UNIT-IV PUMPS

PART – A

1. What is meant by Pump?

A pump is device which converts mechanical energy into hydraulic energy.

2. Define a centrifugal pump

If the mechanical energy is converted into pressure energy by means of centrifugal force cutting on the fluid, the hydraulic machine is called centrifugal pump.

3. Define suction head (hs).

Suction head is the vertical height of the centre lines of the centrifugal pump above the water surface in the tank or pump from which water is to be lifted. This height is also called suction lift and is denoted by hs.

4. Define delivery head (hd).

The vertical distance between the center line of the pump and the water surface in the tank to which water is delivered is known as delivery head. This is denoted by hd.

5. Define static head (Hs).

The sum of suction head and delivery head is known as static head. This is represented by 'Hs' and is written as,

$$Hs = hs + hd$$

6. Mention main components of Centrifugal pump.

i) Impeller ii) Casing

iii) Suction pipe,strainer & Foot valve iv) Delivery pipe & Delivery valve

7. What is meant by Priming?

The delivery valve is closed and the suction pipe, casing and portion of the delivery pipe upto delivery valve are completely filled with the liquid so that no air pocket is left. This is called as priming.

8. Define Manometric head.

It is the head against which a centrifugal pump work.

9. Describe multistage pump with

a. impellers in parallel b. impellers in series. In multi stage centrifugal pump,

a. when the impellers are connected in series (or on the same shaft) high head can be developed.

b. When the impellers are in parallel (or pumps) large quantity of liquid can be discharged.

10.. Define specific speed of a centrifugal pump (Ns).

The specific speed of a centrifugal pump is defined as the speed of a geometrically circular pump which would deliver one cubic meter of liquid per second against a head of one meter. It is denoted by 'Ns'.

11. What do you understand by characteristic curves of the pump?

Characteristic curves of centrifugal pumps are defined those curves which are plotted from the results of a number of tests on the centrifugal pump.

12. Why are centrifugal pumps used sometimes in series and sometimes in parallel?

The centrifugal pumps used sometimes in series because for high heads and in parallel for high discharge

13.Define Mechanical efficiency.

I

t is defined as the ratio of the power actually delivered by the impeller to the power supplied to the shaft.

14. Define overall efficiency.

It is the ratio of power output of the pump to the power input to the pump.

15. Define speed ratio, flow ratio.

Speed ratio: It is the ratio of peripheral speed at outlet to the theoretical velocity of jet corresponding to manometric head.

Flow ratio: It is the ratio of the velocity of flow at exit to the theoretical velocity of jet corresponding to manometric head.

16.. Mention main components of Reciprocating pump.

Piton or Plunger
Suction and delivery pipe
Crank and Connecting rod

17. Define Slip of reciprocating pump. When the negative slip does occur?

The difference between the theoretical discharge and actual discharge is called slip of the pump.

But in sometimes actual discharge may be higher then theoretical discharge, in such a case coefficient of discharge is greater then unity and the slip will be negative called as negative slip.

18. What is indicator diagram?

Indicator diagram is nothing but a graph plotted between the pressure head in the cylinder and the distance traveled by the piston from inner dead center for one complete revolution of the crank

19. What is meant by Cavitations?

It is defined phenomenon of formation of vapor bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure and the sudden collapsing of theses vapor bubbles in a region of high pressure.

20. What are rotary pumps?

Rotary pumps resemble like a centrifugal pumps in appearance. But the working method differs. Uniform discharge and positive displacement can be obtained by using these rotary pumps, It has the combined advantages of both centrifugal and reciprocating pumps.

UNIT – IV
PUMPS
PART-B

(1) The internal and external diameters of the impeller of a centrifugal pump are 200mm and 400mm respectively. The pump is running at 1200rpm. The vane angles of the impeller at inlet and outlet are 20° and 30° respectively. The water enters the impeller radially and velocity of flow is constant. Determine the work done by the impeller per unit weight of water. [AU-A/M-13]

Sol

Internal diameter of impeller, $D_1 = 200mm = 0.20m$

External diamer of impeller $D_2 = 400mm = 0.40m$

speed $N = 1200rpm.$

Vane angle at inlet $\theta = 20°$

Vane angle at outlet, $\phi = 30°$

water enters radially* means $\alpha = 90°$ and $V_{w1} = 0$

velocity of flow $V_{f1} = V_{f2}$

$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.20 \times 1200}{60} = 12.56\ m/s$

$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.4 \times 1200}{60} = 25.13\ m/s$

∴ From inlet velocity traingle, $\tan\theta = \frac{V_{f1}}{u_1} = \frac{V_{f1}}{12.50}$

$V_{f1} = 12.56 \tan\theta = 12.56 \times \tan 20^\circ = 4.57\ m/s$

$V_{f2} = V_{f1} = 4.57\ m/s$

From Outlet velocity traingle, $\tan\theta = \frac{V_{f2}}{u_2 - V_{w2}}$

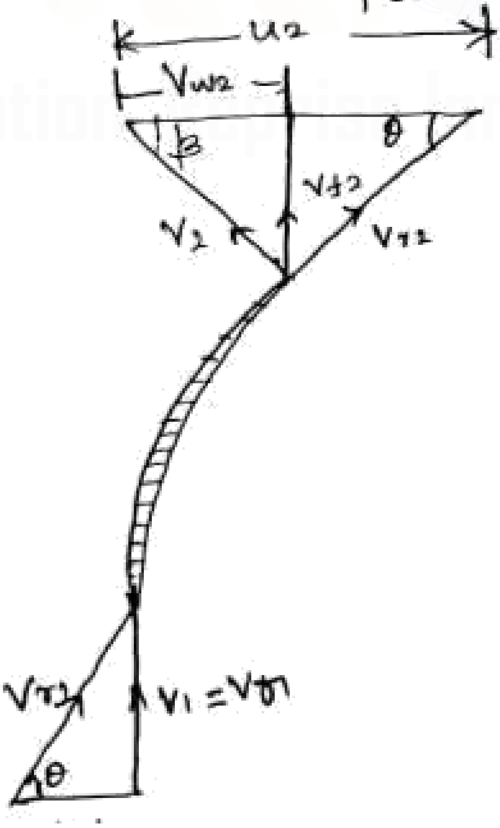
$= 4.57 / 25.13 - V_{w2}$

$25.13 - V_{w2} = \frac{4.57}{\tan\theta} = \frac{4.57}{\tan 30^\circ} = 7.915$

$V_{w2} = 25.13 - 7.915 = 17.215\ m/s$

The work done by impeller/kg of water per second is given by equation as

$= \frac{1}{g} V_{w2} U_2 = \frac{17.215 \times 25.13}{9.81} = 44.1\ Nm/N.$



2) A centrifugal pump having outer diameter equal to two times the inner diameter and running at 1000 r.p.m works against a total head of 40m. The velocity of flow through the impeller is ... of the impeller is 500mm and width at outlet is 50mm, determine:

(i) Vane angle at inlet (ii) work done by impeller on water per second.

iii) Manometric efficiency [A/M-13]

