SYLLUBUS

Unit - 5

1 23

Centrifugal pump: classification, working, workdone, Manometric head losses & Efficiencies, Specific speed - pumps in series and parallel, performance characteristic curves Cavitation & NPSH

Reciprocating pump: working, Discharge, slip, Indicator diagrams

PUMP:-

PUMP IS DEVICE which converts Mechanical Energy into Hydraulic Energy is in the form of pressure Energy.

(M.E) → PUMP → (H.E)

PUMP is also called as Hydraulic machine
(or)
Turbo machine
(or)
Fluid machine
(or)
Prime mover

Pump is power consuming Device

Pump can takes Mechanical Energy from
- → Electrical motor
- → I.C Engine
- → E.C Engine
- → wind mill
- → Hand cranking

APPLICATIONS OF PUMPS:-

1. PUMPS are used In "House hold purpose"
2. " " " " "Irrigation purpose"
3. " " " " "Different Industries"
   - Auto mobile Industry
   - chemical Industry
   - Medical Industry
   - Energy Industry
4. PUMPS are used In "aquarium filtering"
5. PUMPS are used as "aritificial Heart"
6. PUMPS are used In "paint Guns"

classification of PUMPS :-

PUMPS
- Rotodynamic pumps
- Positive Displacement pumps

Rotodynamic pumps

The pressure of fluid Increases by centrifugal action of Impeller and due to change of its angular momentum

EX:-
① centrifugal pump
② Axial pump
③ mixed flow pump
④ self priming pump.

Positive Displacement pumps

The pressure of fluid Increases by pushing the fluid with the moving members

EX:-
① Reciprocating pumps
② Rotary Gear pump
③ Screw pump
④ Vane pump
⑤ Lobe pump.

CENTRIFUGAL PUMP :-

① It is a Rotodynamic pump

② In centrifugal pump The Mechanical Energy is converted Into pressure Energy by means of centrifugal force acting on the fluid

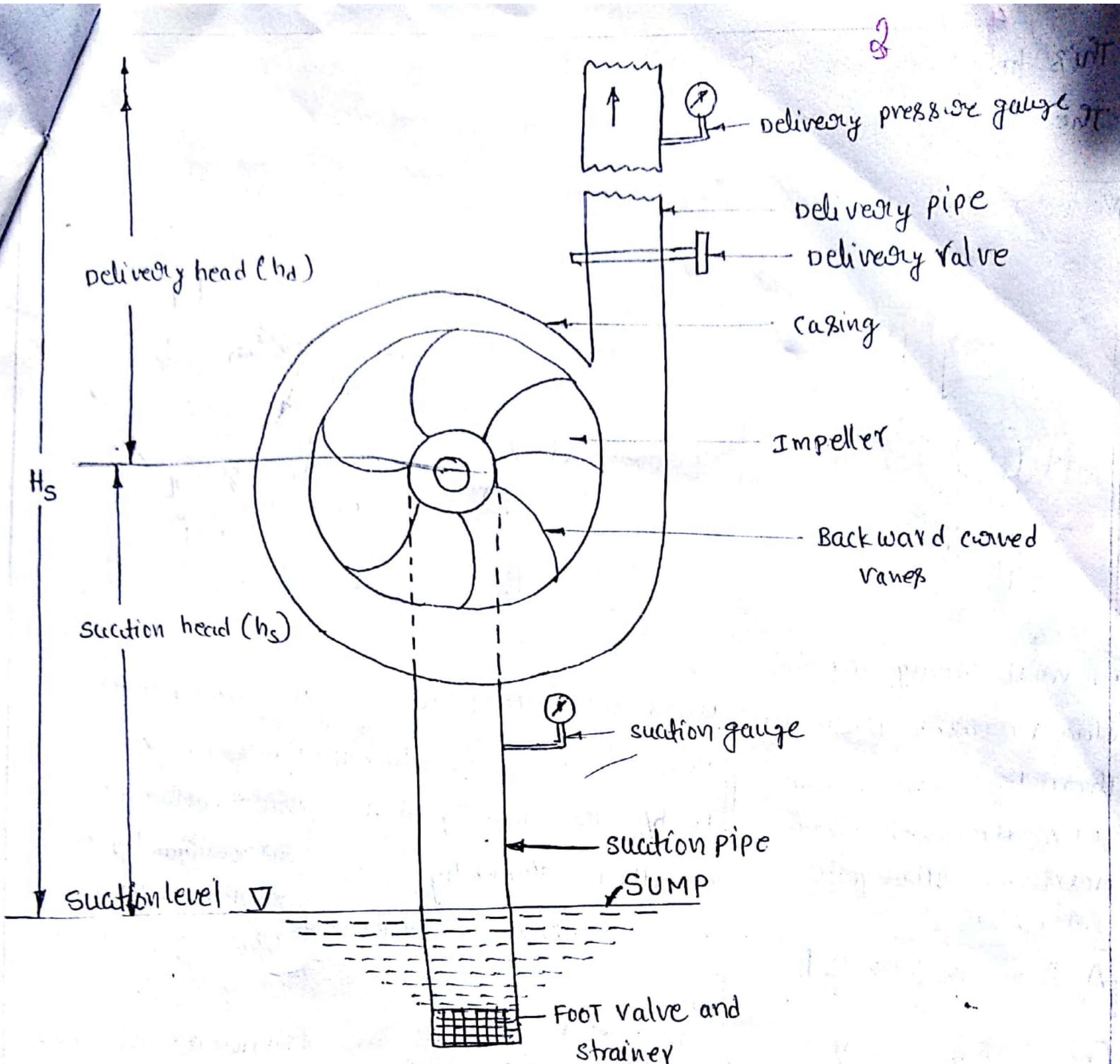
③ centrifugal pump acts as a Reverse of an Inward flow Reaction Turbine This means that the flow In centrifugal pumps is In the Radial outward direction.

④ The centrifugal pump works on the principal of "forced vortex flow" which means certain mass of fluid is Rotated by an External torque, The rise In pressure head of the Rotating Liquid takes place

MAIN PARTS OF A CENTRIFUGAL PUMP :-

① Impeller
② Casing
- ⓐ Volute casing
- ⓑ vortex casing
- ⓒ casing with Guide Blades

③ suction pipe
④ Delivery pipe
⑤ Foot valve
⑥ strainer
⑦ pressure Gauges.



MAIN PARTS OF CENTRIFUGAL PUMP

Impeller:-

Rotating part of a centrifugal pump is called Impeller
It consists of a series of backward curved vanes
It is made to Rotate at high speed Inside the spiral casing
Its mechanical Energy is converted Into pressure Energy of Liquid
Reduction of pressure is caused at the centre of Rotation as the Liquid is thrown outwards This reduction of pressure causes suction of Liquid

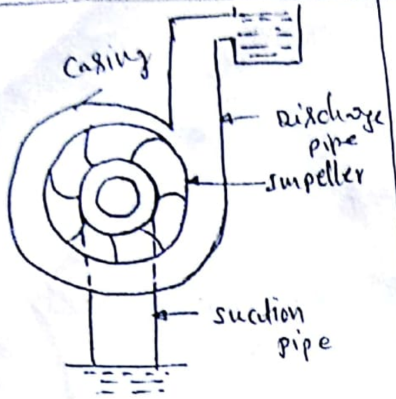
Casing :-

It is an air tight passage surrounding the Impeller
Its cross sectional area gradually increases toward the outlet of pump

