having equispaced cylindrical pistons in radial direction is placed in a circular housing eccentrically. While the shaft (placed centrally to the housing and eccentric to the cylindrical block) rotates the piston reciprocate as the ends always touch the casing due to centrifugal force, pressure force and or the spring force. In the cylindrical block valve is placed close to the shaft. Usually such a unit is used as a motor. The piston diameter can be made relatively large in comparison the inline axial piston unit, and the eccentricity is made small. The motor unit can discharge high torques at low speeds. Combining an axial piston pump and a radial piston motor an output of low speed high torque (LSHT) is available for the HST system with high speed low torque input.

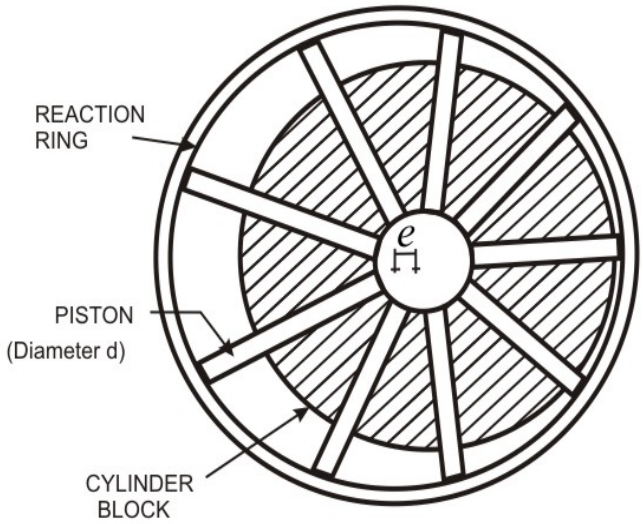


Fig. 5.18-9 : Radial Piston Pump/Motor

The swept volume of a radial piston unit can be estimated as:

$$D_p = \frac{\pi d^2}{4} 2en \qquad \ldots 5.18\text{-}8$$

Ball Piston type Hydrostatic unit

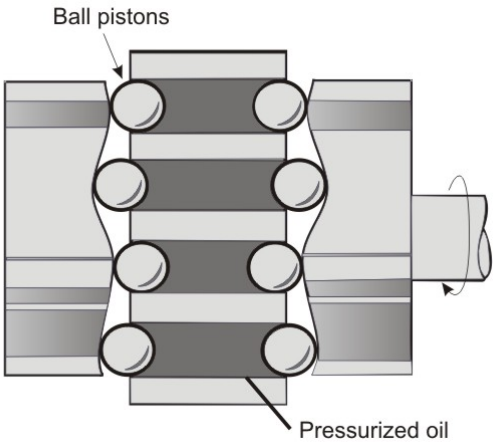


Fig. 5.18-10 : Axial Ball Piston Motor

Similar to the radial piston unit 'ball piston' type radial hydrostatic units are also available. In this unit balls are used instead of cylindrical pistons. The eccentricity is small and less than the radius of

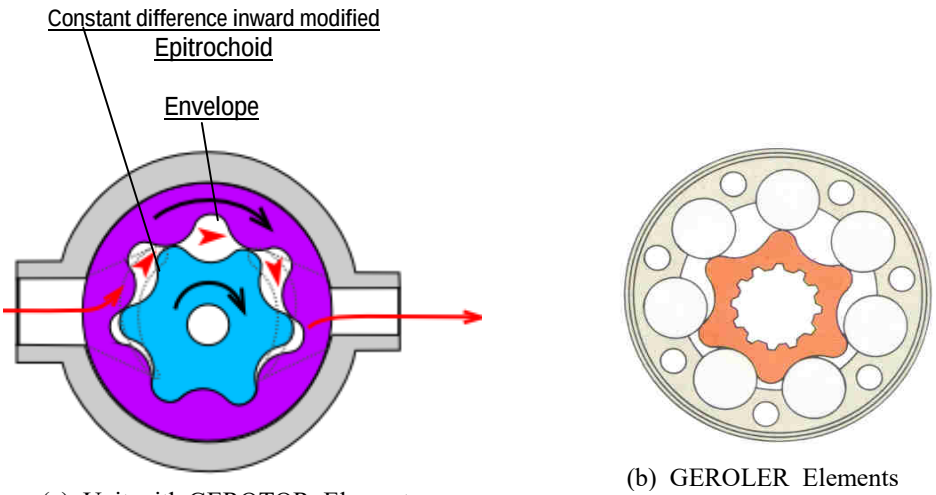
the ball. It is convenient to use such a unit as a motor only. It is used as low speed high torque (LSHT) motor. However, it has poor leakage characteristics.

Fig. 5.18-10 shows a schematic view of an axial ball piston LSHT motor. The left hand cam is kept fixed. With the high pressure oil in the two balls, in a cylinder, try to be apart with high force. The reaction forces on the multi lobe cam generate torque.

Gerotor Pump/Motor

This is an alternative form of internal gear type unit with geometrically form closed spaces between the teeth in contacts of cyloidal class gears. Referring to the Fig. 5-17-11 (a) the inner member, usually having one tooth less than the outer member, is having the profile called as 'constant difference inward modified epitrochoid', The profile of the outer member is the envelope of the inner member profile. The active portions of lobes of the outer member are circular arcs. Therefore, in an alternative version the integral lobes of the outer member are replaced by cylindrical rollers (Fig. 5-17-11 (b)). This later version is called GEROLER where as the former one as GEROTOR. These generic names are trade names. An ordinary kidney port type valve can be used. The separation of chambers depends on metal to metal contacts and therefore the leakage is accuracy dependent. Although, the volumetric efficiency is not so very high in such a unit but it is very simple in construction and also cheap in mass production.

With epicyclic motion the gearing strength can be added to the ordinary motoring action. The unit then can be used as LSHT motor, which has trade name as ORBIT motor (more discussion in next lectures).



(a) Unit with GEROTOR Elements

(b) GEROLER Elements

Fig. 5.18-11 : GEROTOR / GEROLER Pump/Motor

Summary:

Basic features of some commonly used and a few special hydrostatic rotary units i.e., pumps and motors are described in brief. Detail analyses of some units will be discussed in next sections.

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