Sol

speed $N = 1000$ rpm

Head $H_m = 40$ m

Velocity of flow, $V_{f1} = V_{f2} = 2.5$ m/s

Vane angle at outlet $= \phi = 40^\circ$

Outer dia of impeller, $D_2 = 500$ mm $= 0.50$ m

Inner dia of impeller, $D_1 = \frac{D_2}{2} = \frac{0.50}{2} = 0.25$ m

width at outlet, $B_2 = 50$ mm $= 0.05$ m

Tangential velocity of impeller at inlet and outlet are

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.25 \times 1000}{60} = 13.09 \text{ m/s}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.50 \times 1000}{60} = 26.18 \text{ m/s}$$

Discharge is given by $Q = \pi D_2 B_2 \times V_{f2}$

$$= \pi \times 0.50 \times .05 \times 2.5$$

$$= 0.1963 \text{ m}^3/\text{s}$$

(i) Vane angle at inlet (θ)

From inlet velocity triangle $\tan\theta = \frac{V_{f1}}{u_1} = \frac{2.5}{13.09}$

$= 0.191$

$\theta = \tan^{-1} 0.191 = 10.81°$ (or) $10°48'$

ii) Work done by impeller on water/second

$= W/g \times V_{w2} u_2 = \frac{\rho \times g \times Q}{g} \times V_{w2} \times u_2$

$= \frac{1000 \times 9.81 \times 0.1963}{9.81} \times V_{w2} \times 26.18$

But from outlet velocity triangle, we have

$\tan\theta = \frac{V_{f2}}{u_2 - V_{w2}} = 2.5/(26.18 - V_{w2})$

$26.18 - V_{w2} = 2.5/\tan\theta = \frac{2.5}{\tan 40°} = 2.979$

$V_{w2} = 26.18 - 2.972 = 23.2$ m/s

∴ Substituting this value of V_{w2} in equation (1) we get the work done by impeller as

$= \frac{1000 \times 9.81 \times 0.1963}{9.81} \times 23.2 \times 26.18 = 119227.9 \text{ Nm/s}$

iii) Manometric efficiency (η_{man})

$\eta_{man} = \frac{g H_m}{V_{w2} u_2} = \frac{9.81 \times 40}{23.2 \times 26.18} = 0.646$

$= 64.4\%$

(3) Find the power required to drive a centrifugal pump which delivers 0.04 m³/s of water to a height of 20 m through a 15 cm diameter pipe and 100 m long. The overall efficiency of the pump is 70% and co-efficient of friction 'f' = 0.15 in the formula

$h_f = \frac{4 f l v^2}{2 g d}$

4) A centrifugal pump with 1.2 m diameter runs at 200 r.p.m and pumps 1880 litres/s. the average lift being 6 m. the angle which the vanes make at exit with the tangent to the impeller is 26° and the radial velocity of flow is 2.5 m/s. Determine the manometric efficiency and the least speed to start pumping against a head of 6 m, the inner diameter of the impeller being 0.6 m. N/D-15

Sol

$D_2 = 1.2\ m$

$N = 200\ r.p.m$

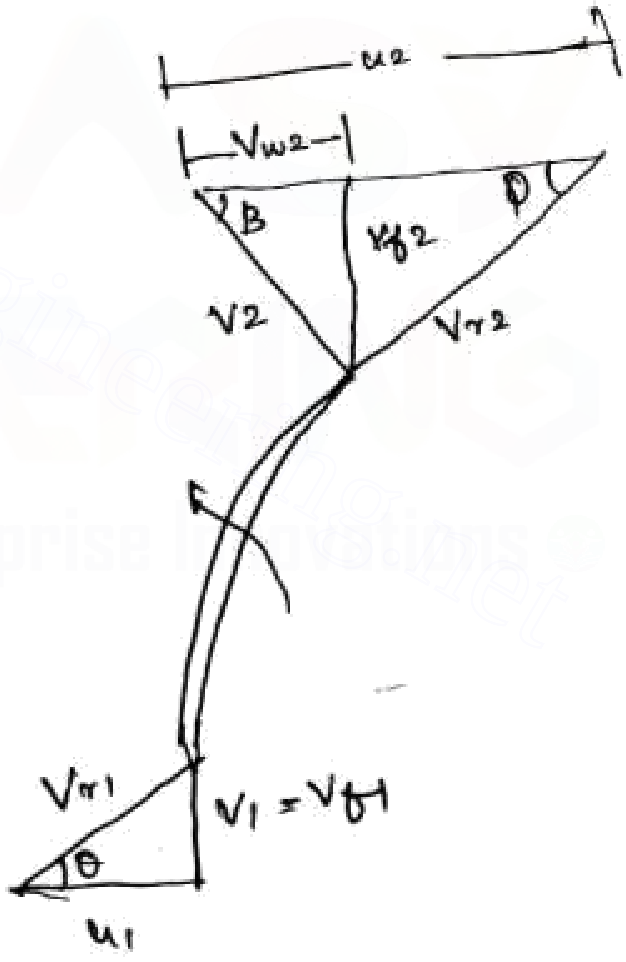
$Q = 1880\ L/s = 1.88\ m^3/s$

$H_m = 6\ m$

$\phi = 26°$

$V_{f2} = 2.5\ m/s$

$D_1 = 0.6\ m$



(i) Manometric efficiency (η_{man})

$$\eta_{man} = \frac{gH_m}{V_{w2} \times u_2} \quad \text{—(i)}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 1.2 \times 200}{60} = 12.56 \text{ m/s}$$

$$\tan\phi = \frac{V_{f2}}{u_2 - V_{w2}} \text{ or } u_2 - V_{w2} = \frac{V_{f2}}{\tan\phi} = \frac{2.5}{\tan 26^\circ} = 5.13$$

$$V_{w2} = u_2 - 5.13 = 12.56 - 5.13 = 7.43 \text{ m/s}$$

Substituting these values in equation (i) we get

$$\eta_{man} = \frac{9.81 \times 6.0}{7.43 \times 12.56} = 0.63 = 63\%.$$

(ii) Least speed to start the pump

Least speed to the pump is given by equation

$$\frac{u_2^2}{2g} - \frac{u_1^2}{2g} = H_m$$

where u_2 and u_1 are the tangential velocities of the vane at outlet and inlet respectively, corresponding to least speed of the pump.

But

$$u_2 = \omega \times r_2 \text{ and } u_1 = \omega \times r_1$$

Substituting these values in equation (ii) we get

$$\frac{(\omega \times r_2)^2}{2g} - \frac{(\omega \times r_1)^2}{2g} = H_m = 6.0 \text{ (or) } \frac{\omega^2}{2g}(r_2^2 - r_1^2) = 6.0$$

(or)

$$\frac{\omega^2}{2 \times 9.81}\left[0.6^2 - 0.3^2\right] = 6 \quad \left[\because r_2 = \frac{D_2}{2} = \frac{1.2}{2} = 0.6 \text{ m and } r_1 = \frac{D_1}{2} = \frac{0.6}{2} = 0.3 \text{ m}\right]$$

$$\omega^2 = \frac{6.0 \times 20.0 \times 9.81}{0.36 \cdot - 09} = 436 \therefore \omega = \sqrt{436} = 20.88 = \frac{2\pi N}{60}$$

$$\omega^2 = \frac{H_m \times N \times g}{}$$

$$N = \frac{60 \times 20.88}{2 \times \pi} = 200 \text{ r.p.m}$$

5) Explain in Details about the Multistage Centrifugal pumps and types?