This helps conversion of kinetic energy of water into pressure energy

The following are three types of casing

Volute casing



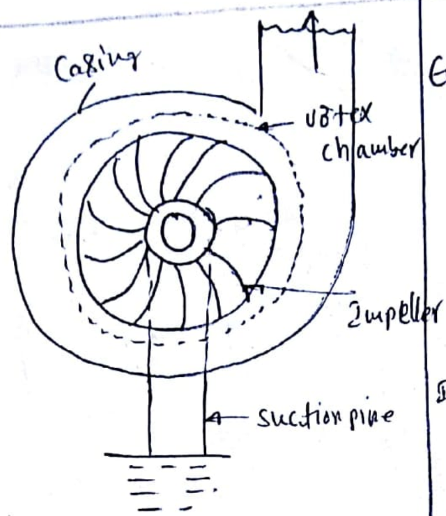
In volute casing area of flow increases gradually. There by velocity of fluid gets decreases then pressure of fluid gets increases

$A_f \uparrow \Rightarrow V_f \downarrow \Rightarrow P_f \uparrow$

$\eta_{volute} < \eta_{vortex} < \eta_{guide\text{-}vanes}$

✓Eddie losses takes place

Vortex casing



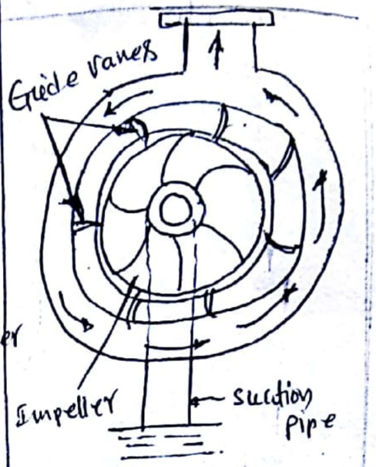
In vortex casing a new chamber introduced in b/w the casing and impeller. Thereby Eddie losses are minimised

So

$\eta_{volute} < \eta_{vortex} < \eta_{Guide\ Vanes}$

$A_f \uparrow \Rightarrow V_f \downarrow \Rightarrow P_f \uparrow$

Casing with Guide Vanes



In casing with guide vanes the impeller is surrounded by a series of guide blades mounted on a ring which is known as Diffuser

$A_f \uparrow \Rightarrow V_f \downarrow \Rightarrow P_f \uparrow$

$\eta_{volute} < \eta_{vortex} < \eta_{Guide\ Vanes}$

Suction pipe:- It is a pipe whose one end is connected to the inlet of pump and other end dips into the sump

Delivery pipe:- It is a pipe whose one end is connected to the outlet of pump and other end delivers to the tank

Foot Valve:- It is a non return valve it allows water into suction pipe. It prevents water from flowing back to the sump when the pump is off. It is fitted at end of the suction pipe

Strainer:- It is fitted at the bottom of the suction pipe to prevent the entry of the impurities (or) foreign matter from reaching the impeller of the pump.

④

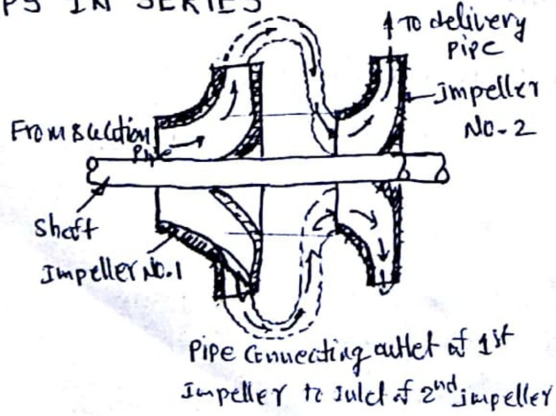
Operation of Single stage Centrifugal pump :- [Working]

1) priming is done before starting the pump means casing must be filled with water to remove air
2) Delivery valve kept closed before start the motor
3) start the motor
4) Then Impeller Rotates
5) By centrifugal force water flows towards periphery of pump casing
6) Flow creates vaccum at the Eye in Impeller
7) Due to pressure difference, water enters the pump
8) Impeller blades provide diverging passage to water
9) Due to Rotation of impeller, velocity of water Increases
10) Kinetic Energy is converted into pressure Energy due to diverging in casing. for continuous supply of water, delivery valve is open
11) *** Suitable for low head and high discharge

MULTI STAGE CENTRIFUGAL PUMPS :-

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) different shafts. A multistage pump having the following two important functions

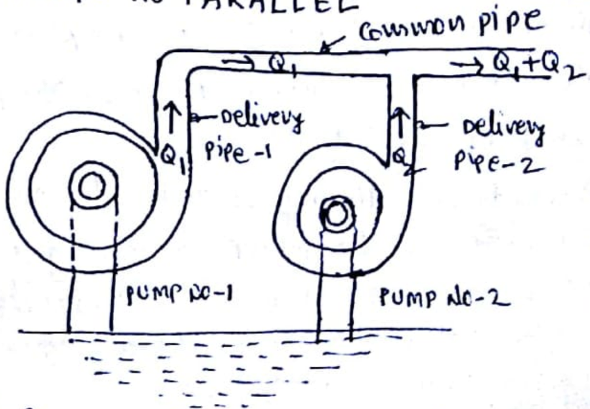
① PUMPS IN SERIES



*For developing "a High head, a no. of impellers mounted on same shaft

Total Head $H_{m_{Total}} = n \times H_{m_{single}}$

② PUMPS IN PARALLEL



* For obtaing "High Discharge" The pumps are connected in parallel

∴ Total Discharge $Q_{Total} = n \times Q_{single}$

Priming In Centrifugal pump :-

✓ Priming is filling of casing, suction pipe and a part of delivery pipe up, HARAC... delivery valve generally with liquid to be pumped

Charac... Cur...

✓ It is done to Remove Entrapped air In the pump

✓ It is generally done by External Means

Necessity of priming :

When the Centrifugal pump is not working, The liquid present In the casing and suction line may flow back Into the source. This may cause air to Enter Into the suction pipe. The Impeller then Rotates In air, and develops Negligible pressure. So these pressure is not sufficient to suck the water from the sump This causes the Necessity of priming.

prevention of priming :-

① The casing, suction pipe and some portion of delivery pipe must be kept with full of water always

② Air vent screw should be provided on the casing

③ The Delivery valve should be kept closed, when the pump is not working.

Cavitation :-

When the fluid pressure at any point In the flow below it's vapour pressure, Local boiling takes place and bubbles are formed.

The bubbles travel to High pressure Region and collapse suddenly with tremendous shock.

The surrounding liquid Rushes to fill the gap

The process produces shock waves of very High frequency

The Erode The surfaces which They contact and produce Cavities

Effect of cavitation :-

⊙ Smooth functioning of Hydraulic machines is affected

⊙ Impeller of the pump is damaged. this is called pitting of pump

⊙ Vibrations are Induced and operation of pump is noisy

⊙ Erosion of blade material takes place leading to Fatigue failure

Prevention of Cavitation :-

⊛ pump should be designed to avoid High velocity

⊛ suction head should be limited

⊛ stainless steel (or) chrome Nickel can be used to construction of pump.

⊛ surfaces are coated with polymers.

