

## RECIPROCATING PUMP

### INTRODUCTION

The reciprocating pump is a positive displacement pump as it sucks and raises the liquid by actually displacing it with a piston/plunger that executes a reciprocating motion in a closely fitting cylinder. The amount of liquid pumped is equal to the volume displaced by the piston.

The pumps designed with disk pistons create pressures upto 25 bar and the plunger pumps built up still higher pressures. Discharge from these pumps is almost wholly dependent on the pump speed.

The total efficiency of a reciprocating pump is about 10 to 20% higher than a comparable centrifugal pump. Reciprocating pumps for industrial uses have almost become obsolete owing to their high capital cost as well as maintenance cost as compared to that of centrifugal pumps. However, small hand-operated pumps such as cycle pumps, football pumps, kerosene pumps, village well pumps and pumps used as important parts of hydraulic jack etc. still find wide applications. The reciprocating pump is best suited for relatively small capacities and high heads. This type of pump is very common in oil drilling operations.

The reciprocating pump is generally employed for:

- (i) Light oil pumping,
- (ii) Feeding small boilers condensate return, and
- (iii) Pneumatic pressure systems.

### CLASSIFICATION OF RECIPROCATING PUMPS

Reciprocating pumps are classified as follows:

1. According to the water being in contact with piston:

- (i) Single-acting pump ...water is in contact with one side of the piston
- (ii) Double-acting pump ...water is in contact with both sides of the piston.

2. According to number of cylinders:

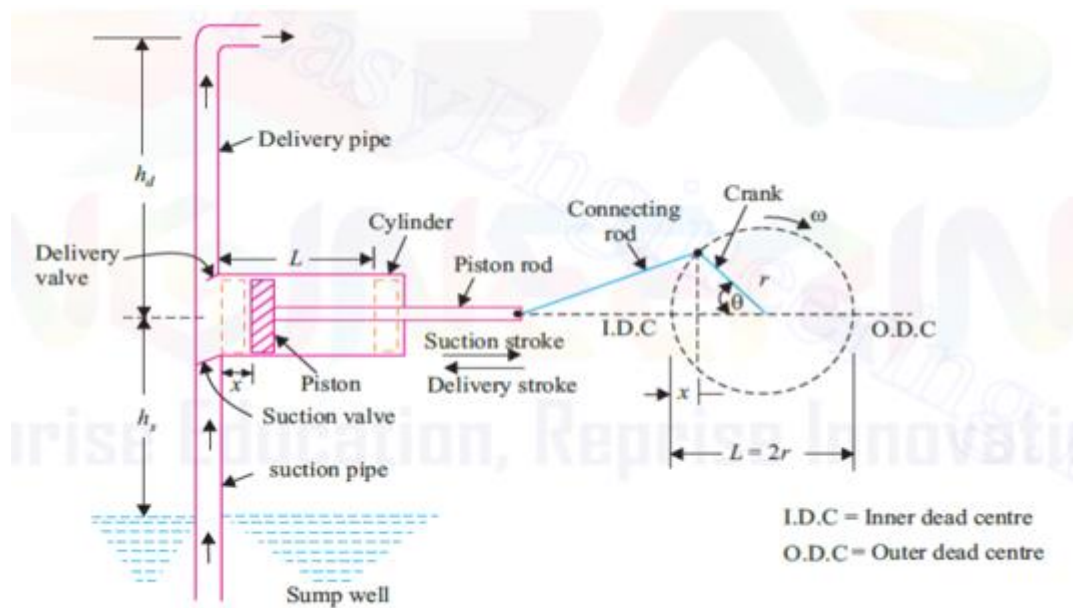
- (i) Single cylinder pump
- (ii) Double cylinder pump (or two throw pump)
- (iii) Triple cylinder pump (or three throw pump)
- (iv) Duplex double-acting pump (or four throw pump)
- (v) Quintuplex pump or (five throw pump).

In general the reciprocating pumps having more than one cylinder are known as multi-cylinder pumps.

## MAIN COMPONENTS AND WORKING OF A RECIPROCATING PUMP

Refer to Fig. The main parts of a reciprocating pump are:

1. Cylinder
2. Piston
3. Suction valve
4. Delivery valve
5. Suction pipe
6. Delivery pipe
7. Crank and connecting rod mechanism operated by a power source e.g. steam engine, internal combustion engine or an electric motor.