If a centrifugal pump consists of two (or) more impellers, the pump is called a multistage centrifugal pump. The impellers may be mounted on the same shaft or on different shaft.

function of Multistage pump

1* To produce a high head

2* To discharge a large quantity of liquid.

6) A three stage centrifugal pump has impellers 40cm in diameter and 2cm wide at outlet. The vanes are curved back at the outlet at 45° and reduce the circumferential area by 10%. The manometric efficiency is 90% and the overall efficiency is 80%. Determine the head generated by the pump when running at 1000 r.p.m delivering 50 Litres/second. What should be the shaft horse power

Sol

$n = 3$

$D_2 = 40\text{cm} = 0.40\text{ m}$

$B_2 = 2\text{cm} = 0.02\text{ m}$

vane angle $\phi = 45°$

Reduction in area at outlet $= 10\% = 0.1$

∴ Area of flow at outlet $= 0.9 \times \pi \times .4 \times .02$

$= 0.9 \times \pi \times .4 \times .02$

$= 0.02262\ m^2$

Manometric efficiency, $\eta_{man} = 90\% = 0.90$

Overall efficiency, $\eta_o = 80\% = 0.80$

Speed, $N = 1000$ r.p.m

$Q = 50$ Lt/s $= 0.05\ m^3/s$

Determine

(i) Head generated by the pump

ii) Shaft power.

Velocity of flow at outlet, $V_{f2} = \frac{Q}{A} = \frac{0.05}{0.2262} = 2.21\ \frac{m}{s}$

Tangential velocity of impeller at outlet

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.4 \times 1000}{60} = 20.94\ \frac{m}{s}$$

From velocity ~~triangle~~ at outlet,

$$\tan\phi = \frac{V_{f2}}{u_2 - V_{w2}}$$

$$u_2 - V_{w2} = \frac{V_{f2}}{\tan\phi} = \frac{2.21}{\tan 45^\circ} = 2.21\ m/s$$

$V_{w2} = u_2 - 2.21 = 20.94 - 2.21 = 18.73$ m/s

using equation $\eta_{man} = \frac{g H_m}{V_{w2} u_2}$, $0.90 = \frac{9.81 \times H_m}{18.73 \times 20.94}$

$$H_m = \frac{0.90 \times 18.73 \times 20.94}{9.81} = 35.98\ m$$

Total head generated by pump

$= n \times H_m = 3 \times 35.98 = 107.94$ m

Power output of the pump $= \frac{\text{weight of water lifted} \times \text{Total head}}{1000}$

$$= \frac{\rho g \times Q \times 107.94}{1000}$$

$= \frac{1000 \cdot \ldots}{1000}$

$$\eta_o = \frac{\text{power output of pump}}{\text{power input to the pump}} = \frac{52.94}{S.P}$$

$$\text{Shaft power} = \frac{52.94}{\eta_o} = \frac{52.94}{0.80} = 66.175 \text{ kW.}$$

7) Explain and details of the cavitation? cavitation (982) pg

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure and the sudden collapsing of these vapour bubbles in a region of higher pressure. When the vapour bubbles collapse, a very high pressure is created. The metallic surfaces, above which these vapour bubbles collapse is subjected to these high pressures, which cause pitting action on the surface. Thus cavities are formed on the metallic surface and also considerable noise and vibrations are produced.

Thoma's cavitation factor

$$\sigma = \frac{(H_b) - H_s - h_{LS}}{H} = \frac{(H_{atm} - H_v) - H_s - h_{LS}}{H}$$

Specific speed

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}, \text{ where } H_m = \text{Manometric head}$$

a) $N_s = \left[\frac{N\sqrt{Q}}{H_m^{3/4}}\right]_{model} = \left[\frac{N\sqrt{Q}}{H_m^{3/4}}\right]_{prototype}$

b) $\left[\frac{\sqrt{H_m}}{DN}\right]_{model} = \left[\frac{\sqrt{H_m}}{DN}\right]_{prototype}$

c) $\left[\frac{Q}{D^3 N}\right]_{model} = \left[\frac{Q}{D^3 N}\right]_{prototype}$

d) $\left(\frac{P}{D^5 N^3}\right)_{model} = \left(\frac{P}{D^5 N^3}\right)_{prototype}$

2) A one fifth scale model of a pump was tested in a laboratory at 1000 r.p.m. the head developed and the Power input at the best efficiency point were found to be 8 m and 30 kW respectively. If the prototype pump has to work against a head of 25 m, determine its working speed, the power required to drive it and the ratio of the flow rates handled by the two pumps. [A-M-16]

Sol

Given:,

One-fifth scale model means that the ratio of linear dimensions of a model and it's prototype is equal to 1/5.

Speed of model, $N_m = 1000$ rpm

Head of model $H_m = 8$ m

Power of model $P_m = 30$ kW

Head of prototype $H_p = 25$ m

let N_p = Speed of prototype

P_p = Power of prototype

Q_p = Flow rate of prototype

Q_m = Flow rate of model

(i) Speed of prototype

$$\left[\frac{\sqrt{H}}{DN}\right]_m = \left[\frac{\sqrt{H}}{DN}\right]_P \quad (\text{or}) \quad \frac{\sqrt{H_m}}{D_m N_m} = \frac{\sqrt{H_p}}{D_p N_p}$$

$$N_p = \frac{\sqrt{H_p}}{\sqrt{H_m}} \times \frac{D_m}{D_p} \times N_m$$

$$= \sqrt{25}/\sqrt{8} \times \frac{1}{5} \times 1000$$

$$= 353.5 \text{ rpm}$$

ii) Power developed by prototype

$$\left[\frac{P}{D^5N^3}\right]_m = \left[\frac{P}{D^5N^3}\right]_p \text{ (or) } \left[\frac{P_m}{D_m^5 N_m^3}\right] = \frac{P_p}{D_p^5 N_p^3}$$

$$P_p = P_m \times \left[\frac{D_p}{D_m}\right]^5 \times \left(\frac{N_p}{N_m}\right]^3 = 30 \times 5^5 \times \left[\frac{353.5}{1000}\right]^3$$

$$= 30 \times 3125 \times 0.04419 \qquad \left[\because \frac{D_p}{D_m} = \frac{5}{1}\right]$$

$$= 4143 \text{ kW}.$$

iii) Ratio of the flow rates of two pumps

$$\left[\frac{Q}{D^3N}\right]_m = \left[\frac{Q}{D^3N}\right]_p \text{ (or) } \frac{Q_m}{D_m^3 N_m} = \frac{Q_p}{D_p^3 N_p^3}$$

