38

Pumping Devices

38·1 Introduction

In the previous chapter, we have discussed centrifugal and reciprocating pumps. But, sometimes, in certain industrial plants and power stations, oil and other liquids have to be handled, under different conditions. Moreover, instead of conventional devices like electric motor, petrol or diesel engines, other sources of power such as falling water, compressed air or steam is also utilized for lifting the liquids. Though there are numerous pumping devices, yet the following are important from the subject point of view :

38·2 Hydraulic Ram

This is an automatic machine, which can lift a small quantity of water to a greater height, when a large quantity of water is available at a smaller height.

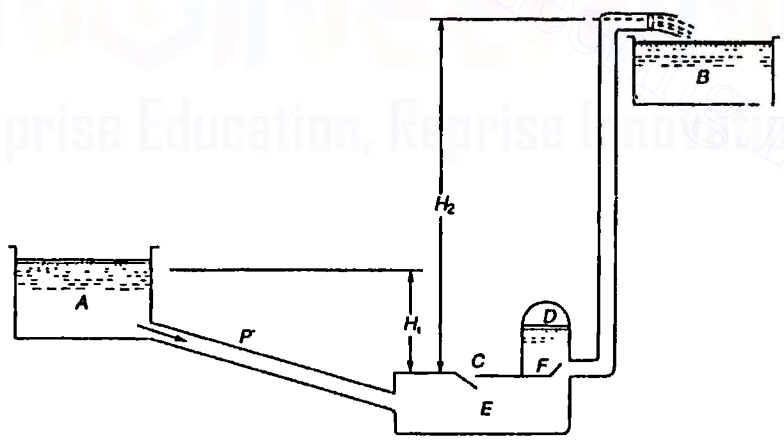


Fig. 38·1. Hydraulic ram.

Fig. 38·1 shows a diagrammatic view of a hydraulic ram, in which water is available from source. *A* at a height H_1. By means of the hydraulic ram, a small quantity of this water is raised through a height H_2 into tank *B*.

The water starts flowing from the tank *A* to the chamber *E* through the pipe *P*. The waste-value *C* is open and the water flows out through it. As the speed of the water in the pipe *P* increases, the dynamic pressure on the waste-valve *C* increase, until it is greater than the weight of ...

pressure, in the chamber *E*, lifts the valve *F* and some water flows into the air vessel *D*, which will compress the air in the vessel, causing its pressure to increase. This increased air pressure in the vessel *D* closes the valve *F* and forces up the water into the tank *B*.

When the momentum of the water in the chamber *E* is destroyed, the waste-valve *C* opens which causes the flow of water from the tank *A* to recommence.

Let W = Weight of the water flowing from tank *A* into the chamber *E*,

w = Weight of the water flowing from the chamber *E* into the tank *B*,

H_1 = Height of water in the tank *A*, above the chamber *E*, and

H_2 = Height of water in the tank *B*, above the chamber *E*.

We know that nergy supplied by the tank *A*

$$= WH_1 \quad ...(i)$$

energy supplied to the tank *B* $= wH_2$ ...(*ii*)

Equating equations (*i*) and (*ii*),

$$WH_1 = wH_2$$

$$\therefore \quad w = \frac{H_1}{H_2} \times W$$

If losses are taken into account, then efficiency of the ram (known as D' Aubuisson's efficiency),

$$\eta = \frac{wH_2}{WH_1}$$

There is another relation for the efficiency of the ram ((known as Rankine's efficiency). In this relation, it is assumed that the water was initially at a height H_1 and is only lifted through a height equal to $(H_2 - H_1)$. Thus the Rankine's formula for the efficiency of a ram,

$$\eta = \frac{w\ (H_2 - H_1)}{WH_1}$$

Notes : Ig. instead of the weights of water in the two tanks, the two discharge (*i.e.*, from the tank *A* to the chamber, as Q and from the chamber *E* to the tank *B*, as q) are given, then the efficiency of the ram will be given by the relation,

$$\eta = \frac{qH_2}{QH_1}$$

and the corresponding Rankine's efficiency will be given by the relation.

$$\eta = \frac{q\,(H_2 - H_1)}{QH_1}$$

Example 38·1. *A hydraulic ram, suitable for demonstration, in a research laboratory has the following data :*

Supply head	=	2·5 metres
Total water supplied	=	*1000 litres/min*
Discharge	=	*100 litres/min*
Delivery head	=	*15 metres*

Determine the Rankine's efficiency.

We know that Rankine's efficiency,

$$\eta = \frac{q(H_2 - H_1)}{QH_1} = \frac{100 \times (15 - 2{\cdot}5)}{1000 \times 2{\cdot}5} = 0{\cdot}50 = 50\% \quad \textbf{Ans.}$$

Example 38·2 *A hydraulic ram utilizes water under a head of 3 metres and delivers against an effective head of 30 metres. If the ratio of water raised to the water wasted by the ram is 1 : 15, calculate the D'Aubuisson's and Rankine's efficiencies of the ram.*

Solution. Given : $H_1 = 3$ m; $H_2 = 30$ m and ratio of water raised to the water wasted = 1 : 15.

