37

Performance of Pumps

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37·1 Introduction

In the last two chapters *i.e.*, (Centrifugal Pumps and Reciprocating Pumps), we have assumed that the pump will be required to lift a constant quantity of water to a constant height. But in actual practice, these assumptions rarely prevail. It is thus essential to know the working of the pump under changed conditions also.

37·2 Variation in Speed and Diameter of a Centrifugal Pump

Sometimes, there is a minor* change in the requirement of the head of water or discharge of a pump from its designed head of water or discharge. In such a case, a slight adjustment in the pump is made to suit the new set of conditions. This is done either :

1. By varying speed of the pump impeller, or
2. By changing the diameter of the pump impeller.

Now we shall study the effect of there two variations on the discharge, head of water, and the power required to drive the pump.

37·3 Effect of Variation in Speed

Consider a centrifugal pump, whose speed is changed to suit the new set of conditions.

Let N = Designed speed in r.p.m.,

Q = Discharge of pump with the designed speed of N r.p.m.,

H = Head of water with the designed speed of N r.p.m.,

P = Power required to drive the pump with the designed speed of N r.p.m.,

N_1 = New speed to suit the changed set of conditions, and

Q_1, H_1, P_1 = Corresponding values with the new speed of N_1 r.p.m.

A little consideration will show, that when the speed of the impeller is changed from N to N_1, shape of the velocity triangle will remain the same (*i.e.*, various angles will remain the same). But the values of the velocities will change proportionately. We know that the tangential velocity of the impeller at inlet,

$$v = \frac{\pi DN}{60}$$

$$\propto N$$

*If the change is a major one, then a new pump is designed and manufactured with altogether different

Similarly $$v_1 \propto N$$

and $$V_{w1} \propto N \qquad ...(\because V_{w1} \propto v_1)$$

We also know that velocity of flow,

$$V_f \propto v$$

$$\propto N \qquad ...(\because v \propto N)$$

But discharge, $$Q = \pi D b V_f$$

$$\propto V_f$$

$$\propto N \qquad ...(\because V_f \propto N)$$

Similarly $$Q_1 \propto N_1$$

$$\therefore \quad \frac{Q}{Q_1} = \frac{N}{N_1} \qquad ...(i)$$

It is thus obvious that the discharge of a centrifugal pump is proportional to the speed of its impeller.

We know that the head of water,

$$H = \eta \times \frac{V_{w1} \cdot v_1}{g}$$

$$\propto V_{w1} \cdot v_1$$

$$\propto N \cdot N \qquad ...(\because V_{w1} \propto N \text{ and } v_1 \propto N)$$

$$\propto N^2$$

Similarly $$H_1 \propto N_1^2$$

$$\therefore \quad \frac{H}{H_1} = \frac{N^2}{N_1^2} = \left(\frac{N}{N_1}\right)^2 \qquad ...(ii)$$

It is thus obvious, that the head of a centrifugal pump is proportional to the square of the speed of its impeller.

We also know that the power required to drive a pump,

$$P = \frac{wQV_{w1} \cdot v_1}{g}$$

$$\propto Q \cdot V_{w1} \cdot v_1$$

$$\propto N \cdot N \cdot N \propto N^3.$$

Similarly $$P_1 \propto N_1^3$$

$$\therefore \quad \frac{P}{P_1} = \frac{N^3}{N_1^3} = \left(\frac{N}{N_1}\right)^3 \qquad ...(iii)$$

It is thus obvious, that the power required to drive a centrifugal pump is proportional to the cube of the speed of its impeller.

It may be noted that the hydraulic losses vary, more or less, uniformly with the speed of the impeller. Thus the hydraulic efficiency practically, remains unchanged with the change of impeller speed. But mechanical losses are relatively small at higher speeds. Thus the mechanical efficiency will slightly increase with the increase in the impeller speed.

Example 37·1. *A centrifugal pump delivers 30 litres of water per second against a head of 12*

Solution. Given : Given $Q = 30$ litres/s; $H = 12$ m; $N = 1200$ r.p.m. and $N_1 = 1500$ r.p.m.

Discharge under new speed

Let Q_1 = Discharge under the new speed.