~~$P_p = P_m \times \left(\frac{D_p}{D_m}\right]^5 \times \left[\frac{N_p}{N_m}\right]^3 = 30 \times 5^5 \times \left(\frac{353.5}{1000}\right)^3$~~

$$\frac{Q_p}{Q_m} = \frac{D_p^3 N_p}{D_m^3 N_m} = \left(\frac{D_p}{D_m}\right)^3 \times \frac{N_p}{N_m} = 5^3 \times \frac{353.5}{1000} \quad \because \left(\frac{D_p}{D_m} = \frac{5}{1}\right)$$

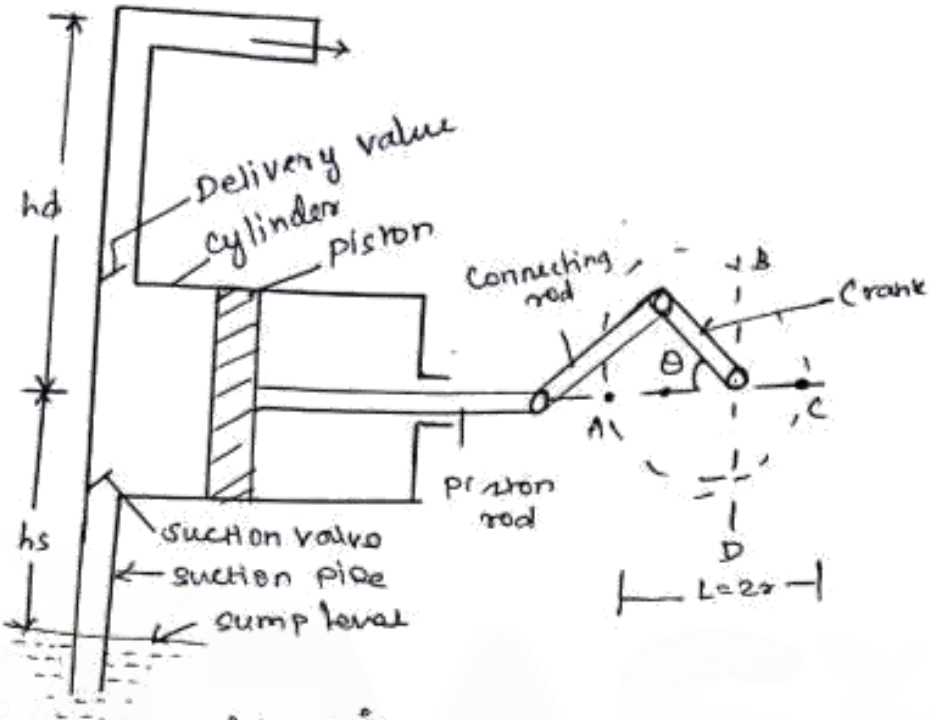
$$= 44.1875 \text{ // Ans}$$

Explain briefly about the Reciprocating pumps?

9) **Reciprocating pumps.**

The Mechanical Energy is converted into hydraulic energy (or pressure energy) by sucking the liquid into a cylinder in which a piston in reciprocating (moving backwards and forw which exerts the thrust on the liquid and increas its hydraulic energy (pressure energy) the pump known as reciprocating pump.

MAIN PARTS OF A Reciprocating pump.



θ=0° to θ=180° θ=180° to 360°

Discharge through a Reciprocating pump

$$Q = A \times L \times N/60 = \frac{ALN}{60}$$

$A = \frac{\pi}{4} \times d^2$

$L = 2r$

$N =$ r.p.m of crank

$h_s =$ suction

$h_d =$ delivery head

Weight of water delivered per second,

$$W = \rho \times g \times Q = \frac{\rho g ALN}{60}$$

Work done by Reciprocating pump

work done per second = Weight of water lifted per second × Total height through which water is lifted

$= W \times (h_s + h_d)$

Where $(h_s + h_d)$ = Total height through which water is lifted

$$W = \rho g \times ALN/60$$

Work done per second $= \frac{\rho g \times ALN}{60} \times (h_s + h_d)$

$\therefore$ Power required to drive the pump, in kw

$$P = \frac{\text{Work done per second}}{1000} = \frac{\rho g \times ALN \times (h_s+h_d)}{60 \times 1000}$$

$$= \boxed{\frac{\rho g \times ALN \times (h_s+h_d)}{60000} \text{ kw}}$$

Work done by double-acting reciprocating pump

$$\left(\frac{2\rho g \times ALN \times (h_s+h_d)}{60,000}\right) \text{kw}$$

Slip of Reciprocating pump

* Slip of a pump is defined as the difference b/w the theoretical discharge and actual discharge of the pump.

Negative slip of the Reciprocating pump.

If actual discharge is more than the theoretical discharge the slip of the pump will bec[ome] Negative sl[ip]

* delivery pipe short
* suction pipe is long

Classification of Reciprocating pumps

* Number of cylinders — single, Double, triple
* piston contact with water → single, Double
*

10) A single-acting reciprocating pump, running at 50 r.p.m delivers 0.01 m^3/s of water. The diameter of the Piston is 200mm and stroke length 400mm. Determine
(i) the theoretical discharge of the pump
ii) co-efficient of discharge & iii) slip and the percentage slip of the pump. [N/D-15]

SOL

speed of the pump $N = 50$ rpm

Actual discharge $Q_{act} = .01\ m^3/s$

$D = 200mm = .20m$

Area $A = \frac{\pi}{4} \times (.2)^2 = .0314\ m^2$

$L = 400mm = 0.40m$

Stroke,

(i) Theoretical discharge for single acting reciprocating pump is given by equation

(i) $Q_{th} = \frac{A \times L \times N}{60} = \frac{.0314 \times .40 \times 50}{60} = 0.01047\ \frac{m^3}{s}$

ii) co-efficient of discharge is given by

$$cd = \frac{Q_{act}}{Q_{th}} = \frac{0.01}{.01047} = 0.955$$

iii) Using equation (20.8)

$$Slip = Q_{th} - Q_{act} = .01047 - .01 = 0.00047\ \frac{m^3}{s}$$

And percentage slip $= \frac{(Q_{th} - Q_{act})}{Q_{th}} \times 100$

$$= \frac{(.01047 - .01)}{.01047} \times 100$$

$$= \frac{.00047}{.01047} \times 100 = 4.489\%$$

11) A double-acting reciprocating pump, running at 40 r.p.m is discharging 1.0 m³ of water per minute. the pump has a stroke of 400mm. the diameter of the piston is 200 mm. the delivery and suction head are 20m and 5m respectively. Find the slip of the pump and power required to drive the pump.