(6)

up to

CHARACTERISTIC CURVES OF CENTRIFUGAL PUMPS

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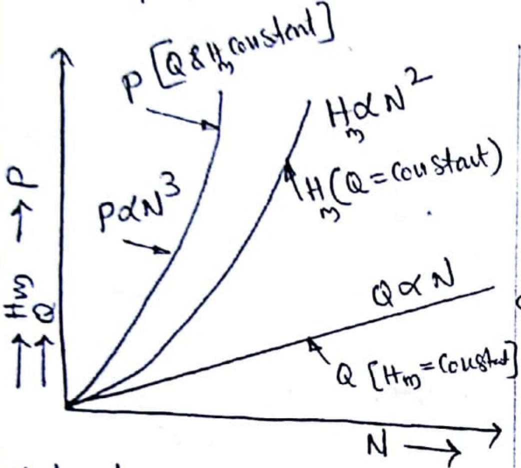
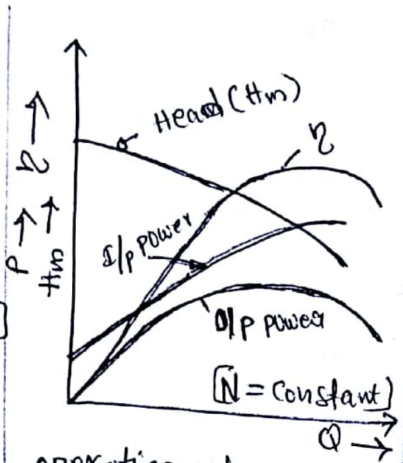
* Characteristic curves of centrifugal pumps are defined as those curves which are plotted from the Results of No. of tests on the centrifugal pump

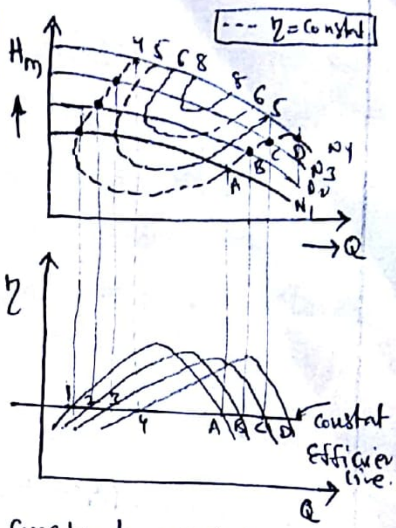
* These curves are Necessary to predict the behaviour and performance of the pump when the pump is working under different flowrate, head and speed.



Main characteristic curves of a pump



operating characteristic curves of a pump



Constant Efficiency curves of a pump

These curves consists of variation of Head (H_m), power & discharge with respect to speed

From the Equation

① $\frac{\sqrt{H_m}}{DN}$ = constant (or) $H_m \propto N^2$

These means H_m v/s N is "parabalic"

② $\frac{P}{D^5 N^3}$ = constant (or) $P \propto N^3$

P v/s N is a 'cubic curve'

③ $\frac{Q}{D^3 N}$ = constant (or) $Q \propto N$

Hence

Q v/s N is 'straight line'

These curves consists of variation of Head (H_m), power & Efficiency with respect to Discharge.

✓ I/p power ~~powe~~ of pump will be more than zero at Q = 0 because have to overcome Mechanical losses

✓ O/p = 0 at Q = 0

Why because

O/p = ρQgH

✓ η = 0 at Q = 0

because $\eta = \frac{O/p}{I/p}$

These curves are obtaining by using Head versus Discharge and Efficiency versus discharge curves for the different speeds.

✓ By combining these H~Q curves and η~Q curves, Constant Efficiency curves are obtained.

* It is also called "ISO-Efficiency curves"

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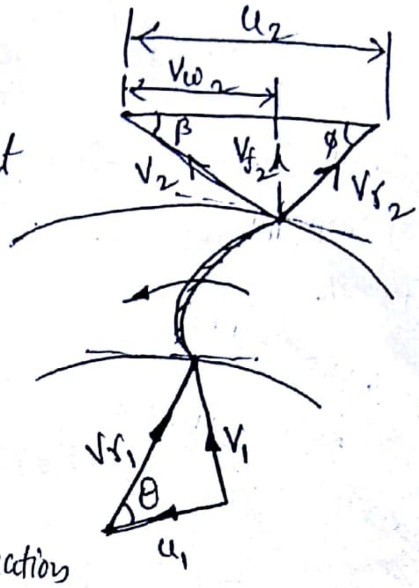
Work done by the centrifugal pump (OR By Impeller) ON water:

ffi ciencies

✓ Work done by the Impeller on the water

✓ The work done by the impeller on the water is obtained by drawing velocity Triangles at Inlet and outlet of the impeller in the same way as for a turbine



✓ The water Enters the Impeller radially at Inlet for best Efficiency of the pump, which means the absolute velocity of water at Inlet makes an angle of 90° with the direction of motion of the impeller at Inlet.

Hence $\alpha = 90^\circ$ and $V_{w_1} = 0$ The $V_1 = V_{f_1}$

N = Speed of The Impeller in R.P.M

D_1 = Diameter of Impeller at Inlet

u_1 = Tangential velocity of Impeller at Inlet

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

V_1 = absolute velocity at Inlet

V_{r_1} = Relative velocity at Inlet

θ = Inlet vane angle α = Inlet Jet angle

D_2 = Diameter at outlet

u_2 = Tangential velocity at outlet

V_2 = absolute velocity at outlet

V_{r_2} = Relative velocity at outlet.

ϕ = outlet vane angle

β = outlet Jet angle

A centrifugal pump is the reverse of Radially Inward flow Reaction turbine.

$$\left(\frac{W.D}{W}\right)_{Turbine} = \frac{1}{g}\left[V_{w_1}u_1 - V_{w_2}u_2\right]$$

pump = X Turbine so $\left[\frac{W.D}{W}\right]_{pump} = -\frac{1}{g}\left[V_{w_1}u_1 - V_{w_2}u_2\right] = \frac{1}{g}\left[V_{w_2}u_2 - V_{w_1}u_1\right]$

$$\boxed{\frac{W.D}{W} = \frac{1}{g}V_{w_2}u_2}$$ Why because $\boxed{V_{w_1} = 0}$

$$W.D_{Pump} = \dot{m}\left[V_{w_2}u_2\right] = \rho Q\left[V_{w_2}u_2\right] = \rho\pi D_1 B_1 V_{f_1}\left[V_{w_2}u_2\right] = \rho\pi D_2 B_2 V_{f_2}\left[V_{w_2}u_2\right]$$

where $Q = A_1 V_{f_1}$ (or) $Q = A_2 V_{f_2}$

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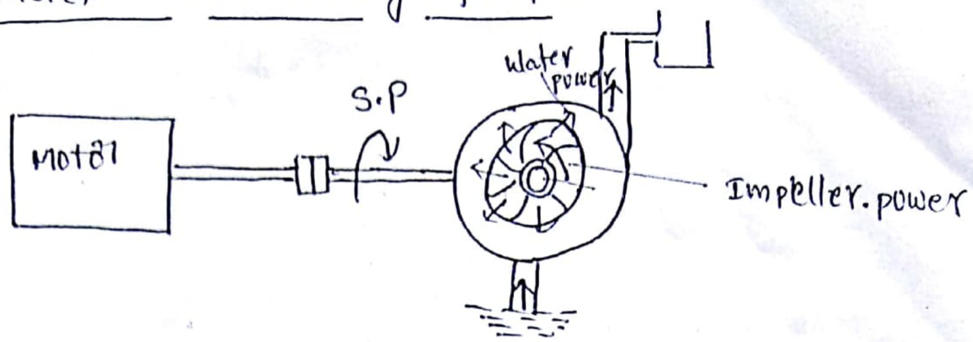
Efficiencies of a centrifugal pump :-



shaft power ⟹ Impeller power ⟹ water power

S.P > Im.p > W.p

✓ Efficiency means The Ratio of output of Device to the Input of Devices

① Mechanical Efficiency (η_{mech})

It is The Ratio of power given to Impeller to The power available at The shaft

$$\eta_{Mech} = \frac{\text{power given to the Impeller}}{\text{power available at shaft}} = \frac{Im.P}{S.P}$$

$$\eta_{Mech} = \frac{\frac{W}{g}\frac{[V_{\omega_2}u_2]}{1000}}{S.P}$$

② Manometric Efficiency ($\eta_{Manometric}$) :-

$$\eta_{Manometric} = \frac{\text{power given to the Water}}{\text{power available at Impeller}} = \frac{W H_m}{\frac{W}{g}[V_{w_2}u_2]} = \frac{g H_m}{V_{w_2}u_2}$$

