DEPARTMENT OF AEROSPACE ENGINEERING

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UNIT IV – PUMPS

Specific speed

It is a dimensionless coefficient that can be used to evaluate a pump's efficiency, performance curve, and other characteristics:

Efficiency

Pumps with higher specific speeds are typically more efficient. Pumps with specific speeds below 1,000 are generally less efficient.

Performance curve

The shape of a pump's performance curve is related to its specific speed:

Low specific speeds: Pumps with specific speeds between 500 and 1,500 produce flat curves.

High specific speeds: Pumps with specific speeds of 6,000 and higher produce steep curves.

Specific Speed of a centrifugal pump

It is defined as the speed of geometrically similar pump which would deliver one cubic meter of liquid per second against a unit head (one meter)

The discharge through impeller of a centrifugal pump is given by

Q = Area x velocity of flow

$= \pi DB \; x \; V_f$

Q $\propto D \; x \; B \; x \; V_f$---------------------------(i)

Q $\propto \; D^2 \; x \; V_f$ (as B $\propto D$)------------(ii)

Now tangential velocity is given by

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

u $\propto DN$-----------------------------(iii)

Also from the relation of tangential velocity (u) and flow velocity (V_f) to the manometric head (H_m),

u $\propto V_f \propto \sqrt{H_m}$------------------------(iv)

Now substituting the value of u from eqn. (iv) in equation (iii) we get

$\sqrt{H_m} \propto DN$

D $\propto \frac{\sqrt{H_m}}{N}$ --------------------------(v)

Substitute iv and v in equation (ii) we get

Q $\propto \frac{H_m}{N^2}$ x $\sqrt{H_m}$

Q = K$\frac{H_m^{3/2}}{N^2}$ -----------(vi) K= constant of proportionality

From the definition of of specific speed of if H_m= 1, Q= 1 m^3/s then N = N_s

1= K$\frac{1^{3/2}}{N_s^2}$, K = N_s^2

Substituting the value of k in equation (vi) we get

$$Q = N_s^2 \frac{H_m^{3/2}}{N^2}$$

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}$$

Minimum speed for starting of Centrifugal Pump

For minimum speed to start the pump

$$\frac{u_2^2 - u_1^2}{2g} \geq H_m \quad \text{------------------------(a)}$$

$$and \qquad \eta_{mano} = \frac{g\,H_m}{V_{w2} u_2}$$

$$H_m = \eta_{mano} \times \frac{V_{w2} u_2}{g}$$

Also $u_1 = \frac{\pi D_1 N}{60}$ and $u_2 = \frac{\pi D_2 N}{60}$

Substituting above value in equation a

$$\frac{u_2^2 - u_1^2}{2g} = \eta_{mano} \times \frac{V_{w2} u_2}{g}$$

$$u_2^2 - u_1^2 = 2\,\eta_{mano} V_{w2} u_2$$

$$\left(\frac{\pi D_2 N}{60}\right)^2 - \left(\frac{\pi D_1 N}{60}\right)^2 = 2\,\eta_{mano} V_{w2} u_2$$

$$\left(\frac{\pi N}{60}\right)^2 (D_2^2 - D_1^2) = 2\,\eta_{mano} V_{w2} u_2$$

$$\left(\frac{\pi N}{60}\right)^2 (D_2^2 - D_1^2) = 2\,\eta_{mano} V_{w2} \times \frac{\pi D_2 N}{60}$$

$$\left(\frac{\pi N}{60}\right)(D_2^2 - D_1^2) = 2\,\eta_{mano} V_{w2} D_2$$

$$N = \frac{2\,\eta_{mano} V_{w2} D2}{(D_2^2 - D_1^2)} \times \frac{60}{\pi}$$

$$N_{min} = \frac{120\,\eta_{mano} V_{w2} D_2}{\pi\,(D_2^2 - D_1^2)} \text{----------------------------(18)}$$

Performance characteristics of Centrifugal Pump

The following are the important characteristics curves of centrifugal pump.