Sol Given

speed of pump, $N = 40 \text{ r.p.m}$

$Q_{act} = 1.0\ m^3/min = \frac{1.0}{60}\ \frac{m^3}{s} = 0.01666\ \frac{m^3}{s}$

Stroke $= L = 400mm = 0.40m$

Diameter of piston $= D = 200mm = 0.20m$

Area $= A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(.2)^2 = 0.031416\ m^2$

suction head $h_s = 5m$

Delivery head $h_d = 20m$

Theoretical discharge for double-acting pump is given by equation

$$Q_{th} = \frac{2ALN}{60} = \frac{2 \times .031416 \times 0.4 \times 40}{60} = .01675\ \frac{m^3}{s}$$

$$\text{slip} = Q_{th} - Q_{act} = .01675 - .01666 = .00009\ \frac{m^3}{s}$$

$$P = \frac{2 \times \rho g \times ALN \times (h_s + h_d)}{6000}$$

$$= \frac{2 \times 1000 \times 9.81 \times .031416 \times .4 \times 40 \times (5+20)}{60,000}$$

$$= 4.109\ kW$$

PUMPS - IV

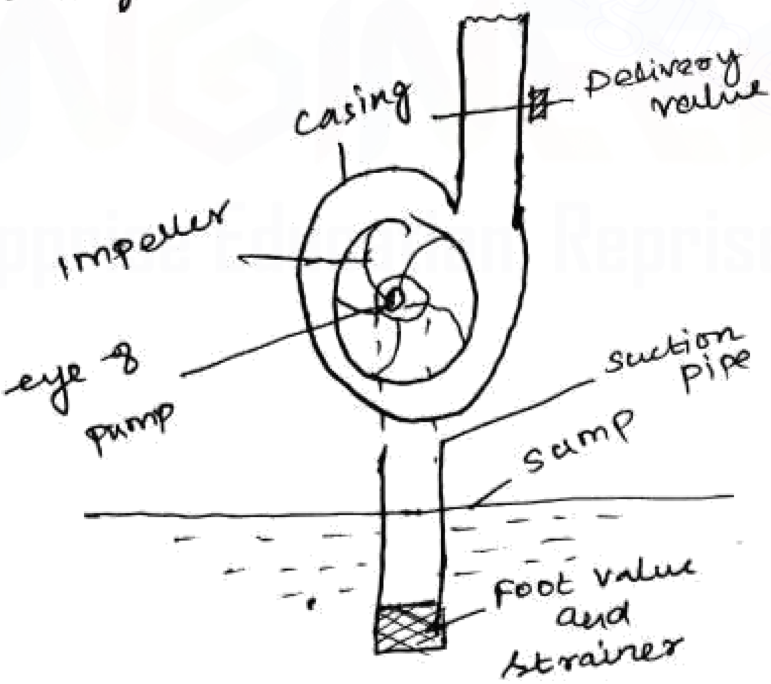
12) Explain & Draw a neat sketch of the centrifugal pum

The hydraulic machines which covert the Mechanical Energy into hydraulic energy are called Pumps. [A/M-14)

The hydraulic energy is in the form of Pressure energy. If the mechanical energy is converted into pressure energy by means of Centrifugal force acting on the fluid, the hydraul mechine is called centrifugal pump

Main parts of a centrifugal pump

1. Impeller
2. Casing
3. Suction pipe with a foot valve and strainer.
4. Delivery pipe.



Uniform flow
varied flow
Rapidly varied fl
pumps
turbine

Definations of Heads and Efficiences of a centrifugal pump

1. Suction head (h_s) → Vt. centrifugal pump & water surface
2. Delivery Head (h_d) → Vt b/w pump and the water surface
3. Static head (H_s) → Σ sh and D head
4. Manametric Head (H_m)

$H_m = h_s + h_d + h_{fs} + h_{fd} + v_d^2/2g$

h_s → suction head, h_d → Delivery head

h_{fs} → Friction head loss in suction pipe, h_{fd} → Friction headloss in delivery pipe

v_d → Velocity of water in delivery pipe.

5. Efficiencies of a centrifugal pump.

In case of a centrifugal pump. the power is transmitted impeller, the power is given to the water. Thus power is decreasing from the shaft of the pump to the impeller and then to the water. the following are the important efficiencies of a centrifugal pump :-

(a) Manometric efficiency, η_{man}
b) Mechanical efficiency η_m
c) Overall efficiency, η_o

a) $\eta_{man} = \dfrac{\text{Manometric head}}{\text{Head imparted by impeller to water}}$

$= \dfrac{g \times H_m}{V_{w2} \times u_2}$

b) Mechanical Efficiency (η_m)

$\eta_m = \dfrac{\text{Power at the impeller}}{\text{Power at the shaft}}$

$K_w = \dfrac{\text{Work done by impeller per second}}{1000}$

$\eta_m = \dfrac{W/g \left(\dfrac{V_{w2} \times u_2}{1000}\right)}{}$ SP → Shaft power

1) A cylinder bore diameter of a single-acting reciprocating pump is 150mm and its stroke is 300mm. The pump runs at 50 r.p.m and lifts water through a height of 25m. The delivery pipe is 22m long and 100mm in diameter. Find the theoretical discharge and the theoretical power required to run the pump. If the actual discharge is 4.2 lit/s find the percentage slip. Also determine the acceleration head at the beginning and middle of the delivery stroke.

Sol

$D = 150mm = 0.15m$

$A = \frac{\pi}{4} \times 0.15^2 = 0.01767 m^2$

$L = 300mm = 0.3m$

$N = 50 r.p.m$

$H = 25m$, $l_d = 22m$, $L_d = 22m$, $d_d = 100mm = 0.1m$

Actual discharge, $Q_{act} = 4.2 lit/s = \frac{4.2}{1000} \frac{m^3}{s} = 0.0042 \frac{m^3}{s}$

(i) theoretical discharge (Q_{th})

$$Q_{th} = \frac{A \times L \times N}{60} = \frac{0.01767 \times 0.3 \times 50}{60} = 0.00442 \frac{m^3}{s}$$

$= 0.00442 \times 1000$ lit/s $= 4.417$ lit/s

ii) theoretical power (P_t)

$$P_t = \frac{(\text{Theoretical weight of water lift}) / \text{Total height}}{1000}$$

$$= \frac{\rho \times g \times Q_{th} \times H}{1000}$$

$$= \frac{1000 \times 9.81 \times 0.00441 \times 25}{1000} \quad (Q_{th} = 0.00442 m^3/s)$$

$= 1.083$ kW

iii) The percentage slip

$$\% \text{ slip} = \left(\frac{Q_{th} - Q_{act}}{Q_{th}}\right) \times 100$$

$$= \left(\frac{4.41 - 4.2}{4.41}\right) \times 100 = 4.92\%$$

iv) Acceleration

$$h_{ad} = \frac{L_d}{g} \times \frac{A}{a_d} \omega^2 r \times \cos\theta$$

a_d = Area of delivery pipe $= \frac{\pi}{4} \times (0.1)^2 = 0.007854$

ω = Angular speed $= \frac{2\pi N}{60} = \frac{2\pi \times 50}{60}$

$= 5.236$

r = Crank radius $= L/2 = \frac{0.3}{2} = 0.15$

$$h_{ad} = \frac{22}{9.81} \times \frac{0.0176}{0.0078} \times 5.236^2 \times 0.15 \times \cos\theta$$

$= 20.75 \times \cos\theta$

At the beginning of delivery stroke $\theta = 0°$ & $\cos\theta = 1$

$h_{ad} = 20.75$ m

v) Acceleration head at the middle of delivery stroke

$\theta = 90°$ & $\cos\theta = 0$

$$h_{ad} = 20.75 \times 0 = 0.$$

15) Calculate the rate of flow in and out of the air vessel on the delivery side in a single acting reciprocating pump of 220 mm bore and 330 mm stroke running at 50 r.p.m. Also find the angle of crank rotation at which there is no flow into or out of the air vessel.