We know that $\dfrac{Q}{Q_1} = \dfrac{N}{N_1}$ or $\dfrac{30}{Q_1} = \dfrac{1200}{1500} = 0{\cdot}8$

$\therefore$ $Q = 30/0\ 8 = 37{\cdot}5$ litres/s **Ans.**

Head of the pump under the new speed

Let H_1 = Head under the new speed.

We know that $\dfrac{H}{H_1} = \left(\dfrac{N}{N_1}\right)^2$ or $\dfrac{12}{H_1} = \left(\dfrac{1200}{1500}\right)^2 = 0{\cdot}64$

$\therefore$ $H_1 = 12/0{\cdot}64 = 18{\cdot}75$ m **Ans.**

Power required to drive the pump under the new speed

Let P_1 = Power required under the new speed.

We know that $\dfrac{P}{P_1} = \left(\dfrac{N}{N_1}\right)^3$ or $\dfrac{6}{P_1} = \left(\dfrac{1200}{1500}\right)^3 = 0{\cdot}512$

$\therefore$ $P_1 = 6/0{\cdot}512 = 11{\cdot}7$ kW **Ans.**

37·4 Effect of Variation in Diameter

We have discussed in Art. 37·2 that a minor change in the requirement of the head of water or discharge of a pump is made either by varying speed or diameter of the pump impeller. It has been experienced that the former (*i.e.*, varying the speed of the pump impeller) is not possible, because the pump impeller is driven by motor, whose speed is fixed. It is thus obvious, that in majority of the cases, the diameter of the pump impeller is enlarged or reduced whenever the head of water or discharged is to be increased or decreased. It is done either by changing the blades of the impeller or fixing rings to its outside diameter.

Now consider a centrifugal pump, whose diameter is changed to suit the new set of conditions

Let D = Outside diameter of the pump,

Q = Discharge of the pump with diameter D,

H = Head of water with diameter D,

P = Power required to drive the pump with diameter D.

D_1 = New outside diameter to suit the changed requirement, and

Q_1, H_1, P_1 = Corresponding values with diameter D_1.

A little consideration will show, that when the diameter of the impeller is changed from D to D_1, the shape of the velocity triangle will remain the same (*i.e.*, the various angles will remain the same). But the values of the velocities will change proportionately. We know that the tangential velocity of the impeller,

$$v = \frac{\pi DN}{60} \propto D$$

Similarly, velocity of flow, $V_f \propto v \propto D$ ...($\because D \propto v$)

But discharge, $Q = \pi DbV_f \propto D \, . \, V_f$

Similarly $\quad Q_1 \propto D_1^2$

$$\therefore \quad \frac{Q}{Q_1} = \frac{D^2}{D_1^2} = \left(\frac{D}{D_1}\right)^2 \quad \text{...(i)}$$

It is thus obvious, that the discharge of a centrifugal pump is proportional to the square of the diameter of its impeller. We know that head of water,

$$H = \eta \times \frac{V_{w1} \cdot v1}{g} \propto V_{w1} \cdot v_{s1} \propto D \cdot D \propto D^2$$

Similarly $\quad H_1 \propto D_1^2$

$$\therefore \quad \frac{H}{H_1} = \frac{D}{D_1^2} = \left(\frac{D}{D_1}\right)^2 \quad \text{...(ii)}$$

It is thus obvious, that the head of water of a centrifugal pump is also proportional to the square of the diameter of its impeller. We also know that the power required to drive a pump,

$$P = \frac{w \cdot QV_{w1} \cdot v1}{g}$$

$$\propto Q \cdot V_{w1} \cdot v1 \propto D^2 \cdot D \cdot D \propto D^4$$

Similarly $\quad P_1 \propto D_1^4$

$$\therefore \quad \frac{P}{P_1} = \frac{D^4}{D_1^4} = \left(\frac{D}{D_1}\right)^4 \quad \text{...(iii)}$$

It is thus obvious, that the power required to drive a centrifugal pump is proportional to the fourth power of the diameter of its impeller.

Example 37·2. *A centrifugal pump was built to supply water against a head of 22·5 metres. But later on it was required to supply the required quantity of water against a head of 20 metres. Find the necessary reduction in the impeller diameter, if it is planned to reduce the original diameter of 300 mm without reducing the speed of impeller.*

Solution. Given : $H = 22{\cdot}5$ m; $H_1 = 20$ m and $D = 300$ mm $= 0{\cdot}3$ m.