Schematic view of single-acting reciprocating pump.

### Working of a single-acting reciprocating pump:

As shown in Fig. 4.1, a single acting reciprocating pump has one suction pipe and one delivery pipe. It is usually placed above the liquid level in the sump. When the crank rotates the piston moves backward and forward inside the cylinder. The pump operates as follows:

Let us suppose that initially the crank is at the inner dead centre (I.D.C.) and crank rotates in the clockwise direction. As the crank rotates, the piston moves towards right and a vacuum created on the left side of the piston. This vacuum causes suction valve to open and consequently the liquid is forced from the sump into the left side of the piston. When the crank is at the outer dead centre (O.D.C) the suction stroke is completed and the left side of the cylinder is full of liquid.

When the crank further turns from O.D.C to I.D.C., the piston moves inward to the left and high pressure is built up in the cylinder. The delivery valve opens and the liquid is forced into the delivery pipe. The liquid is carried to the discharge tank through the delivery pipe.

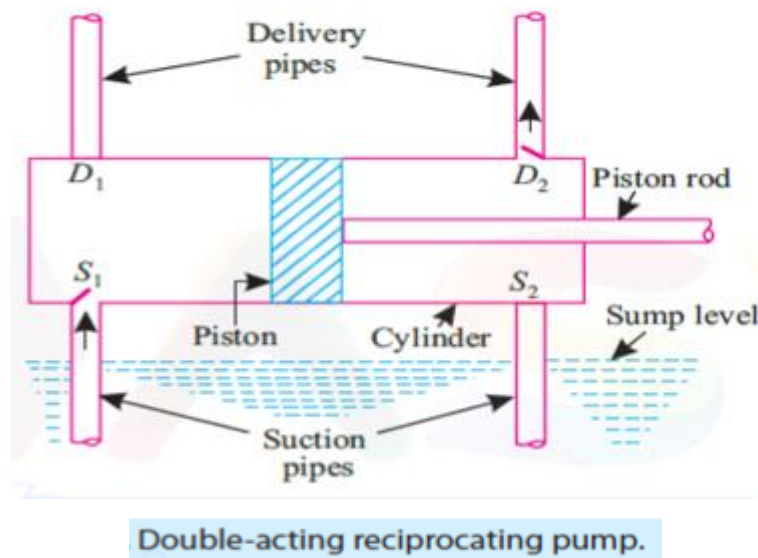
At the end of delivery stroke the crank comes to the I.D.C and the piston is at the extreme left position.

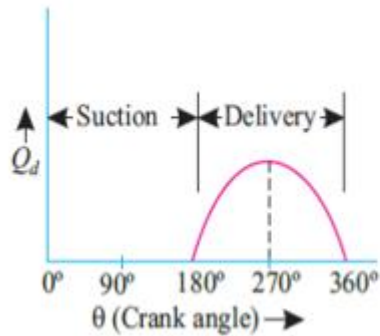
### Working of a double-acting reciprocating pump:

Refer to Fig. 4.2. In a double-acting reciprocating pump, suction and delivery strokes occur simultaneously. When the crank rotates from I.D.C. in the clockwise direction, a vacuum is created on the left side of piston and the liquid is sucked in from the sump through valve  $S_1$ . At the same time, the liquid on the right side of the piston is pressed and a high pressure causes the delivery valve  $D_2$  to open and the liquid is passed on to the discharge tank. This operation continues till the crank reaches O.D.C.

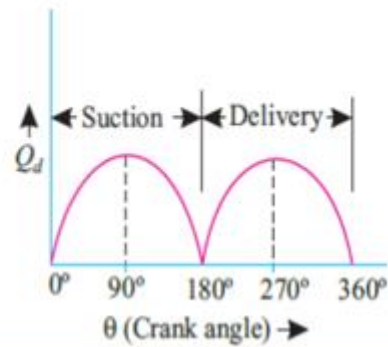
With further rotation of the crank, the liquid is sucked in from the sump through the suction valve  $S_2$  and is delivered to the discharge tank through the delivery valve  $D_1$ . When the crank reaches I.D.C., the piston is in the extreme left position. Thus, one cycle is completed and as the crank further rotates, cycles are repeated. Because of continuous delivery strokes, a double-acting reciprocating pump gives more uniform discharge (as compared to a single-acting pump which pumps the liquid intermittently). To get a still more uniform feed, invariably a multi-cylinder arrangement having two or more cylinders is employed.

