

# The reciprocating pump and fluid mechanics engineering essay



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A pump is a mechanical device which helps to move fluids including liquids or gases. It is basically a hydraulic machine which converts the mechanical energy to the hydraulic energy. The hydraulic energy is been present in form of the pressure energy. There are various types of pumps such as positive displacement pumps, velocity pumps, Buoyancy pumps, Impulse pumps. The various different pumps are also been sub-classified in various other pumps. Positive Displacement pumps are one of the most commonly used pumps. They are sub-divided in to Reciprocating and Rotary pumps. Typical types of the Reciprocating pumps are Plunger pumps and Diaphragm Pumps. The " Plunger pump" is also known as Piston Pumps. The Reciprocating Pumps are highly efficient pumps which are even suitable for the very high heads at low flows. It is a self priming type of pump as it can draw the fluid from the level below the suction flange if the suction pipe is not evacuated. There should be a smooth flow required for achieving a good efficiency (Chinnuraj, 2009).

The complete system is based on the design of the pump. The head of cylinder is been mounted with suction and discharge valves. The fluid enters the pump through the suction valve and goes out threw the discharge valve. In suction stroke, suction valve opens when the plunger retracts. The liquid gets pushes out of the discharge valve in the forward stroke. Reciprocating system has a pulsating discharge and it totally depend on the speed of the pump which can be easily altered. The intake of the fluid in the pump is always at a constant volume. They are often used for slurry and sludge. There are various different designs from rest of the pumps. The design containing single-acting motion discharges fluid from only one side of the piston. There is only one suction and discharge per revolution of the crank

shaft. The other design is the double-acting piston design where the suction and the discharge occurs on the either side of the piston resulting in double suction and double discharge per revolution of crank shaft.

## **Classification of PD Pump**

Positive Displacement pump are been classified as follows:

Positive Displacement Pump

Rotary Pump

Single Rotor

-Vane -Piston -Flexible -Member Screw

-Simplex -Duplex -Triplex -Multiplex

-Simplex -Duplex

Double Acting

Single Acting

Diaphragm

Piston Plunger

Reciprocating Pump

Simplex Multiplex

Multi Rotor

-Gear Lobe Circumferential Piston -Screw

(Gates, 2010)

## **Working Principle of Reciprocating Pump**

The working principle of the Reciprocating pump is very simple; it operates on the principle that a volume of liquid would be displaced by solid equal to its own volume. The mechanical energy is been converted in to the pressure energy and takes place due to the suction of the liquid into the cylinder in which the piston is having a reciprocating motion (linear motion-threw and fore). This exerts the thrust on the fluid and hydraulic energy gets increased gradually. In single acting reciprocating pumps, a single piston moves forward and backward in a closed tight cylinder. The linear motion of the piston in the cylinder is been given by connecting piston to the crank with the help of a connecting rod. An electric motor is been used to give motion to the crank and the rotary motion is been converted to the linear motion by the help of the connecting rod. The working principle is somewhat similar to the car engine's where the piston has the same movement threw some similar kind of motions. In Reciprocating Pump, the suction valve allows the fluid to enter where as the discharge valve tends to discharge it from the cylinder (Chinnuraj, 2009).

Fig 01: Working Principle of Reciprocating Pump (Getting Started in HPLC, 2001)

## **Types of Reciprocating Pumps**

The Reciprocating Pumps are usually classified as follows:

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Direct or Indirect acting

Simplex (single) or duplex (double)

Single acting or double acting

High pressure or low pressure

The direct acting pumps are one of the most common type of pump been used. It is been known so as in the particular design the pump rod is a direct extension of the piston rod in which the lower end is been directly connected to the piston in the cylinder. Single and Double action pumps is as mentioned earlier. Single action has a single suction and a single discharge per revolution and Double action pump has two suctions and discharges per revolution.

## **Applications**

Reciprocating Pumps have a very large contribution to the society with plenty of uses. They are been used for no. of small and large applications including irrigation, chemical movement, sewage movement, flood control and marine applications and even many more. Designing factors like size and type of pump depends on the usage.

They are been used in various purposes such as:

High pressure jets: The purpose of pumps used is producing a direct high jet pressure of the fluid. The inlet flow is at a constant flow and pressure but the discharge at a high velocity and therefore results to high amount of pressure.

Chemical Injection: The Reciprocating Pumps are even used in the chemical industry where they need to inject the chemical in a certain flow or pressure. It is been used at very high precise and accuracy

Irrigation: The pump is usually used in farms and gardens to distribute water throughout equally and automatically without any sort of manual efforts.

Sewage movement: The pump are been used to move the slurry or sewage material in a very easy and automatic way. The main advantage is the time constraint. It takes very less time as well as it is very cheap compared to other techniques.