✱ It is Ratio of power given to the water to The power avialable at Impeller

③ Overall Efficiency [$\eta_{overall}$] :-

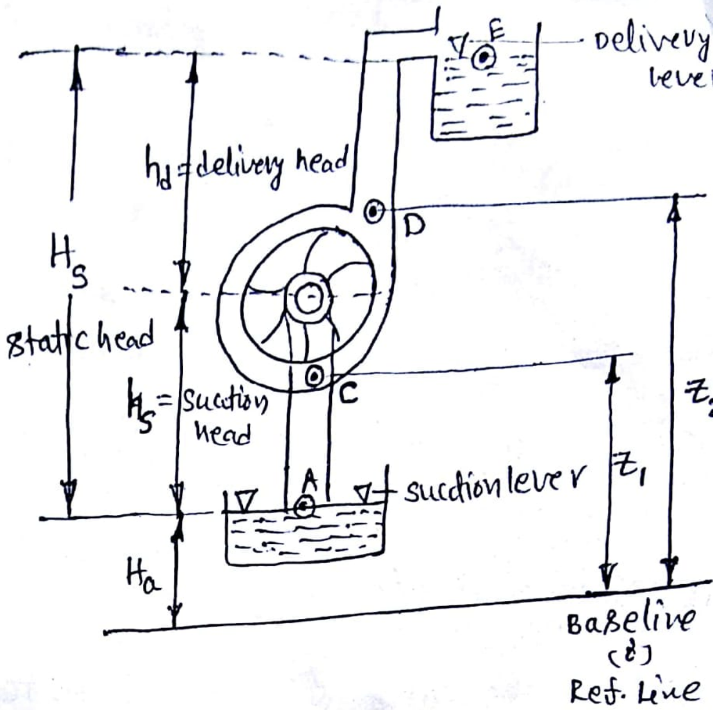
✱ It is Ratio of power given to the water to the power avialable at shaft

$$\eta_{overall} = \frac{\text{Power given to water}}{\text{Power avialable at shaft}} = \frac{\frac{W H_m}{1000}}{S.P}$$

$$\eta_{overall} = \eta_{Mech} \times \eta_{Manometric}$$

Heads of centrifugal pump :-

ⓐ suction head ⓑ Delivery head ⓒ Static head ⓓ Manometric head



Suction head :-

It is vertical height in b/w suction level to the center of the pump. Denoted by "h_s"

Delivery head :-

It is vertical height in b/w center of the pump to the delivery level. Denoted by "h_d"

Static head :-

It is the vertical height in b/w suction level to the delivery level. Denoted by "H_S"

✓ The sum of suction head and delivery head is known as static head

$$H_S = h_s + h_d$$

Manometric Head (H_m) :- It is Defined as The head against which centrifugal pump has to work. It is denoted by "H_m"

H_m = Head imparted by the impeller to the water − Loss of head in the pump

ⓐ $$H_m = \frac{V_{w_2} u_2}{g} - \text{Loss of head in impeller and casing}$$

H_m = Total head at outlet − Total head at inlet of the pump

ⓑ $$H_m = \left[\frac{P_o}{\rho g} + \frac{V_o^2}{2g} + Z_o\right] - \left[\frac{P_i}{\rho g} + \frac{V_i^2}{2g} + Z_i\right]$$

ⓒ $H_m = H_S + h_{fs} + h_{fd} + \frac{V_d^2}{2g}$

$$H_m = H_S + h_{f_s} + h_{f_d} + \frac{V_d^2}{2g}$$

Specific speed of a centrifugal pump :-

The specific speed of a centrifugal pump is defined as the speed of geometrically similar pump which would deliver $1 m^3/sec$ against a head of 1m

It denoted by "N_s"

Expression for specific speed for a pump :-

The discharge, Q, for a centrifugal pump is given by the relation

Q = Area x velocity of flow = $\pi D B V_f$ (or) $Q \propto D B V_f$ ----(i)

Wher D = Diameter of the impeller of the pump and

B = width of the impeller We know that $B \propto D$

∴ From Equation (i) We have $Q \propto D^2 V_f$ ----------(ii)

We also know that Tangential velocity is given by

$$u = \frac{\pi D N}{60} \propto DN \quad \text{------(iii)}$$

Tangential velocity u & velocity of flow V_f are related to the Manometric head $[H_m]$

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

Substituting the value of u in Equation (iii) We get

$$\sqrt{H_m} \propto DN \quad (\text{or}) \quad D \propto \frac{\sqrt{H_m}}{N}$$

Substituting the values of D in Equation (ii)

$$Q \propto D^2 V_f \Rightarrow Q \propto \frac{H_m}{N^2} V_f \Rightarrow Q \propto \frac{H_m}{N^2}\sqrt{H_m} \Rightarrow Q \propto \frac{H_m^{3/2}}{N^2}$$

Then $Q = K \frac{H_m^{3/2}}{N^2}$ -(v) Where K is a constant of proportionality.

If $H_m = 1m$ and $Q = 1 m^3/s$, N becomes $= N_s$

Substituting these values in equation (v) We get $1 = K \frac{1^{3/2}}{N_s^2} = \frac{K}{N_s^2}$

$\boxed{K = N_s^2}$ ∴ Substituting the value of K in Equation (v), we get

$$Q = N_s^2 \frac{H_m^{3/2}}{N^2} \quad (\text{or}) \quad N_s^2 = \frac{N^2 Q}{H_m^{3/2}} \Rightarrow \boxed{N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}}$$

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IMPARTANT FORMULAS :-

① $W.D = \text{Work Done} = \frac{W}{g} V_{w_2} u_2 = \dot{m} V_{w_2} u_2 = \rho Q [V_{w_2} u_2]$

$= \rho \pi D_1 B_1 V_{f_1} [V_{w_2} u_2]$

$= \rho \pi D_2 B_2 V_{f_2} [V_{w_2} u_2]$

② $\eta_{Manometric} = \frac{g H_m}{V_{w_2} u_2}$

③ $\eta_{Mechanical} = \frac{\frac{W}{g}\left[\frac{V_{w_2} u_2}{1000}\right]}{S.P}$

④ $\eta_{overall} = \eta_{mech} \times \eta_{Manometric} = \frac{\frac{W H_m}{1000}}{S.P}$

⑤ $u_1 = \frac{\pi D_1 N}{60}$ ⑥ $u_2 = \frac{\pi D_2 N}{60}$

⑦ Discharge $Q = \pi D_2 B_2 \times V_{f_2} = \pi D_1 B_1 \times V_{f_1}$

⑧ If No losses In the pump then $H_m = \frac{V_{w_2} u_2}{g}$

⑨ pressure Raise $= \frac{1}{2g}\left[V_{f_1}^2 + u_2^2 - V_{f_2}^2 \operatorname{cosec}^2 \phi\right]$

⑩ (***) For Minimum speed

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

⑪ For minimum starting speed

$$N = \frac{120 \times \eta_{man} \times V_{w_2} \times D_2}{\pi \left[D_2^2 - D_1^2\right]}$$

⑫ Specific Speed

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

⑬ $[N_s]_{model} = [N_s]_{prototype} = \left[\frac{N\sqrt{Q}}{H_m^{3/4}}\right]_{model} = \left[\frac{N\sqrt{Q}}{H_m^{3/4}}\right]_{prototype}$

(14) Tangential velocity (u) is given by $u = \frac{\pi DN}{60}$ also $u \propto \sqrt{H_m}$

$$\sqrt{H_m} \propto DN \Rightarrow \boxed{\frac{\sqrt{H_m}}{DN} = \text{constant}}$$

$$\left[\frac{\sqrt{H_m}}{DN}\right]_{model} = \left[\frac{\sqrt{H_m}}{DN}\right]_{proto\ type}$$

(15) We alerady know That

$$V_f \propto u \propto DN$$

$$Q \propto D^2 \times V_f$$

$$Q \propto D^2 \times DN \Rightarrow Q \propto D^3 N$$

$$\boxed{\frac{Q}{D^3 N} = \text{constant}} \text{ (or) } \left[\frac{Q}{D^3 N}\right]_{model} = \left[\frac{Q}{D^3 N}\right]_{prototype}$$

(16) power of The pump

$$P = \rho \times g \times Q \times H_m \text{ Then } P \propto Q \times H_m \qquad \boxed{\sqrt{H_m} \propto DN}$$

$$P \propto D^3 \times N \times H_m$$

$$P \propto D^3 N \, D^2 N^2$$

$$P \propto D^5 N^3$$

$$\boxed{\frac{P}{D^5 N^3} = \text{constant}}$$

$$\left[\frac{P}{D^5 N^3}\right]_{model} = \left[\frac{P}{D^5 N^3}\right]_{proto\ Type.}$$

[2015] [8 M]

Pb-1:- A fluid is to be lifted against a head of 120 m. The pumps That run at a speed of 1200 R.P.M with Rated capacity of 300 Liters/sec are available. How many pumps are Required to pump the water If specific speed 700.