i. Main characteristics curves

ii. Operating characteristics curves

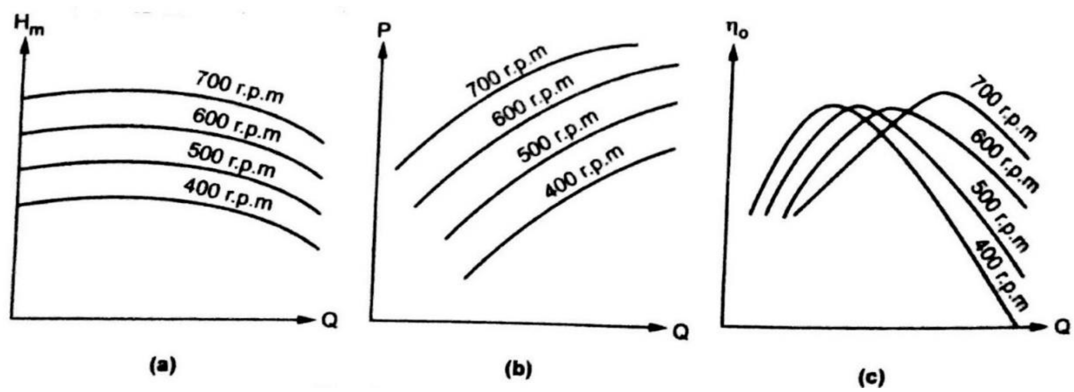
iii. Constant efficiency curves or Muschel curves

iv. Constant head and constant discharge curves.

1. Main characteristics curves

The main characteristics curves are obtained by keeping the pump at constant speed and varying the discharge over desired range.

The discharge is varied by means of deliver valve. For different values of discharge the measurements are taken or calculated for manometric head, shaft power and efficiency These curve are useful in evaluating the performance of pump at different speeds.



2. Operating characteristics curve

The maximum efficiency occurs when centrifugal pump operates at the constant designed speed.

If the speed is kept constant, the variation in manometric head power and efficiency with respect to discharge gives the operating characteristic curves for pump.

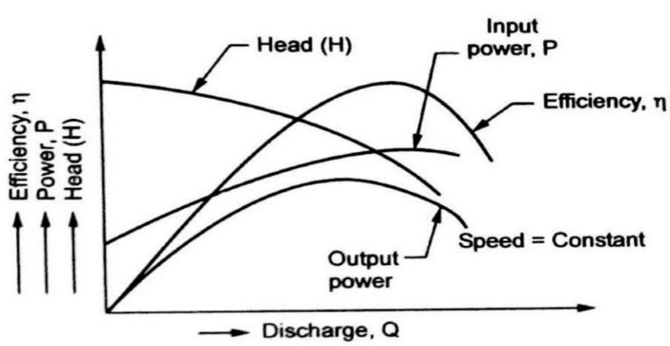


Fig. : Operating characteristics curves of a pump

3. Constant efficiency curve

   The constant efficiency or iso efficieny curve gives the performance of pump over its entire range of operations.

   With the help of data obtained in main characteristic curves the constant efficiency curves are plotted.

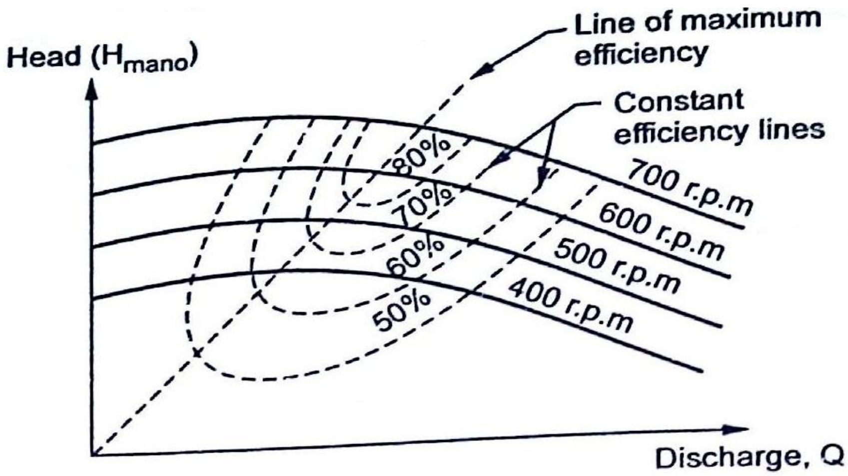


Fig. : Constant efficiency or Muschel curve

4. Constant head and constant discharge curves

   These curves are helpful in determining the performance of variable speed pump.

   These curves are plotted as follows.