Acceleration head had

$$h_{ad} = \frac{l_d}{g}\frac{A}{a_d}\omega^2 r$$

Absolute pressure head $= H_{atm} + (h_d + h_{ad})$

Given data

$D = 220mm = 0.22\,m$

$L = 330mm = 0.33\,m$

$r = L/2 = \frac{0.33}{2} = 0.165\,m$

$N = 50$ r.p.m

Sol

Area of the plunger $A = \frac{\pi}{4}D^2 = \frac{\pi}{4} \times 0.22^2 = 0.038\,m^2$

Angular speed $\omega = \frac{2\pi N}{60} = \frac{2\pi \times 50}{60} = 5.24$ rad/s

Assume $\theta = 30^\circ$

$Q = A\omega r\,(\sin\theta - 2/\pi)$

$= 0.038 \times 5.24 \times 0.165\,(\sin 30^\circ - 2/\pi)$

$= -4.49 \times 10^{-3}\,m^3/s = -4.49$ l/s quantity of water flown from the air vessel

Assume $\theta = 120^\circ$

$Q = A\omega r\,(\sin\theta - 2/\pi) = 0.038 \times 5.24 \times 0.165\,(\sin 120^\circ - 2/\pi)$

$= 7.54 \times 10^{-3}\,m^3/s = 7.54$ l/s quantity of water flows into the air vessel.

At zero flow $Q = 0$

$\therefore Q = A\omega r\,(\sin\theta - 2/\pi)$

$0 = 0.0177 \times 12.57 \times 0.15\,(\sin\theta - 2/\pi)$

$\boxed{\theta = 39.54^\circ}$

UNIT-V TURBINES

PART – A

1. Define hydraulic machines.
Hydraulic machines which convert the energy of flowing water into mechanical energy.

2. Give example for a low head, medium head and high head turbine. Low head turbine – Kaplan turbine
Medium head turbine – Modern Francis
turbine High head turbine – Pelton wheel

3. What is impulse turbine? Give example.
In impulse turbine all the energy converted into kinetic energy. From these the turbine will develop high kinetic energy power. This turbine is called impulse turbine. Example: Pelton turbine

4. What is reaction turbine? Give example.
In a reaction turbine, the runner utilizes both potential and kinetic energies. Here portion of potential energy is converted into kinetic energy before entering into the turbine.
Example: Francis and Kaplan turbine.

5. What is axial flow turbine?
In axial flow turbine water flows parallel to the axis of the turbine shaft. Example:
Kaplan turbine

6. What is mixed flow turbine?
In mixed flow water enters the blades radially and comes out axially, parallel to the turbine shaft. Example: Modern Francis turbine.

7. What is the function of spear and nozzle?
The nozzle is used to convert whole hydraulic energy into kinetic energy. Thus the nozzle delivers high speed jet. To regulate the water flow through the nozzle and to obtain a good jet of water spear or nozzle is arranged.

8. Define gross head and net or effective head.
Gross Head: The gross head is the difference between the water level at the reservoir and the level at the tailstock.
Effective Head: The head available at the inlet of the turbine.

9. Define hydraulic efficiency.
It is defined as the ratio of power developed by the runner to the power supplied by the water jet.

10. Define mechanical efficiency.
It is defined as the ratio of power available at the turbine shaft to the power developed by the turbine runner.

11. Define volumetric efficiency.
It is defied as the volume of water actually striking the buckets to the total water supplied by the jet.

12. Define over all efficiency.
It is defined as the ratio of power available at the turbine shaft to the power available from the water jet.

13. Define the terms
(a) Hydraulic machines (b) Turbines (c)
Pumps. a. Hydraulic machines:

Hydraulic machines are defined as those machines which convert either hydraulic energy into mechanical energy or mechanical energy into hydraulic energy.

b. Turbines;

The hydraulic machines which convert hydraulic energy into mechanical energy are called turbines.

c. Pumps:

The hydraulic Machines which convert mechanical energy into hydraulic energy are called pumps.

14. What do you mean by gross head?

The difference between the head race level and tail race level when no water is flowing is known as gross head. It is denoted by Hg.

15. What do you mean by net head?

Net head is also known as effective head and is defined as the head available at the inlet of te turbine. It is denoted as H

16. What is draft tube? why it is used in reaction turbine?

The pressure at exit of runner of a reaction turbine is generally less than the atmospheric pressure. The water at exit cannot be directly discharged to tail race. A tube or pipe of gradually increasing area is used for discharging water from exit of turbine to tail race. This tube of increasing area is called draft tube.

17. What is the significance of specific speed?

Specific speed plays an important role for selecting the type of turbine. Also the performance of turbine can be predicted by knowing the specific speed of turbine.

18.. What are unit quantities?

Unit quantities are the quantities which are obtained when the head on the turbine is unity. They are unit speed, unit power unit discharge.

19. Why unit quantities are important

If a turbine is working under different heads, the behavior of turbine can be easily known from the values of unit quantities

20. What do you understand by characteristic curves of turbine?

Characteristic curves of a hydraulic turbine are the curves, with the help of which the exact behavior and performance of turbine under different working conditions can be known.

21. Define the term 'governing of turbine'.

Governing of turbine is defined as the operation by which the speed of the turbine is kept constant under all conditions of working. It is done by oil pressure governor.

22. What are the types of draft tubes?

The following are the important types of draft tubes which are commonly used.

a. Conical draft tubes
b. Simple elbow tubes
c. Moody spreading tubes and
d. Elbow draft tubes with circular inlet and rectangular outlet

UNIT –V

TURBINES

PART -B

1 A Pelton wheel has a mean bucket speed of 10m/s with a jet of water flowing at the rate of 700 l/s under a head of 30m. the buckets deflects the jet through an angle of 160° Calculate the power given by water to the runner and the hydraulic efficiency of the turbine. Assume co-efficient of velocity as 0.98.

Soln:

Speed of bucket, $= u = u_1 = u_2 = 10\ m/s$

Discharge $Q =$ (N/D-15,N/D-13) $0.7\ m^3/s$

$V_{w_1} = V_1$, $V_{r_2} = V_{r_1}$

$V_{w_2} = V_{r_2} \cos\phi - u_2$

Head of water $(H) = 30m$

Angle of deflection $= 160°$

Angle $\phi = 180° - 160° = 20°$

Co-efficient of velocity, $C_v = 0.98$

The velocity of jet $V_1 = C_v \sqrt{2gH}$

$= 0.98\sqrt{2 \times 9.81 \times 30}$

$= 23.77\ m/s$

$V_{r_1} = V_1 - u_1 = 23.77 - 10$

$= 13.77\ m/s$

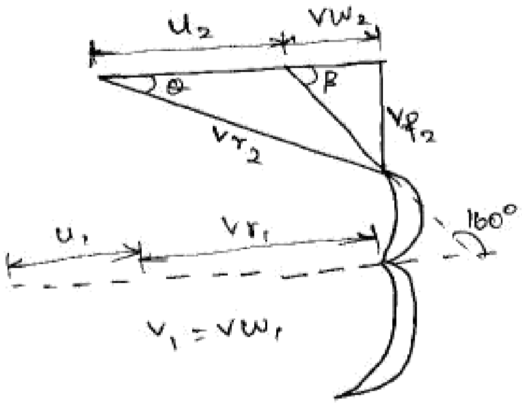
$V_{w_1} = V_1 = 23.77\ m/s$

From outlet velocity triangle $V_{r_2} = V_{r_1} = 13.77$ m/s

$$V_{w_2} = V_{r_2} \cos\phi - u_2$$

$$= 13.77 \cos 20^\circ - 10.0$$

$$= 2.94 \text{ m/s}$$



Work done by the jet per second on the runner is given by equation

$$= \rho a v_1 [V_{w_1} + V_{w_2}] \times u \qquad a v_1 = Q = 0.7 \text{ m}^3/\text{s}$$