Let $\quad D_1 =$ New impeller diameter.

We know that

$$\frac{H}{H_1} = \left(\frac{D}{D_1}\right)^2 \quad \text{or} \quad \frac{22{\cdot}5}{20} = \left(\frac{0{\cdot}3}{D_1}\right)^2 = \frac{0{\cdot}09}{D_1^2}$$

$$\therefore \quad D_1^2 = \frac{0{\cdot}09 \times 20}{22{\cdot}5} = 0{\cdot}08 \quad \text{or} \quad D_1 = 0{\cdot}283 \text{ m} = 283 \text{ mm} \quad \textbf{Ans.}$$

Note. The above example may also be solved without changing the original impeller diameter into metres *i.e.*, keeping the value of D as 300 mm as discussed below :

$$\frac{H}{H_1} = \left(\frac{D}{D_1}\right)^2 \quad \text{or} \quad \frac{22{\cdot}5}{20} = \left(\frac{300}{D_1}\right)^2 = \frac{90\,000}{D_1^2}$$

$$D_1^2 = \frac{90\,000 \times 20}{22{\cdot}5} = 80\,000 \quad \text{or} \quad D = 283 \text{ mm}$$

37·5 Specific Speed of a Centrifugal Pump

The specific speed of a centrifugal pump may be defined as the speed if an imaginary pump

Let
N_S = Specific speed of the pump,
D_1 = Diameter of the impeller at outlet,
N = Speed of the impeller in r.p.m.,
v_1 = Tangential velocity of impeller at outlet, and
H = Lift of the pump in metres.

We know that the tangential velocity of the impeller,

$$v \propto \sqrt{H}$$

and

$$v = \frac{\pi D_1 N}{60}$$

$$\therefore \quad D_1 N \propto v \propto \sqrt{H}$$

$$\therefore \quad D_1 \propto \frac{\sqrt{H}}{N} \qquad \ldots(i)$$

Now let
Q = Discharge of the pump m³/s
b_1 = Width of the impeller at outlet, and
V_{f1} = Velocity of flow at outlet.

We know that the discharge

$$Q = \pi D_1 b_1 V_{f1}$$

But

$$b_1 \propto D_1$$

$$V_{f1} \propto \sqrt{H}$$

$$\therefore \quad Q \propto D_1^2 \sqrt{H}$$

$$\propto \left(\frac{\sqrt{H}}{N}\right)^2 \sqrt{H} \qquad \ldots\left(\because D \propto \frac{\sqrt{H}}{N}\right)$$

$$\propto \frac{H^{3/2}}{N^2}$$

$$\therefore \quad N^2 \propto \frac{H^{3/2}}{Q}$$

or

$$N \propto \frac{H^{3/4}}{\sqrt{Q}} = \frac{N_S \cdot H^{3/4}}{\sqrt{Q}} \qquad \text{.. (where } N_s \text{ is constant of proportionality)}$$

$$\therefore \quad N_S = \frac{N\sqrt{Q}}{H^{3/4}}$$

Example 37·3. *Find the specific speed of a centrifugal pump, delivering 750 litres of water per second against a head of 15 metres at 725 r.p.m.*

Solution. Given : Q = 750 litres/s = 0·75 m³/s; H = 15 m and N = 725 r.p.m.

We know that specific speed of the pump,

$$N_S = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{725\sqrt{0{\cdot}75}}{(15)^{3/4}} = 82{\cdot}4 \text{ r.p.m.} \quad \textbf{Ans.}$$

Example 37·4. *A multi-stage centrifugal pump is required to lift 9 000 litres of water per minute from a mine, the total head including friction being 75 metres. If the speed of the pump is 1200 r.p.m., find the least number of stages, if the specific speed per stage is not to be less than 60 r.p.m.*

Solution. Given : $Q = 9000$ litres/min = 150 litres/s = $0{\cdot}15\ m^3/s$; Total head = 75 m; $N = 1200$ r.p.m. and $N_S = 60$ r.p.m.

Let H = Head of water per stage.