Fig. 4.3 and 4.4 show the variations of discharge through delivery pipe ( $Q_d$ ) with crank angle ( $\theta$ ) for single-acting and double-acting pumps respectively.





$Q_d$  v/s  $\theta$  variations for single-acting pump.



$Q_d$  v/s  $\theta$  variations for double-acting pump.

## DISCHARGE, WORK DONE AND POWER REQUIRED TO DRIVE RECIPROCATING PUMP

### Single-acting reciprocating pump

Considering a single acting reciprocating pump

Let,

$D$  = Diameter of the cylinder, m

$A$  = Cross-sectional area of the piston/cylinder =  $\frac{\pi}{4} D^2 \text{ m}^2$

$r$  = Radius of crank, m

$N$  = Speed of the crank, r.p.m.

$L$  = Length of the stroke ( $= 2r$ ), m

$h_s$  = Height of the centre of the cylinder above the liquid surface, m and

$h_d$  = Height to which the liquid is raised above the centre of the cylinder, m.

Volume of liquid sucked in during suction stroke =  $A \times L$

$$\therefore \text{Discharge of the pump per second, } Q = A \times L \times \frac{N}{60} \quad \dots(4.1)$$

$$\text{Weight of water delivered per second, } W = w Q = \frac{wALN}{60} \quad \dots(4.2)$$

Work done per second = Weight of water lifted/sec.  $\times$  total height through which liquid is lifted

$$= W(h_s + h_d) = \frac{wALN}{60} (h_s + h_d) \quad \dots(4.3)$$

$$\therefore \text{Power required to drive the pump} = \frac{wALN}{60 \times 1000} (h_s + h_d) \text{ kW} \quad \dots(4.4)$$

(where,  $w$  = weight density of liquid in  $\text{N/m}^3$ )

### Single-acting reciprocating pump

Refer to Fig. 4.2.

Let,

$D$  = Diameter of the piston,

$d$  = Diameter of the piston rod,

$$A_{pr} = \text{cross-sectional area of the piston rod} = \frac{\pi}{4} d^2$$

$$\text{Area on one side of the piston, } A = \frac{\pi}{4} D^2$$

Area on other side of the piston where piston rod is connected to the piston,

$$A' = A - A_{pr} = \frac{\pi}{4} D^2 - \frac{\pi}{4} d^2 = \frac{\pi}{4} (D^2 - d^2).$$

Volume of liquid delivered in one revolution of crank

$$= A L + A' L = (A + A') L = \left[ \frac{\pi}{4} D^2 + \frac{\pi}{4} (D^2 - d^2) \right] L$$

$$\therefore \text{Discharge of the pump per second} = \left[ \frac{\pi}{4} D^2 + \frac{\pi}{4} (D^2 - d^2) \right] L \times \frac{N}{60} \quad \dots(4.5)$$

If the diameter of the piston rod ' $d$ ' is very small as compared to the diameter of the piston ' $D$ ' then it can be neglected and hence discharge of the pump per second will become

$$Q = \left( \frac{\pi}{4} D^2 + \frac{\pi}{4} D^2 \right) \times \frac{LN}{60} = 2 \times \frac{\pi}{4} D^2 \times \frac{LN}{60} = \frac{2 A L N}{60} \dots(4.6)$$

Evidently the output of a double acting pump is two-times that of a single acting pump.

*Work done per second* = Weight of water delivered  $\times$  total height through which liquid is lifted

$$\begin{aligned} &= \left( w \times \frac{2ALN}{60} \right) \times (h_s + h_d) \\ &= \frac{2wALN}{60} (h_s + h_d) \quad \dots(4.7) \end{aligned}$$

$$\text{Power required to drive the pump, } P = \frac{2wALN}{60 \times 1000} (h_s + h_d) \text{ kW} \quad \dots(4.8)$$

(where,  $w$  = weight density of liquid in  $\text{N/m}^3$ )