Given data:-

Head $H_m = 120$ m [Total]

Speed $N = 1200$ R.P.M

Discharge $Q = 300$ Liters/sec

$N_s = 700$

We know That

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

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

$$H_m^{3/4} = \frac{N\sqrt{Q}}{N_s} = \frac{1200 \times \sqrt{300 \times 10^{-3}}}{700}$$

$$H_{m_{single}} = 0.919\,m$$

$$\text{No. of pumps } n = \frac{H_{m\,Total}}{H_{m\,single}} = \frac{120}{0.919} = 130.5 = \underline{131 \text{ pumps}}$$

-3 [2015] centrifugal ... against a ... If the ... Deter...

Pb:-2 [2015] [8M]

Water is to be pumped to a height of 90m. The pumps that run at a speed of 1000 rpm with Rated capacity 200 litres/sec are available. How many pumps are required to pump the water If specific speed is 800.

Given data:-

Total Manometeric head $H_{m_{Total}} = 90\,m$

Speed $N = 1000$ R.P.M

Discharge $Q = 200$ liters/sec $= 200 \times 10^{-3}\, m^3/sec$

Sp. speed $N_s = 800$

$$\text{No. of pumps } n = ? = \frac{H_{m\,Total}}{H_{m\,single}}$$

But We know The formula for sp. speed of a pump

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}} \quad \text{Then} \quad H_{m_{single}}^{3/4} = \frac{N\sqrt{Q}}{N_s}$$

$$H_m^{3/4} = \frac{1000\sqrt{200 \times 10^{-3}}}{800}$$

$$H_m = (0.5590)^{4/3} \Rightarrow H_{m_{single}} = 0.4605\,M$$

$$\text{no. of pumps } n = \frac{H_{m\,Total}}{H_{m\,single}} = \frac{90}{0.4605} = 195.43 \Rightarrow 196 \text{ pumps}$$

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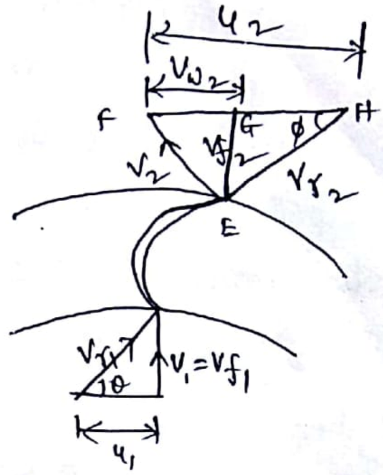
:- 3 [2015] [8M]

centrifugal pump while running at 800 rpm discharges 100 litres/sec against a net head of 14m The manometric efficiency of pump is 78%. If the vane angle at the outlet is 35° and the velocity of flow is 2 m/sec Determine the outer diameter of the impeller

Given data:-



Speed $N = 800$ R.P.M

Discharge $Q = 100$ litres/sec $= 100 \times 10^{-3}\ m^3/sec$

Net Head $H_m = 14M$

$\eta_{Manometric} = 78\% \Rightarrow 0.78$

Vane angle at outlet $\phi = 35^\circ$

velocity of flow $V_{f_2} = 2\ m/sec$

Diameter at outlet $D_2 = ?$

FROM The Triangle EGH

$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}}$$

Then

$$u_2 - V_{w_2} = \frac{V_{f_2}}{\tan\phi} = \frac{2}{\tan 35^\circ}$$

$$u_2 - V_{w_2} = 2.8562$$

$$\boxed{u_2 = 2.8562 + V_{w_2}}$$

From $\eta_{manometric} = 0.75$

$$\eta_{Mano} = \frac{gH_m}{V_{w_2} u_2} = 0.75$$

$$V_{w_2} u_2 = \frac{gH_m}{0.75}$$

$$V_{w_2} u_2 = \frac{9.81 \times 14}{0.75} = 176.076$$

Subsitute The u_2 Value In these Equation

$$V_{w_2}\left[2.8562 + V_{w_2}\right] = 176.076$$

$$V_{w_2}^2 + 2.8562\, V_{w_2} - 176.076 = 0$$

Then From calculator $V_{w_2} = 11.917\ m/s$

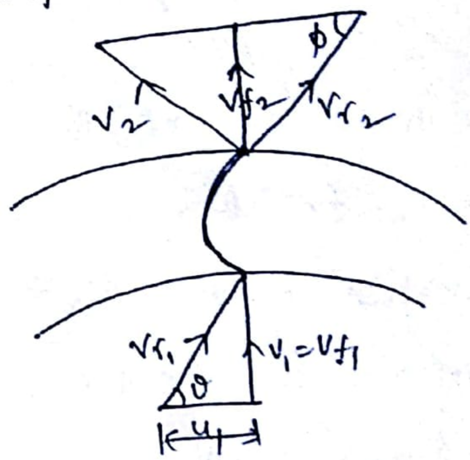
Then $u_2 = \frac{176.076}{11.917} = 14.775\ m/s$

$$\frac{\pi D_2 N}{60} = u_2 = 14.775 \text{ m/s}$$

$$D_2 = \frac{60 \times 14.775}{\pi \times 800} = 0.3527 \text{ m} = \underline{\underline{352.7 \text{ mm}}}$$

Pb:- 4 [2015] [8M]

A centrifugal pump delivers water against a net head of 10m at a design speed of 800 rpm. The vanes are curved backwards and make an angle of 30 degrees with the tangent at the outer periphery. The impeller diameter is 30cm and has a width of 5cm at the outlet. Determine the discharge of the pump if the manometric efficiency is 85%



Net head $H_m = 10\text{m}$

Design speed $N = 800$ R.P.M

outlet vane angle $\phi = 30^\circ$

Diameter at outlet $D_2 = 30\text{cm} = 0.3\text{m}$

width at outlet $B_2 = 5\text{cm} = 0.05\text{m}$

$$\boxed{Q = \pi D_2 B_2 V_{f_2} = ?}$$

$$\eta_{manometric} = 0.85 = \frac{gH_m}{V_{w_2} u_2}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.3 \times 800}{60} = 12.566 \text{ m/s}$$

Then $\eta_{man} = 0.85 = \frac{gH_m}{V_{w_2} u_2}$

$$V_{w_2} = \frac{9.81 \times 10}{0.85 \times 12.566} = 9.184 \text{ m/s}$$

$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}} \quad \text{Then} \quad V_{f_2} = (u_2 - V_{w_2})\tan\phi = (12.566 - 9.184)\tan 30^\circ$$

$$V_{f_2} = 1.952 \text{ m/s}$$

$$Q = \pi D_2 B_2 \times V_{f_2} = \pi \times 0.3 \times 0.05 \times 1.952 = 0.0919 \text{ m}^3/\text{sec}$$