We know that specific speed (N_S),

$$60 = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1200\ \sqrt{0{\cdot}15}}{H^{3/4}} = \frac{464{\cdot}4}{H^{3/4}}$$

$$\therefore \quad H^{3/4} = 464{\cdot}4/60 = 7{\cdot}74 \quad \text{or} \quad H = 15{\cdot}3 \text{ m}$$

We also know that number of stages

$$= \frac{\text{Total head of water}}{\text{Head od water per stage}} = \frac{75}{15{\cdot}3} = 4{\cdot}9 \text{ say } 5 \quad \textbf{Ans.}$$

Example 37·5. *A single stage centrifugal pump with impeller diameter of 300 mm rotates at 2000 r.p.m. and lifts 3 m³ of water per minute to a height of 30 metres with an efficiency of 75%. Find the number of stages and the diameter of each impeller of a similar multistage pump to lift 4·5 m³ of water per minute to a height of 130 m when rotating at 1500 r.p.m.*

Solution. Given : $D = 300$ mm = $0{\cdot}3$ m; $N = 2000$ r.p.m., $Q = 3\ m^3/min = 0{\cdot}05\ m^3/s$; Height through which water is lifted in one stage = 30 m; $\eta = 75\% = 0{\cdot}75$; $Q_1 = 4{\cdot}5\ m^3/min = 0{\cdot}075\ m^3/s$; Total height through which water is to be lifted = 130 m and $N_1 = 1500$ r.p.m.

Number of stages

First of all, consider the first pump. We know that actual head against which the first pump has to work

$$H = 30/0{\cdot}75 = 40 \text{ m}$$

and specific speed of the pump, $N_S = \dfrac{N\sqrt{Q}}{H^{3/4}} = \dfrac{2000\ \sqrt{0{\cdot}05}}{(40)^{3/4}} = 28{\cdot}1$ r.p.m.

Now consider the second pump. Since both the pumps are similar, therefore their specific speeds must be equal.

Let H_1 = Height through which the pump can lift water.

We know that specific speed of the second pump (N_S)

$$28{\cdot}1 = \frac{N_1\sqrt{Q_1}}{H_1^{3/4}} = \frac{1500\ \sqrt{0{\cdot}075}}{H_1^{3/4}} = \frac{410{\cdot}8}{H_1^{3/4}}$$

$$\text{or} \quad H_1^{3/4} = 410{\cdot}8/28{\cdot}1 = 14{\cdot}62 \quad \text{or} \quad H_1 = 35{\cdot}7 \text{ m}$$

∴ Actual height to which the water can be lifted in one stage

$$= 35{\cdot}7 \times 0{\cdot}75 = 26{\cdot}8 \text{ m}$$

and number of stages $= \dfrac{\text{Total height through which water is to be lifted}}{\text{Actual height of one stage}}$

$$= \frac{130}{26{\cdot}8} = 4{\cdot}85 \text{ say } 5 \quad \textbf{Ans.}$$

Diameter of each impeller

Let D_1 = Diameter of each impeller.

We know that $$\frac{H}{H_1} = \left(\frac{D}{D_1}\right)^2 \quad \text{or} \quad \frac{30}{35\cdot7} = \left(\frac{0\cdot3}{D_1}\right)^2 = \frac{0\cdot09}{D_1^2}$$

$$\therefore \quad D_1^2 = \frac{0\cdot09 \times 35\cdot7}{30} = 0\cdot107 \quad \text{or} \quad D_1 = 0\cdot327 \text{ m} = 327 \text{ mm} \quad \textbf{Ans.}$$

37·6 Selection of Centrifugal Pumps Based on Specific Speed

The specific speed of a centrifugal pump, like that of a turbine, helps us in selecting the type of centrifugal pump. Following table gives the type of centrifugal pump for the corresponding specific speed.

Table 37·1

S. No.	*Specific speed*	*Type of centrifugal pump*
1	10 to 30	Slow speed pump, with radial flow at outlet.
2	30 to 50	Medium speed pump, with radial flow at outlet.
3	50 to 80	High speed pump, with radial flow at outlet.
4	80 to 160	High speed pump, with mixed flow at outlet.
5	160 to 500	High speed pump, with axial flow at outlet.
6	Above 500	Very high speed pump.

Example 37·6. *A centrifugal pump delivers 120 litres of water per second against a head of 85 metres at 900 r.p.m. Find the specific speed of the pump. What type of impeller would you select for the pump ?*

Solution. Given. Q = 120 litres/s = 0·12 m^3/s; H = 85 m and N = 900 r.p.m.