Marine application: The vast amount of usage is being the marine sector where they need to use water movement from one part to other through a pump. The pump is very easy and compact source of product which can be installed very easily and without any maintenance in future. In marine field pump is used for:

Lubricating oil transfer

Fuel oil transfer

Auxiliary circulating and condensate.

Domestic uses: Reciprocating pump is even used as domestic purposes. In olden days it was very common to use a hand pump which was a type of reciprocating pump with help of which we can pull the underground water for various purposes such as home usage, irrigation, construction, small scale industry and many more.

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## **Discharge and Pressure Characteristics**

The working principle and the characteristic is been keenly observed earlier. It is been very easy to analyse the discharge and pressure constraints of reciprocating pumps. The discharge of the reciprocating pump is not uniform and stable. The discharge characteristic depends on:

Head flow of fluid

Fluid density

Speed of reciprocating piston

Pump size and design

The discharge is completely non-uniform and throttling. The pulsating property of the discharge fluid is seen. This is because the piston moves at a high velocity hitting the fluid out wards and the hitting of the piston is not a continuous act which can give a uniform pressure outlet. Despite of vital use, the reciprocating pump still encounter pulsating pressure which is been seen at the suction and discharge lines. This pulsating feature is result of the interaction between unstable flow of fluid and the dynamic characteristics of the fluid particles. Pressure pulsating in the suction line can lead to the cavitation, either in the line itself or in the cylinder chamber. If cavitation is been experienced at the start of the piston stroke than the piston loading and the crank assembly can fail. Because of all this factors it reduces the life of the pump and also affects the safety conditions (K A Edge, 1997)

## Pump Performance and Efficiency

The head of flow against which the pump works is called total head,  $H$ . The total head of the pump is the energy imparted to the liquid by the pump.

$$H = h_d - h_g$$

Therefore, the effective head of a pump is expressed by the following equation:

$$H = - \dots \dots \dots \text{Equation 1 (Sorensen, 1969)}$$

This design principle of the pump work similarly as that of the turbines. The energy of supplied to the pump by the rotating shaft to move the piston inside the cylinder, in terms of bhp:

$$\text{Energy, } e = =$$

The capacity of the pump is proportional to its displacement per unit time,  $D$ . Assuming 100% of the hydraulic efficiency of the pump, the displacement of the pump is calculated. The displacement is the calculated capacity of pump which is proportional to:

Cross-sectional area of piston,  $A$

Length of the stroke,  $S$

No. of cylinders,  $n$

Pump speed in rpm (gallons per minute)

$$D = (A \cdot S \cdot n \cdot \text{rpm}) / 231$$



In case of double acting pumps, the cross sectional area is twice to be taken in to account from which the cross sectional area of piston rod (a) is subtracted.

In double acting pumps,  $D = ((2A - a) \cdot S \cdot n \cdot \text{rpm}) / 231$

The volumetric efficiency of the pump is expressed in terms of percentage. It is directly proportional to the ratio of the total discharge volume to piston displacement.

The ratio (r) is equal to (c + d)/d where:

D = volume displaced by piston

C = Additional volume between the discharge and suction valves.

So it is clearly seen that smaller the ratio, the volumetric efficiency is tend to be better. Mathematically it is expressed as:

$$VE = 1 - (P \cdot b \cdot r) - S$$

Where P is pressure

B is the liquid compressibility factor

R is volume ratio

S is the slip. (Joe Evans, 2004)

## Losses in Reciprocating Pump

There are various losses which are been encountered in the pump such as:

Frictional losses

Head losses

Heat transfer losses

The various losses occur due to the friction and the movement of the fluid. It depends on the head flow of fluid, density of the fluid, piston speed and the fluid suction capacity as well as discharge. There are lots of constraints been involved here, but it simply can be minimised but not 100% avoided.

## **Advantages**

Easy in working

Inexpensive

Compact and Easy to install

Low maintenance

Works at high speed and at low power

## **Disadvantages**

The major disadvantage of the reciprocating pump is that it has a discontinuous discharge flow which with variable pressure and hence it adversely affects the potential of the pump usage. There are various techniques been used to minimise the pulsating feature but it still tend to create problems. There are some technical ways used to minimise it by using sensors or throttle valves which keeps the discharge pressure uniform, but it

does affect the overall flow and creates a kind of friction to the overall discharge pressure.

Secondly, it has a disadvantage that it is prone to flow separation at the lowest pressure point in the system. The design of the system is such that this problem would be there and cannot be solved. The various different tries and practical experiments to minimise it would not work till the design is not thoroughly changed. In spite of all this disadvantages it is still a very useful product and widely used.