D' Aubuisson's efficiency

Let the quantity of water raised by the ram,

$$q = 1 \text{ m}^3$$

Since the ratio of water raised to the water wasted is 1 : 15, therefore, quantity of water wasted = 15 m^3. Or in other words total quantity of water delivered,

$$Q = 1 + 15 = 16 \text{ m}^3$$

We know that D'Aubuisson's efficiency,

$$\eta = \frac{qH_2}{QH_1} = \frac{1 \times 30}{16 \times 3} = 0{\cdot}625 = 62{\cdot}5\% \quad \textbf{Ans.}$$

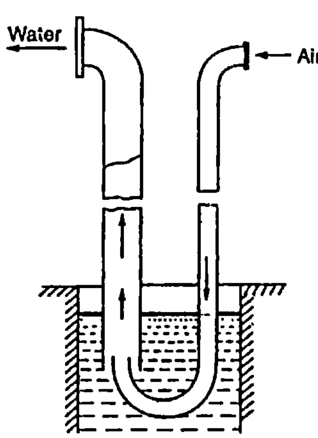
Rankine's efficiency

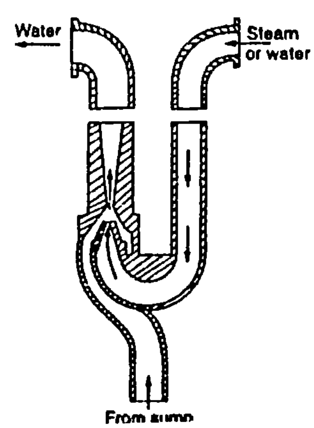
We also know that Rankine's efficiency,

$$\eta = \frac{q(H_2 - H_1)}{QH_1} = \frac{1(30 - 3)}{16 \times 3} = 0{\cdot}5625 = 56{\cdot}25\% \quad \textbf{Ans.}$$

38·3 Air Lift Pump

It is successfully used for lifting water form deep wells or against high heads. An air lift pump, in its simplest form, consists of an open vertical pipe with its lower end submerged into the liquid to be raised. The upper end of the pipe leads to the required height. The compressed air is introduced at the bottom of the pipe through a nozzle as shown in Fig. 38·2.





The efficiency of this pump is very low (about 25%). This is due to the loss of energy of the compressed air while mixing with the liquid. An air jet has the following advantages :

1. It is quite simple in design.
2. Since there are no moving parts, therefore, there is no wear and tear.
3. There is no problem of lubrication.
4. The initial as well as maintenance cost is very small.

38·4 Jet Pump

It is successfully used for lifting water to the boilers. A jet pump, in its simplest form, consists of a pipe having a convergent end at its bottom. The upper end of the pipe leads to the required. height. Now steam (or sometimes water) under a high pressure is introduced through a nozzle as shown in Fig. 38·3. The pressure energy of the steam is converted into kinetic energy, as it passes through the nozzle. As a result of this, the pressure in the convergent portion of the pipe is considerably reduced and water is sucked into the pipe from the sump. The sucked water after coming in contact with the jet, is carried into the delivery pipe.

Here the kinetic head of the water steam is converted into pressure head, which forces the water into the delivery pipe.

38·5 Rotary Pumps

A rotary pump resembles a centrifugal pump in its outward appearance. But it differs in action. It combines the advantages of both the centrifugal and reciprocating pumps (*i.e.*, constant discharge of a centrifugal pump, and positive displacement of a reciprocating pump). The following rotary pumps are important from the subject point of view :

1. External gear pump, 2. Internal gear pump, 3. Lobe pump, and 4. Vane pump.

38·6 External Gear Pump

An external gear pump, in its simplest form, consists of two identical intermeshing spur wheels *A* and *B* working with a fine clearance inside inside the casing. The wheels are so designed, that they form a fluid tight joint at the point of contact as shown in Fig 38·4. One of the wheels is keyed to the driving shaft, and the other revolves as a driven wheel.

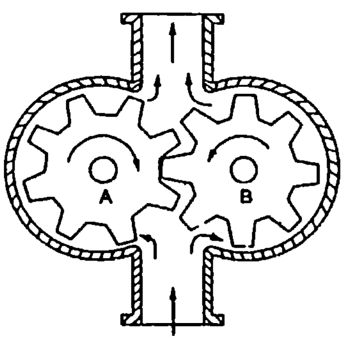


Fig. 38.4. External gear pump.

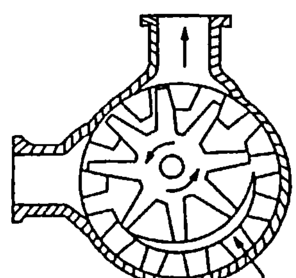


Fig. 38.5. Internal gear pump.