Specific speed of the pump

We know that specific speed of the pump,

$$N_S = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{900\sqrt{0\cdot12}}{(85)^{3/4}} = 11\cdot1 \text{ r.p.m.} \quad \textbf{Ans.}$$

Type of impeller

Since the specific speed of the pump is 11·1 r.p.m., therefore slow speed centrifugal pump with radial flow should be selected. **Ans.**

37·7 Suction Head

In the previous articles, we have discussed the term suction head. As a matter of fact, it is of utmost importance for the smooth and efficient working of a centrifugal pump.

Strictly speaking, a pump (centrifugal or reciprocating) lifts water from a reservoir because of atmospheric pressure acting on the surface of water. The pump reduces the pressure in the casing, to such an extent, that the atmospheric pressure forces up water in the suction pipe. A little consideration will show, that as the pump cannot produce a pressure below the vapour pressure of the liquid, therefore the limiting pressure difference is the atmospheric pressure minus the vapour pressure. This available pressure difference is responsible for lifting the water in the suction pipe. A little consideration will show, that this pressure difference should be capable enough :

1. to lift water through the suction head (H_s)

2. to overcome frictional loss in the suction pipe (H_{fs}), and
3. to produce velocity head $\left(\frac{v_s^2}{2g}\right)$

Now consider a pump lifting water from a sump.

Let
p_a = Atmospheric pressure in kPa (*i.e.*, kN/m²)
p_v = Vapour pressure in kPa (*i.e.*, kN/m²)
H_a = Atmospheric pressure in metres,
H_v = Vapour pressure in metres, and
w = Specific weight of liquid.

We know that
$$\frac{p_a}{w} - \frac{p_v}{w} = H_a + H_v$$

$$\frac{p_a - p_v}{w} = H_s + H_{fs} + \frac{v_s^2}{2g}$$

or
$$H_s = \frac{p_a - p_v}{w} - H_{fs} - \frac{v_s^2}{2g} \quad \text{.. (In terms of } p_a \text{ and } p_v\text{)}$$

$$= H_a - H_v - H_{fs} - \frac{v_s^2}{2g} \quad \text{...(in terms of } H_a \text{ and } H_v\text{)}$$

where H_s is the suction head. In actual practice, the value of H_s is not kept equal to that obtained from the above relation. But it is generally kept from 5 to 6 metres only.

37·8 Vapour Pressure

The vapour pressure of a liquid may be defined as the pressure at which the liquid will transform into vapour at the given temperature. A little consideration will show, that the vapour pressure is a function of temperature. Higher the temperature, higher will be the vapour pressure. As a matter of fact, the pressure at any point should not fall below the vapour in any pumping system. The vapour bubbles when collapse result in the corrosion of the suction pipe and other parts.

37·9 Net Positive Suction Head (NPSH)

It is a commercial term used by the pump manufacturers, and indicates the suction head which the pump impeller can produce. We have already discussed in the last articles, the suction head and vapour pressure. There we derived a relation for the suction head (or more accurately the limiting suction head), such that

$$H_s = \frac{p_a - p_v}{w} - H_{fs} - \frac{v_s^2}{2g} \quad \text{...(in terms of } p_a \text{ and } p_v\text{)}$$

$$= H_a - H_v - H_{fs} - \frac{v_s^2}{2g} \quad \text{...(in terms of } H_a \text{ and } H_v\text{)}$$

The right hand side of the above equations represents the suction head or net positive suction head.

Note. For any pump installation, a distinction is generally made between the required NPSH and the available NPSH. The required NPSH varies with the pump design, its speed, capacity etc. The available NPSH depends upon the site conditions and the available equipment. In order to have a smooth working of the pump, the available NPSH should be more (or equal) to the required NPSH.

37·10 Cavitation in Centrifugal Pumps

The cavitation can be eliminated (or minimised) by the following precautions :

1. The liquid temperature should be as low as possible to keep the vapour pressure down and to obtain an increased NPSH.
2. The velocity of liquid in the suction pipe should be as low as practicable.
3. As far as possible, the sharp bends in the suction pipe should be avoided to reduce loss of head.