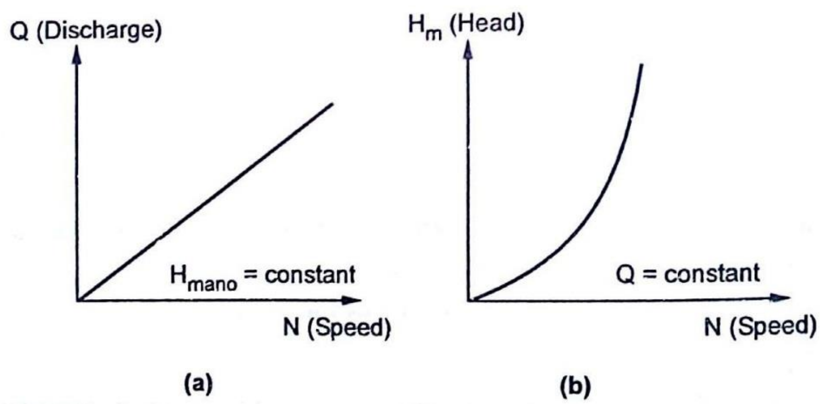


Fig. : (a) Q v/s N and (b) H_m v/s N curves of a centrifugal pump

Multistage Centrifugal Pump

A multistage centrifugal pump consist of two or more identical impellers monted on the same shaft or on different shafts.

To produce the heads higher than that of using single impeller keeping the discharge constant. This is achieved by ***Series arrangement of pumps***

To discharge the large quantity of fluid keeping the head constant. This is achieved by ***parallel arrangement of pumps.***

Series Arrangement of Pumps

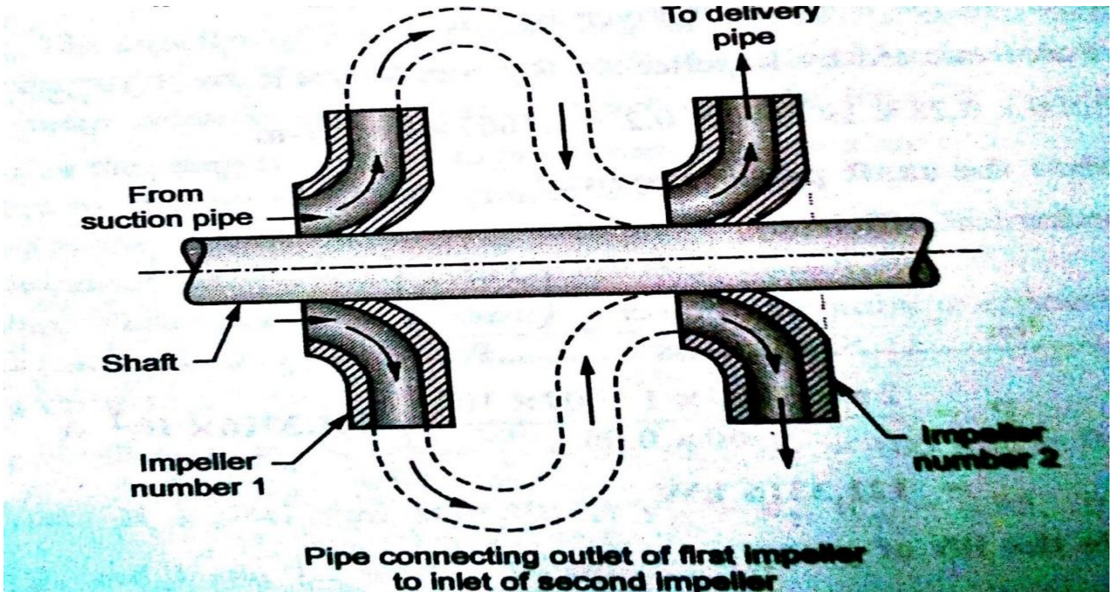


Fig. : Two-stage pumps with impellers in series

The discharge from first impeller having high pressure is fed to second impeller through guided passage.

The pressure at the outlet of second impeller will be more than the pressure at the outlet of first impeller.

If the more number of impellers are mounted on the same shaft in series arrangement then the pressure will be increases further.

For each stage, the head developed will be H_m hence for number of stages (n) total head developed will be given by