$$= 1000 \times 0.7 \times [23.77 + 2.94] \times 10$$

$$= 186970 \text{ Nm/s}$$

Power given to turbine $= \dfrac{186970}{1000} = 186.70$ kW

The hydraulic efficiency of the turbine is given by

$$\eta_h = \frac{2[V_{w_1} + V_{w_2}] \times u}{V_1^2}$$

$$= \frac{2(23.77 + 2.94) \times 10}{23.77 \times 23.77}$$

$$= 0.94 \text{ (or) } 94\%$$

— x —

$d/D = 1/6$

$d = 1/6 \times 0.989 = 0.165\ m$

Discharge of one jet, q = Area of jet × velocity of jet

$= \pi/4\ d^2 \times V_1 = \pi/4\ (0.165)^2 \times 85.05$

$= 1.818\ m^3/s$

Now,

$\eta_0 = S.P / W.P$

$= \dfrac{11772}{\rho g \times Q \times H / 1000}$

$0.86 = \dfrac{11772 \times 1000}{1000 \times 9.81 \times Q \times 380}$

$Q = 3.672\ m^3/s$

Number of jets $= \dfrac{\text{Total discharge}}{\text{Discharge of one jet}}$

$= \dfrac{Q}{q}$

$= 3.672 / 1.818$

$= 2$ Jets

——— x ———

(2) A pelton wheel is to be designed for the following specification : (A/M-16,N/D-15)

Shaft power = 11772 kW , Head = 380 m

Speed = 750 rpm , overall efficiency = 86 %

Jet diameter is not to exceed one sixth of the wheel diameter, Determine (i) The wheel diameter

(ii) The number of jet required

(iii) Diameter of the jet

Take $k_{v_1} = 0.985$, $k_{u_1} = 0.45$

Given:

Shaft power (S.P) = 11772 kW

Head (H) = 380 m

Speed (N) = 750 rpm

Over all efficiency η_o = 86 % or 0.86

Ratio of jet dia to wheel dia = $d/D = 1/6$

Co-efficient of velocity $k_{v_1} = C_v = 0.985$

Speed ratio $k_{u_1} = 0.45$

Velocity of jet $V_1 = C_v \sqrt{2gH}$

$= 0.985 \sqrt{2 \times 9.81 \times 380}$

$= 85.05$ m/s

Soln:

$$u = \frac{\pi D N}{60}$$

$$38.85 = \frac{\pi D N}{\quad} \Rightarrow D = \frac{60 \times 38.85}{\quad} = 0.989 \text{ m}$$

1 The following data is related to a pelton wheel :

Head at the base of the nozzle = 80m

Diameter of the jet = 100mm

Discharge of the nozzle = 0.3 m^3/s

Power at the shaft = 206 kW

Power absorbed in mechanical resistance = 4.5 kW

Determine : (i) Power lost in nozzle (A/M-14,N/D-16)

(ii) Power lost due to hydraulic resistance in the runner

Given :

Head at the base of nozzle $H_1 = 80m$

$d = 100mm = 0.1m$

Area $a = \pi/4 (0.1)^2 = 0.007854$

$Q = 0.3 m^3/s$

Shaft power = 206 kW

Soln :

Discharge $Q = a \times V_1 \Rightarrow V_1 = \frac{Q}{a}$

$$V_1 = \frac{0.3}{0.007854} = 38.197 \ m/s$$

Power at the base of the nozzle in kW

$$= \frac{\rho \times g \times Q \times H_1}{1000}$$

$$= \frac{1000 \times 9.81 \times 0.3 \times 80}{1000}$$

$$= 235.44$$

Power corresponding to kinetic energy of the jet in kW

$$= \frac{1}{2} \frac{m(v_1)^2}{1000} = \frac{1}{2} \frac{(\rho \times a v_1) v_1^2}{1000}$$

$$= \frac{1}{2} \frac{\rho \times Q \times v_1^2}{1000}$$

$$= \frac{1}{2} \times 1000 \times \frac{0.3 \times 38.197^2}{1000}$$

$$= 218.85 \text{ kW}$$

(i) Power at the base of the nozzle

= Power of the jet + Power lost in nozzle

235.44 = 218.85 + Power lost in nozzle

Power lost in nozzle = 16.59 kW

(ii) Also power at the base of nozzle = Power at the shaft + Power lost in nozzle + Power lost in runner + Power lost due to machanical resistanc

235.44 = 206 + 16.59 + Power lost in runner + 4.5

Power lost in runner = 235.44 − (206 + 16.59 + 4.5)

= 235.44 − 227.09

= 8.35 kW

— x —

The water available for a pelton wheel is 4 cumec and the total head from the reservior to the nozzle is 250 mtr. The turbine has two runners with two jets per runner. All the four jets have the same diameters. The pipe line is 3000 mtr. long. The efficiency of power transmission through the pipe line and the nozzle is 91% and efficiency of each runner is 90%. The velocity & efficiency of each nozzle is 0.975 and co-efficient of friction 4F for the pipe is 0.0045. (N/D-15,A/M-16)

1) The power developed by the turbine.

(ii) The diameter of the jet, and

(iii) The diameter of the pipe line

Solution

Given

Total discharge $= Q = 4$ cumec $= 4.0\ m^3/s$

Total or gross head, $H_g = 250\ m$

Total number of jets $= 2 \times 2 = 4$

Length of pipe $= L = 3000\ m$

Efficiency of the pipe line and nozzle $= 91\%$ or 0.91

Efficiency of runner or $= \eta_h = 90\%$ or 0.90

Co-efficiency of velocity $C_v = 0.975$

Co-efficient of friction $4F = 0.045$

Efficiency of power transmission through pipe lines and nozzle is is given by

$$\eta = \frac{H_g - h_f}{H_g} \quad \text{or} \quad 0.91 = \frac{250 - h_f}{250}$$

Where h_f = Head lost due to friction;

$$h_f = 250 - 0.91 \times 250 = 22.5\,m.$$

Net head on the turbine = $H = H_g - h_f = 250 - 22.50 = 227.5\,m$

Velocity of jet $V_1 = C_v\sqrt{2gH} = 0.975\sqrt{2 \times 9.81 \times 227.5} = 65.14\,m/s$

(i) Power at the inlet of the turbine is given as

W.P = Kinetic energy of the jets

$$= \frac{\frac{1}{2} m V_1^2}{1000} = \frac{\frac{1}{2}(\rho \times Q)V_1^2}{1000} = \frac{1}{2} \times 1000 \times \frac{4.0 \times 65.14^2}{1000} = 8486.44\,kW$$

$$\eta_h = \frac{\text{power developed by turbine}}{W.P}$$

Power developed by turbine = $0.90 \times 8486.44 = 7637.8\,kW$ Ans.