37·11 Multiple Cylinder Reciprocating Pumps

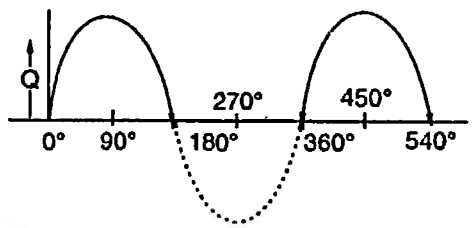

Fig. 37·1. Flow pattern in a reciprocating pump.

We have already discussed in the last chapter that in a single acting reciprocating pump, the discharge takes place only during the delivery stroke. Even the rate of flow, during the delivery stroke, is not constant and fluctuates as a sine curve as shown in Fig. 37·1. Since the velocity of water is proportional to the velocity of crank, therefore the figure represents the velocity of water to some scale.

In order to have a continuous flow (preferably a uniform flow too) multiple cylinder pumps are used. Though there are many types of multiple cylinder pumps, yet the following are important from the subject point of view.

1. Double cylinder pump, and
2. Triple cylinder pump.

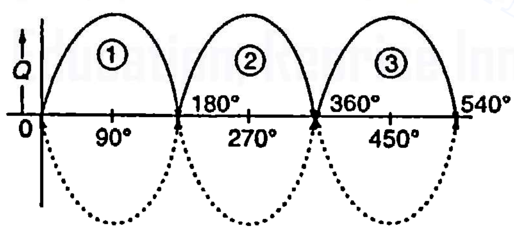

Fig. 37·2. Double cylinder pump.

37·12 Double Cylinder Pump

A double cylinder pump is a pump which has two cylinders in which the pistons are moving simultaneously. The motion of the two pistons is so arranged that during each stroke, there is a delivery stroke in one cylinder and suction stroke in the other at the same time as shown in Fig. 37·2. By this arrangement, we get water continuously from the delivery pipe as shown by the resultant of two sin curves at a phase difference of 180° as shown in Fig. 37·2.

37·13 Triple Cylinder Pump

A triple cylinder pump is a pump which has three cylinders in which the pistons are moving simultaneously. The motion of the three pistons is arranged at a phase difference of 120°. The velocity of water or discharge received by a triple cylinder pump is fairly uniform as shown in Fig. 37·3.

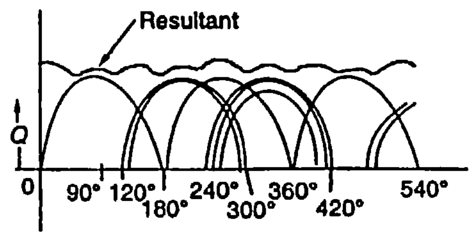

Fig. 37·3. Triple cylinder pump.

37·14 Priming of a Centrifugal Pump

We have already discussed that the pressure developed by the impeller of a centrifugal pump, is proportional to the density of the fluid in the impeller. It is thus obvious, that if impeller is running in air, it will produce only a negligible pressure, which may not suck water, from its source, through the suction pipe. To avoid this, the pump is first primed. *i.e.*, filled up with water.

For doing so, first of all the suction pipe and the impeller is completely filled with water. The delivery valve is closed and the pump is started. The rotating impeller pushes the water in the delivery pipe, opens the delivery valve and sucks water through the suction pipe.

37·15 Characteristic Curves of Centrifugal Pumps

As a matter of fact a centrifugal pump, like a turbine is designed and manufactured to work under a given set of conditions (or a limited range of conditions) such as discharge, speed, power required, head of water, efficiency etc. But a pump may have to be used under conditions, other than those for which it has been designed. It is, therefore, essential that the exact behaviour of the pump under varied conditions should be predetermined. This is represented graphically by means of curves, known as characteristic curves. Though there are many types of characteristic curves, yet the following are important from the subject point of view :

1. Characteristic curves for speed, and
2. Characteristic curves for discharge with varying speeds.

1. *Characteristic curves for speed*

Speed versus discharge

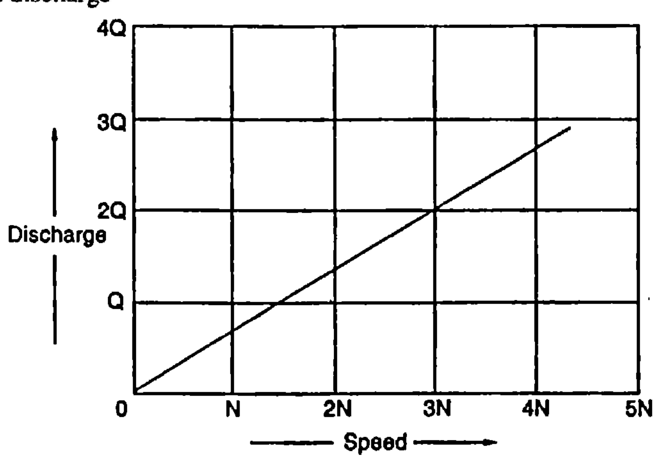

Fig. 37·4. Characteristic curve for speed *vs* discharge.