Q-5 [2016] [8M] 17

The Internal and External diameters of the impeller of a centrifugal pump are 300mm and 600 mm Respectively The pump is running at 1000 R.P.M The vane angles at Inlet and outlet are 20° & 30° respectively The water Enters the Impeller Radially and velocity of flow is constant Determine the W.D by The Impeller per unit weight of water

Given data:-

Internal Diameter $D_1 = 300mm = 0.3 m$

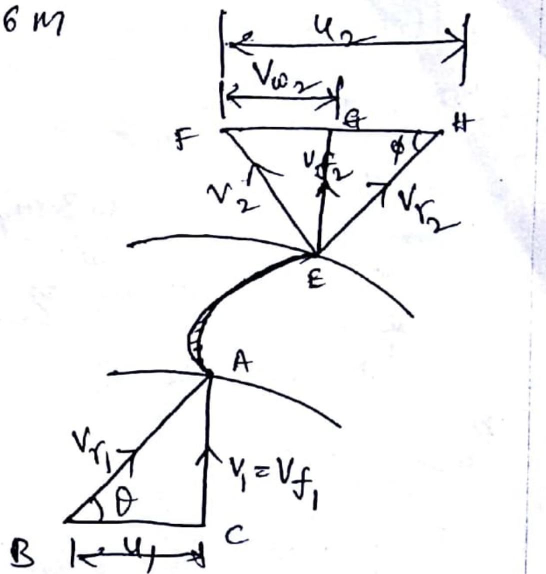
External Diameter $D_2 = 600mm = 0.6 m$

Speed $N = 1000$ R.P.M

Vane angle at Inlet $\theta = 20°$

Vane angle at outlet $\phi = 30°$

$V_{f_1} = V_{f_2} =$ constant



$\frac{\text{Work done}}{W} = ?$ $\quad \frac{W[V_{w_2} u_2]}{W g}$

$= \frac{1}{g}[V_{w_2} u_2]$

But $u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times 1000}{60}$

$u_2 = 31.415$ m/s

From Inlet velocity Triangle ΔABC

$\tan\theta = \frac{V_{f_1}}{u_1}$ $\quad \left[\because u_1 = \frac{\pi D_1 N}{60} \quad u_1 = \frac{\pi \times 0.3 \times 1000}{60} \quad u_1 = 15.71 \right]$

$\tan 20 = \frac{V_{f_1}}{15.71} \Rightarrow V_{f_1} = V_{f_2} = 5.717$ m/s

From Triangle ΔEGH

$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}}$

$\tan 30 = \frac{V_{f_2}}{u_2 - V_{w_2}}$

Then $V_{w_2} = ~~5.8057~~$ m/s 21.6

$\frac{W.D}{W} = \frac{1}{g}[~~5.8057~~ 21.6 \times 31.415]$

$\frac{W.D}{W} = ~~9.8~~$ 69.2 N.m/N

15

pb-6 [2016] [8M]

A centrifugal pump is running at 1000 R.P.M The outlet vane angle of the impeller is 30° and velocity of flow at outlet is 3m/s. The pump is working against a total head of 30m and the Discharge Through the pump is 0.3 m³/s. If the Manometric Efficiency of the pump is 75% Determine (i) the Diameter of the Impeller and width.

Given data:-

Speed $N = 1000$ R.P.M

outlet vane angle $\phi = 30°$

outlet velocity of flow $V_{f_2} = 3\ m/s$

Total Head $H_m = 30\ m$

Discharge $Q = 0.3\ m^3/s$

Manometric Efficiency $\eta_{Mano} = 0.75$

$D_2 = ?$ $B_2 = ?$

$$\eta_{mano} = 0.75 = \frac{gH_m}{V_{w_2}u_2}$$

$$V_{w_2}u_2 = \frac{9.81 \times 30}{0.75} = 392.4 \quad \text{—(i)}$$

$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}}$$

$$u_2 - V_{w_2} = \frac{V_{f_2}}{\tan\phi} = \frac{3}{\tan 30} = 5.196$$

$$u_2 = 5.196 + V_{w_2} \quad \text{—(ii)}$$

Substitue (ii) In (i)

$$V_{w_2}[5.196 + V_{w_2}] = 392.4$$

$$5.196\,V_{w_2} + V_{w_2}^2 = 392.4$$

$$V_{w_2}^2 + 5.196\,V_{w_2} - 392.4 = 0$$

Then $V_{w_2} = 17.3\ m/s$

$$u_2 V_{w_2} = 392.4$$

$$u_2 = \frac{392.4}{17.3} = 22.68\ m/s$$

$$\frac{\pi D_2 N}{60} = u_2 = 22.68$$

$$D_2 = .433\ m = 433\ mm$$

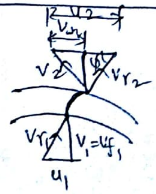
Then

$$Q = \pi \times D_2 \times B_2 \times V_{f_2}$$

$$B_2 = \frac{Q}{\pi \times D_2 \times V_{f_2}}$$

$$B_2 = \frac{0.3}{\pi \times 0.433 \times 3}$$

$$B_2 = 0.07349\ m = 73.49\ mm$$



angle
3 m/s.
discharge
the

Prob:- 7 [2016] [8M]

19

The diameter of an impeller of a centrifugal pump at inlet and outlet are 300 mm and 600 mm Respectively. The velocity of flow at outlet is 2.5 m/s and vanes are set back at an angle of 45° at outlet Determine the minimum starting speed of the pump If the Manometric Efficiency is 75%

Given data:-

Diameter at Inlet $D_1 = 300$ mm

Diameter at outlet $D_2 = 600$ mm

Velocity of flow at outlet $V_{f_2} = 2.5$ m/s

outlet vane angle $\phi = 45°$

$$\eta_{Mano} = 75\% = \frac{75}{100} \Rightarrow 0.75$$

Let the minimum starting speed = N

velocity triangles at outlet is

$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}} \quad (or) \quad u_2 - V_{w_2} = \frac{V_{f_2}}{\tan\phi} = \frac{2.5}{\tan 45} = 2.5$$

Then $\boxed{V_{w_2} = u_2 - 2.5}$ — ①

But $$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times N}{60} = 0.03141 N$$

$$\therefore V_{w_2} = 0.03141 N - 2.5$$

use the Formula for min starting speed

$$N = \frac{120 \times \eta_{Man} \times V_{w_2} \times D_2}{\pi [D_2^2 - D_1^2]} = \frac{120 \times 0.75 \times [0.3141N - 2.5] \times 0.6}{\pi [0.6^2 - 0.3^2]}$$

$$N = \frac{54 [0.03141N - 2.5]}{0.84823} = \frac{1.6956 N - 135}{0.84823} \Rightarrow 0.84737 N = 135$$

$\boxed{N = 159.31 \text{ R.P.M}}$

Pb:-3 [2016] [8M]

Find The Rise in pressure in the impeller of centrifugal pump through which water is flowing at the Rate of 15 Litre/sec. The Internal and External diameters of the impeller are 20 and 40 cm Respectively. The width of Impeller at Inlet and outlet are 1.6 cm and 0.8 cm. The pump is Running at 1200 r.p.m. The water Enters The impeller Radially at Inlet and The impeller vane angle at outlet is 30°. Neglect losses through The impeller.