$H_{total} = n \times H_m$

Parallel Arrangement of Pumps

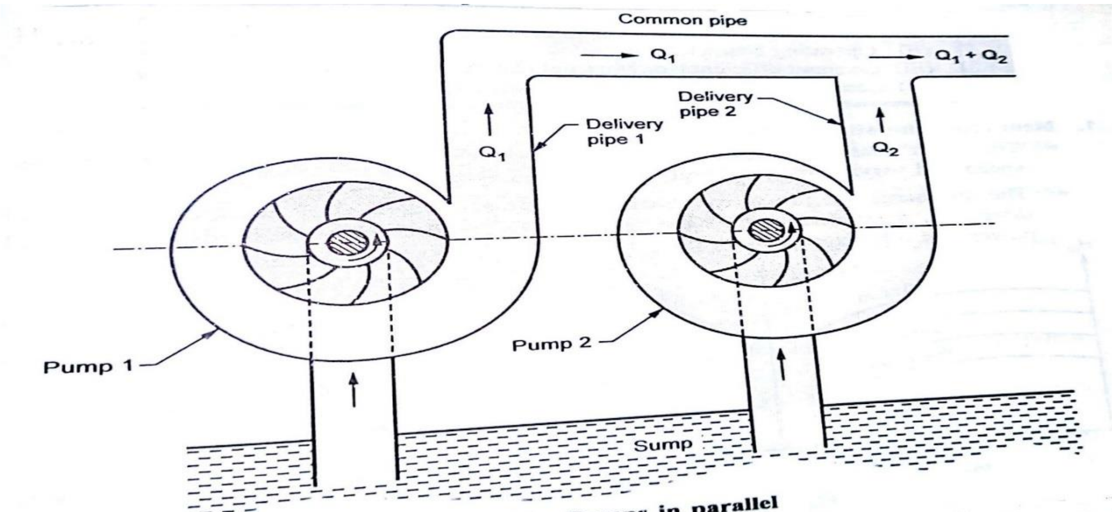


Fig. : Pumps in parallel

To obtain a high discharge at relatively small head number of impellers are mounted in parallel arrangement.

The pumps are arranged such that each of these pump is working separately to lift the liquid from common sump and deliver it to the common delivery pipe

In this arrangement the head remains constant and the discharge of each pump gets added to give large quantity of liquid at the outlet

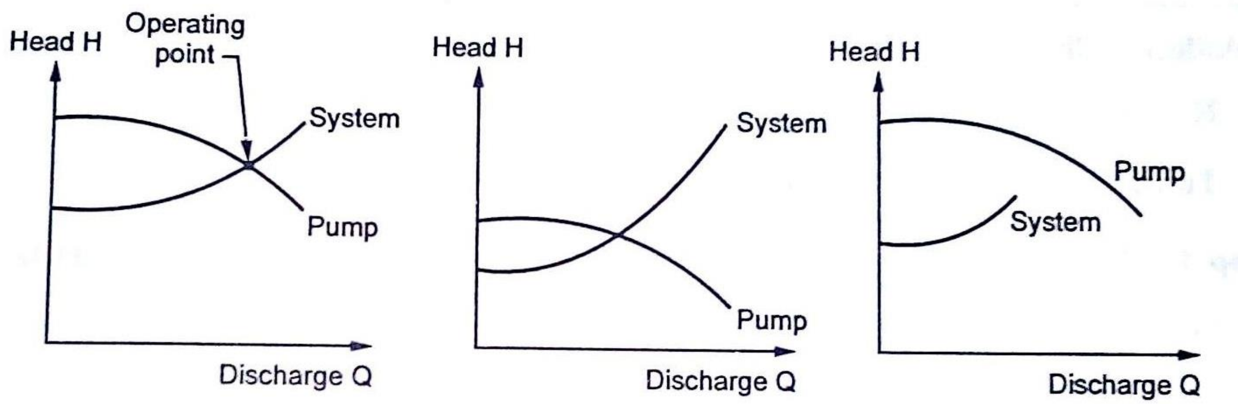
$Q_{total} = Q_1 + Q_2 + \ldots\ldots Q_n$

Selection pump based on system resistance curve

The pump manufacture always gives the head discharge characteristic curve for their manufactured pump and operated under different test conditions.

But in actual application this pump is required to operate under different conditions with respect to suction and discharge pipelines elbows and number of valves.

The user of the pump find out his system requirement and a head discharge curve is drawn. This curve is called as system resistance curve or system characteristic curve. As shown in following figure.



(a) System resistance curve **(b) Undersized pump** **(c) Oversized pump**

Now the pump characteristics curve (supplied by manufacture) are superimposed on system characteristic curve.as shown in above figure.

The point of intersection represent the operating point of pump .

If the pump can not meet the head and discharge requirements of the pump the it is called as undersized or under capacity pump. (refer fig (b))

If the pump delivers much higher head and discharge than the requirements the it is called ad oversized pump.(refer fig. c)

Selection of Pumps:

Selection of pump is based on the specific speed for the pump.

The specific speed is calculated from the values of discharge (Q) head (H) and speed (N)

For low heads of about 6 m and large discharge, axial flow pumps are used.

For high heads, radial flow pumps are used.

If it is possible to increase the speed for low specific pump, multistage pump are suitable.

Depending upon type of impeller, the pump is selected for particular operation as follows

i) Shrouded type impeller are used for pumping fresh and clean water.

ii) Unshrouded or propeller type impeller is used for pumping solid-liquid mixture.

iii) Mixed flow impellers with diffusers vanes are used for deep well or submersible pumps.