Speed versus power

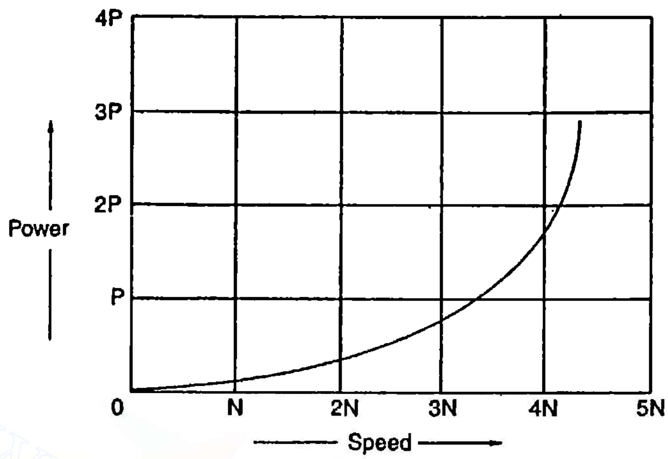

Fig. 37·5. Characteristic curve for speed *vs* power.

Fig. 37·5 shows the performance of a centrifugal pump under a constant head and discharge. It is a parabolic curve, which shows that the power increases with the speed.

Speed versus head

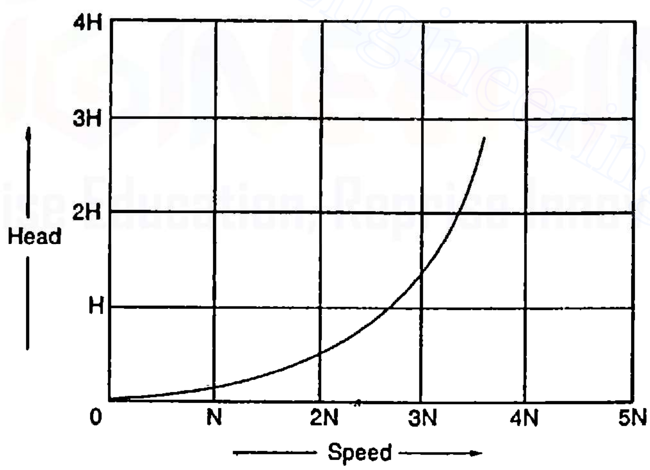

Fig. 37·6. Characteristic curves for speed *vs* head.

Fig. 37·6 shows the performance of a centrifugal pump under constant discharge. It is a parabolic, curve which shows that the head increases with the speed.

2. *Characteristic curves for discharge with varying speed*

Discharge versus head

Fig. 37·7 shows the performance of a centrifugal pump under variable rotational speeds. It is a parabolic curve, which shows that for a given rotational speed, the manometric head decreases with the discharge.

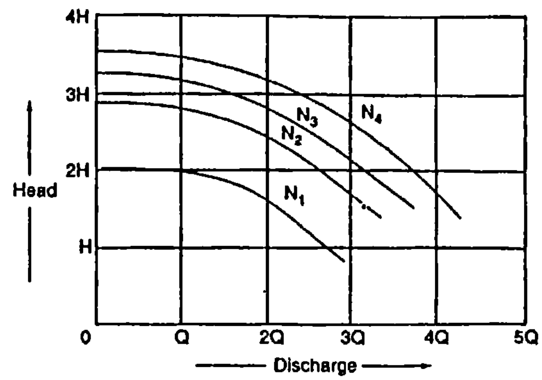

Fig. 37·7. Characteristic curves for discharge *vs* head.