Given data:-

Discharge $Q = 15$ Litre/sec $= 15 \times 10^{-3}$ m³/sec

Internal diameter $D_1 = 20$ cm $= \frac{20}{100} = 0.2$ m

External diameter $D_2 = 40$ cm $= \frac{40}{100} = 0.4$ m

width at Inlet $(B_1) \Rightarrow B_1 = 1.6$ cm $\Rightarrow 0.016$ m

width at outlet $B_2 = 0.8$ cm $= 8 \times 10^{-3}$ m

Speed $N = 1200$ R.P.M

outlet vane angle $\phi = 30°$

$$V_{f_2} = \frac{Q}{A_2} = \frac{Q}{\pi D_2 B_2} = \frac{15 \times 10^{-3}}{\pi \times 0.4 \times 8 \times 10^{-3}} = 1.4920 \text{ m/s}$$

$$V_{f_1} = \frac{Q_1}{A_1} = \frac{Q}{\pi D_1 B_1} = \frac{15 \times 10^{-3}}{\pi \times 0.2 \times 0.016} = 1.4920 \text{ m/s}$$

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

press raise $= ? = \frac{1}{2g}\left[V_{f_1}^2 + u_2^2 - V_{f_2}^2 \operatorname{cosec}^2\phi\right]$

$$= \frac{1}{2 \times 9.81}\left[(1.492)^2 + (25.13)^2 - 1.4920^2 \operatorname{cosec}^2 30°\right]$$

Pr. Raise = 31.346 m

NPSH :- [2015] [4M]

21

- NPSH Means Net positive suction Head
- NPSH is very commonly used in pump Industry
- Actually the minimum suction conditions are more frequently specified In terms of NPSH
- The NPSH is Defined as the abosulute pressure Head at the Inlet to the pump, minus thus Vapour pressure Head, plus the velocity Head

$$\therefore NPSH = \frac{P_1}{\rho g} - \frac{P_v}{\rho g} + \frac{V_s^2}{2g}$$

[∵ Ab solute pressure at Inlet $= P_1$]

and

$$NPSH = H_a - H_v - h_s - h_{fs}$$

[Where H_a = atmospheric pr. Head
H_v = Vapoure pr. Head
h_s = suction Head
h_{fs} = friction losses in suction]

- If calulated NPSH value of pump is greater than the Required NPSH (or) standard NPSH Then That pump is cavitation free pump means less noise and Efficiental operated.
- If the calculated NPSH value of pump is less than the Required NPSH (or) Standard NPSH Then that pump is under cavitation Effect.

Pb:-9 The diameters of an Impeller of a centrifugal pump at Inlet and outlet are 30cm and 60cm Respectively. Determine the minimum starting speed of the pump If It works against a head of 30m

Given data:-

Dia of Impeller at Inlet $D_1 = 30cm = 0.3m$

Dia of Impeller at outlet $D_2 = 60cm = 0.6m$

Head $H_m = 30\ cm$

Let the minimum starting speed = N

use The Formula

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

$$\because u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times N}{60}$$

$$u_2 = 0.03141N$$

$$\because u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.3 \times N}{60}$$

$$u_1 = 0.0157N$$

$$\therefore \frac{(0.03141N)^2}{2g} - \frac{(0.0157N)^2}{2g} = 30 \Rightarrow (0.03141N)^2 - (0.0157N)^2 = 30 \times 2 \times 9.81$$

$$N = 891.8\ R.P.M$$

02

Pb:-10

Two geometrically similar pumps are Running at the same speed of 1000 R.P.M one pump has an Impeller Diameter of 0.3 metre and Lifts water at the Rate of 20 Liters/sec against a head of 15 metres. Determine the head and Impeller Diameter of the other pump to deliver half the discharge

For pump No:-1

Speed $N_1 = 1000$ R.P.M

Diameter $D_1 = 0.30$ m

Discharge $Q_2 = 20$ L/s $= 20 \times 10^{-3} m^3/s$

Head $H_{m_1} = 15$ m

For pump No:-2

Speed $N_2 = 1000$ R.P.M

Discharge $Q_2 = \frac{Q_1}{2} = \frac{20}{2} = 10$ Litres/sec $= 10 \times 10^{-3} m^3/s$

D_2 = Diameter of Impeller

H_{m_2} = Head Developed

$$\boxed{\frac{N_1\sqrt{Q_1}}{H_{m_1}^{3/4}} = \frac{N_2\sqrt{Q_2}}{H_{m_2}^{3/4}}} \Rightarrow \frac{1000 \times \sqrt{.02}}{15^{3/4}} = \frac{1000 \times \sqrt{.01}}{H_{m_2}^{3/4}}$$

Then $H_{m_2} = 9.44$ m

using Equation $\boxed{\frac{\sqrt{H_m}}{DN} = \text{Constant}}$ $\left(\frac{\sqrt{H_m}}{DN}\right)_1 = \left(\frac{\sqrt{H_m}}{DN}\right)_2$

$$\frac{\sqrt{H_{m_1}}}{D_1 N_1} = \frac{\sqrt{H_{m_2}}}{D_2 N_2} \Rightarrow \frac{\sqrt{15}}{0.3 \times 1000} = \frac{\sqrt{9.44}}{D_2 \times 1000}$$

$$D_2 = \frac{\sqrt{9.44} \times 0.3}{\sqrt{15}} = 0.238 \text{ m}$$

$\boxed{D_2 = 238.0 \text{ mm}}$

(22)

RECIPROCATING PUMPS

① Reciprocating pump is one type of "positive displacement pump"

② Reciprocating pump is used to convert Mechanical Energy into Hydraulic Energy in the form of pressure Energy.

③ The pressure Energy of the fluid is increased by the means of pushing action of plunger (or) piston

Classification of Reciprocating pumps:-

① Based on No. of cylinders

- ⓐ Single cylinder Reciprocating pump
- ⓑ Double cylinder Reciprocating pump } Multi cylinder Reciprocating pump.
- ⓒ Triple cylinder Reciprocating pump

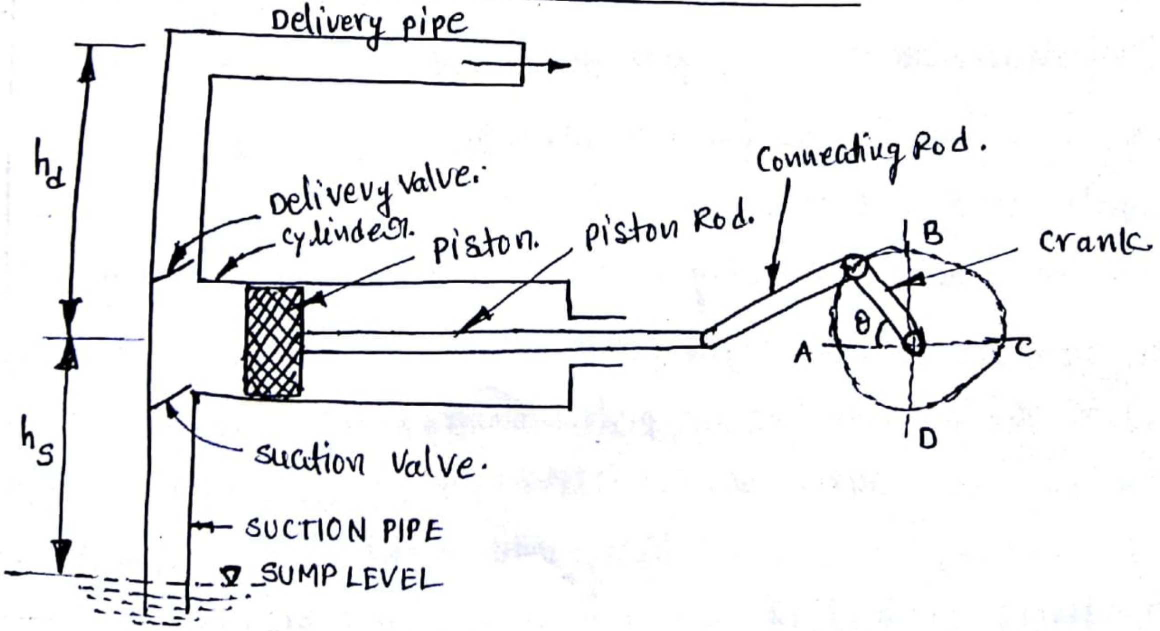
② Based on action of the fluid

- ⓐ single acting Reciprocating pump
- ⓑ Double acting Reciprocating pump

③ Based on the presence of Air vessel.