The pump is first filled with the liquid before it is starts. As the gears rotate, the liquid is trapped in between their teeth and is flown to the discharge end round the casing. The rotating gears build up sufficient ... A little consideration will show that each tooth of the

38·7 Internal Gear Pump

As internal gear pump, in its simplest form, consists of two spur wheels intermeshing internally. the wheels are so designed, that on one side, they form a fluid tight joint at the point of contact, and a space for crescent on the other as shown in Fig. 38·5.

A crescent shaped partition is provided between the two wheels to act as a seal between suction and discharge. This is done by placing the inner wheel eccentrically in the outer wheel. The inner wheel is keyed to the driving shaft and the outer revolves as a driven wheel.

The pump is first filled with the liquid before it is started. As the wheels rotate, the teeth come out of the mesh, near the suction end. As a result of this, the pace between the two wheels increases and the liquid flows into this space. As the wheels continue to rotate, the liquid is trapped, between the teeth and crescent of both the wheels and flown to the discharge end. A little consideration will show at each tooth of the gear, like external gear pump, acts like a piston or plunger of a reciprocating pump to force the liquid inside the discharge pipe.

38·8 Lobe Pump

A lobe type pump resembles with a gear pump in action. There are many designs of lobe type rotary pumps. But the wheels have usually two or three lobes, and sometimes even more. In all cases, the action remains the same. In Fig. 38·6 shown two types of lobe pumps.

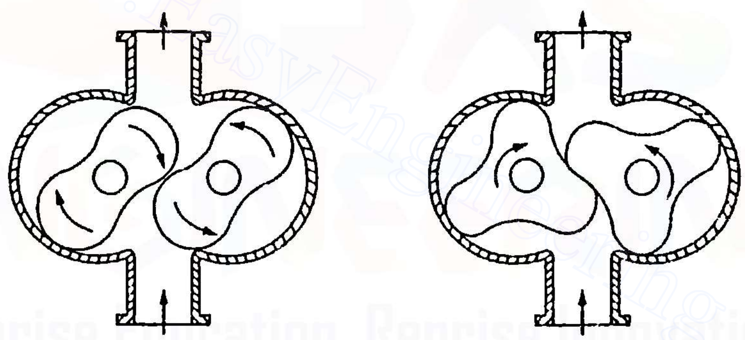
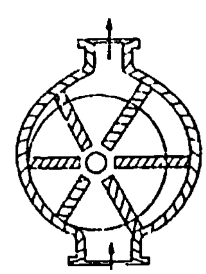


Fig. 38·6. Lobe pumps.

The lobes are so designed, that they from a fluid tight joint at the point of contact. As the lobes rotate, the liquid is trapped in the pockets formed between the lobes and casing . The lobes build up sufficient pressure to force the liquid into delivery pipe. The only drawback, in a lobe type, is that its discharge is not so constant as that of a gear pump.

38·9 Vane Pump

A vane pump in its simplest form, consists of a disc rotating eccentrically in the pump casing. The disc has a number of slots (generally 4 to 8) containing vanes, which are free to slide radially into the vanes. When the rotor rotates the disc, the vanes are pressed against the casing due to centrifugal force, and forms a liquid tight seal. As the dics rotates, the liquid is trapped in the pockets formed between the vanes and the casing. The vanes build up sufficient pressure to force the liquid into the delivery pipe.



In some designs the springs are used to press the vanes against the casing. But in some more designs, swinging vanes are

EXERCISE 38·1

1. A hydraulic ram model has the following data :

   Supply head = 1 m

   Delivery head = 6 m

   Total water available = 1 500 litres/s

   Discharge = 100 litres/s

   Find the efficiencies of the ram. [Ans. D' Aubuisson's η = 40%; Rankine's η = 33%]

2. A hydraulic ram is supplied water under a head of 2 metres and is to deliver against an effective head of 16·8 metres. If the ratio of water used to the water supplied is 16, find the efficiencies of the ram.

   [Ans. D' Aubuisson's η = 49.4%; Rankine's η = 46.25%]

QUESTIONS

1. Explain, with a neat sketch, the working of hydraulic ram and define its efficiency.
2. What is an air lift pump ? Where it is used ?
3. Give the advantages of air lift pump..
4. Distinguish between an internal gear pump and external gear pump.
5 Describe lobe pump. On what principle does it work ?
6. Explain the working of a vane pump.

OBJECTIVE TYPE QUESTIONS

1. A hydraulic ram is a device used to

   (*a*) store energy of water (*b*) increase pressure of water

   (*c*) lift water from depwells (*d*) none of these

2. Which of the following pump is successfully used for lifting water to the turbines

   (*a*) centrifugal pump (*b*) reciprocating pump

   (*c*) jet pump (*d*) air lift pump

3. Which of the following pump has the advantages of both the centrifugal pumps (*i.e.*, constant discharge) and reciprocating pump (positive displacement) ?

   (*a*) jet pump (*b*) air lift pump

   (*c*) rotary pump (*d*) all of these

ANSWERS

1. (*d*) 2. (*c*) 3. (*c*)