Discharge versus power

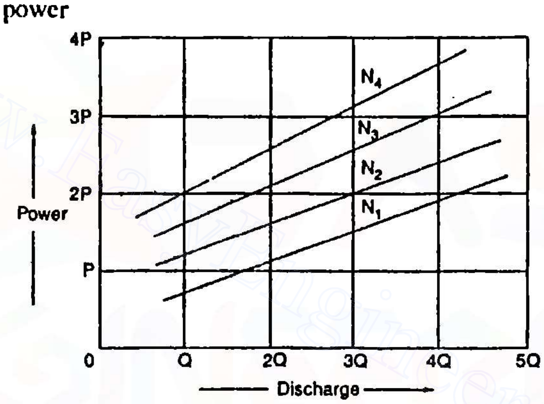

Fig. 37·8. Characteristic curves for discharge *vs* power.

Fig. 37·8 shows the performance of a centrifugal pump under variable rotational speeds. It is almost a straight curve, which shows that for a given rotational speed, the power increases with the discharge.

Discharge versus efficiency

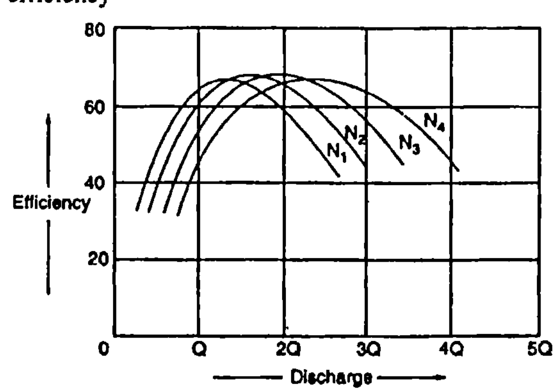

Fig. 37·9. Characteristic curves for discharge *vs* efficiency.

Fig. 37·9 shows the performance of a centrifugal pump under variable rotational speeds. It is a

EXERCISE 37·1

1. A centrifugal pump running at 900 r.p.m. delivers 50 litres of water per second against a head of 10 metres. Find the discharge and head of the pump, when the same pump is running at 1000 r.p.m.
(Ans. 55·6 litres/s; 12·3 m)
2. A centrifugal pump running at 1250 r.p.m. requires 3 kW to deliver water against a certain head of water. Find the power required to deliver the same quantity of water to the same head, while running at 1000 r.p.m. **(Ans. 1·54 kW)**
3. A centrifugal pump is discharging 500 litres of water against a head of 200 metres, while running at 900 r.p.m. What is the specific speed of the pump ? **(Ans. 67·3 r.p.m.)**
4. A three stage pump delivers 200 litres of water per second against a total head of 50 metres at 1450 r.p.m. What is the specific speed of each pump ? What type of impeller would you use ?
(Ans. 34·5 r.p.m.; Medium pump with radial flow at outlet)

QUESTIONS

1. Explain the effect of change of speed or diameter of the pump impeller on the discharge of the pump.
2. What is the specific speed of a centrifugal pump ? Describe its uses.
3. Define the terms 'Suction head', and 'Vapour pressure'. Describe their importance.
4. What do you understand by the term 'NPSH'? What important value does it give ?
5. What is priming ? Explain its necessity.
6. What is a multiple cylinder reciprocating pump ? Describe the speciality of such a pump.

OBJECTIVE TYPE QUESTIONS

1. The specific speed (N_s) of a centrifugal pump is given by
(*a*) $\frac{N\sqrt{Q}}{H^{5/4}}$ (*b*) $\frac{N\sqrt{Q}}{H}$ (*c*) $\frac{N\sqrt{Q}}{H^{3/4}}$ (*d*) $\frac{N\sqrt{Q}}{H^{2/3}}$
2. The type of centrifugal pump preferred for a specific speed of 40 r.p.m. is
(*a*) slow speed pump with radial flow at outlet
(*b*) medium speed pump with radial flow at outlet
(*c*) high speed pump with radial flow at outlet
(*d*) high speed pump with axial flow at outlet
3. If the net positive suction head (NPSH) requirement for the pump is not satisfied, then
(*a*) no flow will take place (*b*) cavitation will be formed
(*c*) efficiency will be low (*d*) all of these
4. Which of the following pump is suitable for small discharge and high heads ?
(*a*) centrifugal pump (*b*) axial pump
(*c*) mixed flow pump (*d*) reciprocating pump

ANSWERS

1. (*c*) 2. (*b*) 3. (*b*) 4. (*d*)