Discharge per jet $q = \frac{\text{Total discharge}}{\text{No. of jets}} = \frac{4.0}{4.0} = 1.0\,m^3/s$

q = Area of one jet × velocity of jet

$$= \frac{\pi}{4} d^2 \times V_1$$

$$1.0 = \frac{\pi}{4} d^2 \times 65.14$$

$$d = \sqrt{\frac{4 \times 1.0}{\pi \times 65.14}} = 0.14\,m.$$

Definations of Heads and Efficiences of a centrifugal Pump

1. Suction head (h_s) → Vt. centrifugal pump & water surface
2. Delivery Head (h_d) → Vt b/w pump and the water surface.
3. Static head (H_s) → Σ sh and D head
4. Manametric Head (H_m)

$$H_m = h_s + h_d + h_{fs} + h_{fd} + V_d^2/2g$$

h_s → suction head, h_d → Delivery head
h_{fs} → Friction head loss in suction pipe, h_{fd} → Friction headloss in delivery pipe
V_d → Velocity of water in delivery pipe.

5. Efficiencies of a Centrifugal pump.

In case of a centrifugal pump, the power is given the power is transmitted impeller, the power is decreasing from the to the water. Thus power is decreasing from the shaft of the pump to the impeller and then to the water. the following are the important efficiencie of a centrifugal pump :-

(a) Manometric efficiency, η_{man}
b) Mechanical efficiency η_m
c) Overall efficiency, η_o

a) $$\eta_{man} = \frac{\text{Manometric head}}{\text{Head imparted by impeller to water}}$$

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

b) Mechanical Efficiency (η_m)

$$\eta_m = \frac{\text{Power at the impeller}}{\text{Power at the shaft}}$$

$$K_w = \frac{\text{Work done by impeller per second}}{1000}$$

$$\eta_m = \frac{W/g \left(\frac{V_{w2} \times u_2}{1000}\right)}{\quad}$$ SP → shaft power

velocity variation

19958999

A cylinder bore diameter of a single - acting reciprocating pump is 150mm and its stroke is 300mm. the pump runs at 50 r.p.m and lifts water through a height of 25m. the delivery pipe is 22m long and 100mm in diameter. Find the theoretical discharge and the theoretical power required to run the pump. If the actual discharge is 4.2 lit/s find the percentage slip. Also determine the acceleration head at the beginning and middle of the delivery stroke.

Sol

$D = 150mm = 0.15m$

$A = \frac{\pi}{4} \times 0.15^2 = 0.01767 m^2$

$L = 300mm = 0.3m$

$N = 50 \, r.p.m$

$H = 25m$, $ld = 22m$, $Ld = 22m$, $dd = 100mm = 0.1m$

Actual discharge, $Q_{act} = 4.2 \, lit/s = \frac{4.2}{1000} \frac{m^3}{s} = 0.0042 \frac{m^3}{s}$

(i) theoretical discharge (Q_{th})

$$Q_{th} = \frac{A \times L \times N}{60} = \frac{0.01767 \times 0.3 \times 50}{60} = 0.00442 \frac{m^3}{s}$$

$= 0.00442 \times 1000 \, lit/s = 4.417 \, lit/s$

(ii) theoretical power (P_t)

$$P_t = \frac{(\text{Theoretical weight of water lift} / \text{Total height})}{1000}$$

$$= \frac{\rho \times g \times Q_{th} \times H}{1000}$$

$$= \frac{1000 \times 9.81 \times 0.00441 \times 25}{1000} \quad (Q_{th} = 0.00442 \, m^3/s)$$

$= 1.083 \, kW$

iii) The percentage slip

$$\%\ \text{slip} = \left(\frac{Q_{th} - Q_{act}}{Q_{th}}\right) \times 100$$

$$= \left(\frac{4.41 - 4.2}{4.41}\right) \times 100 = 4.92\%$$

iv) Acceleration

$$h_{ad} = \frac{L_d}{g} \times \frac{A}{a_d} \omega^2 r \times \cos\theta$$

a_d = Area of delivery pipe $= \frac{\pi}{4} \times (0.1)^2 = 0.007854$

ω = Angular speed $= \frac{2\pi N}{60} = \frac{2\pi \times 50}{60}$

$= 5.236$

r = Crank radius $= L/2 = \frac{0.3}{2} = 0.15$

$$h_{ad} = \frac{22}{9.81} \times \frac{0.0176}{0.0078} \times 5.236^2 \times 0.15 \times \cos\theta$$

$$= 20.75 \times \cos\theta$$

At the beginning of delivery stroke $\theta = 0°$, $\cos\theta = 1$

$h_{ad} = 20.75\ m$

v) Acceleration head at the middle of delivery stroke

$\theta = 90°$ & $\cos\theta = 0$

$$h_{ad} = 20.75 \times 0 = 0.$$

15) Calculate the rate of flow in and out of the air vessel on the delivery side in a single acting reciprocating pump of 220 mm bore and 330 mm stroke running at 50 r.p.m. Also find the angle of crank rotation at which there is no flow into or out of the air vessel.

Acceleration head had

$$h_{ad} = \frac{l_d}{g}\frac{A}{a_d}\omega^2 r$$

Absolute pressure head

$$= H_{atm} + (h_d + h_{ad})$$

Given data

$D = 220mm = 0.22\,m$

$L = 330mm = 0.33\,m$

$r = L/2 = \frac{0.33}{2} = 0.165\,m$

$N = 50\,r.p.m$

Sol

Area of the plunger $A = \frac{\pi}{4}D^2 = \frac{\pi}{4} \times 0.22^2 = 0.038\,m^2$

Angular speed $\omega = \frac{2\pi N}{60} = \frac{2\pi \times 50}{60} = 5.24\,rad/s$.

Assume $\theta = 30°$

$$Q = A\omega r\,(\sin\theta - 2/\pi)$$

$$= 0.038 \times 5.24 \times 0.165\,(\sin 30° - 2/\pi)$$

$$= -4.49 \times 10^{-3}\,m^3/s = -4.49\,l/s$$ quantity of water flown from the air vessel

Assume $\theta = 120°$

$$Q = A\omega r\,(\sin\theta - 2/\pi) = 0.038 \times 5.24 \times 0.165\,(\sin 120° - 2/\pi)$$

$$= 7.54 \times 10^{-3}\,m^3/s = 7.54\,l/s$$ quantity of water flown into the air vessel.

At zero flow $Q = 0$

$$\therefore Q = A\omega r\,(\sin\theta - 2/\pi)$$

$$0 = 0.0177 \times 12.57 \times 0.15\,(\sin\theta - 2/\pi)$$

$$\boxed{\theta = 39.54°}$$