- ⓐ Reciprocating pump with Air vessel
- ⓑ Reciprocating pump without Air vessel.

MAIN PARTS OF A RECIPROCATING PUMP :-



24

Major parts are ① A cylinder with piston, piston rod, connecting rod and a crank.
② suction pipe
③ Delivery pipe
④ suction valve :- one way valve (or) Non return valve
⑤ Delivery valve :- one way valve (or) Non return value

(*) The first total crank mechanism is used rotary form energy of crank which is coming from Electrical motor is used to create Reciprocating motion of the ~~pum~~ piston

(*) suction pipe is connection b/w sump to the cylinder block.

(*) Delivery pipe is connection b/w cylinder block to discharge tank.

Working of A single acting Reciprocating pump :-

The crank is rotated by means of an Electric motor when crank starts rotating, The piston moves to and fro in the cylinder. When crank is at A., The piston is at the Extreme left position in the cylinder. As the crank is rotating from A to C [i.e from $\theta = 0°$ to $\theta = 180°$] The piston is moving towards right in the cylinder. The movement of the piston towards right creates a partial vaccum in the cylinder. But on the surface of the liquid in the sump atmospheric pressure is acting, which is more than The pressure inside The cylinder. Thus The liquid is forced in the suction pipe from the sump. This liquid opens The suction valve and Enters The cylinder

When crank is rotating from C to A [i.e from $\theta = 180°$ to $\theta = 360°$] The piston from its Extreme right position starts moving towards left in The cylinder. The movement of the piston towards left increases The pressure of the liquid inside The cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. The liquid is forced into the delivery pipe and is raised to a required height.

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Discharge through Single acting Reciprocating pump:-

Let d = Diameter of cylinder

A = cross-sectional area of the piston (or) cylinder

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

R = Radius of The crank Then stroke length $\boxed{L = 2R}$

N = R.P.M of The crank.

h_s = suction head h_d = delivery head

Volume of water Delivered In one Revolution

(or)

Discharge of water In one Revolution = $A \times L$

No. of Revolution per second = $N/60$

Discharge of pump per second = Q = Discharge in one Revolution × No. of Revolution per sec

$$\boxed{Q = AL \times \frac{N}{60} = \frac{ALN}{60}}$$

Work done by Reciprocating pump:-

Work done by Reciprocating pump per second is given by the

$\frac{W.D}{sec}$ = Weight of water lifted per second × Total height through which water is lifted

$= \dot{W} \times (h_s + h_d)$

$= \dot{m} g (h_s + h_d)$

$= \rho V a g (h_s + h_d)$

$\Rightarrow \rho Q g (h_s + h_d)$

$$\boxed{\frac{W.D}{sec} \Rightarrow \rho g Q (h_s + h_d) = \omega \times \frac{ALN}{60} \times [h_s + h_d]}$$

$\because \omega = \rho g$

$\because Q = \frac{ALN}{60}$

For Double acting

$$\frac{W.D}{sec} = \omega \cdot Q \cdot [h_s + h_d] \quad \left[\because \text{wher } Q = \frac{2ALN}{60}\right]$$

If piston Rod diameter is Negligable

$$\boxed{\frac{W.D}{sec} = \text{Power} = \omega \cdot \frac{2ALN}{60} [h_s + h_d]}$$

Co-efficient of Discharge:-

It is The Ratio of actual discharge to The theoritical discharge It is symbalically Represented as "C_d"

$$\boxed{C_d = \frac{Q_{actual}}{Q_{theoritical}}}$$

Slip:-

Slip of The pump is defined as the difference between the Theoretical discharge and actual discharge of the pump.

$$\boxed{\text{Slip} = Q_{theoritical} - Q_{actual}}$$

* The actual discharge of the pump is less than theoretical discharge due to leakage.
* If actual discharge of a pump is ~~les~~ more than the theoretical Discharge The slip of the pump will become "$-ve$"
* Negative slip occurs when delivery pipe is short, suction pipe is Long and pump is Running at High speed.

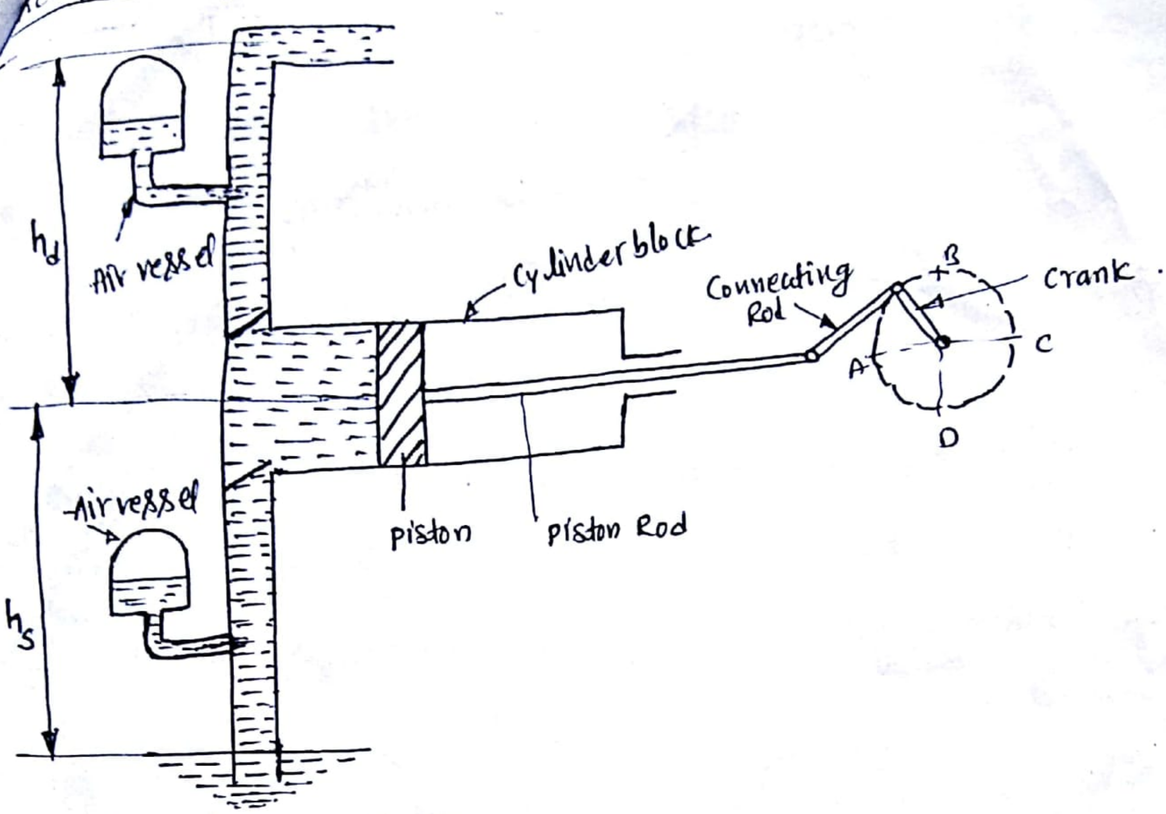
Percentage of slip:-

$$\% \text{ slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100 = \left[1 - \frac{Q_{act}}{Q_{th}}\right] \times 100$$

$$\% \text{ slip} = [1 - C_d] \times 100 \quad \boxed{\because \frac{Q_{act}}{Q_{th}} = C_d}$$

(26)

Reciprocating pump with Air vessel :-



✓ Air vessel is a closed chamber containg compressed air in top portion and liquid (or water) at the bottom of the chamber.

✓ At the base of the chamber there is an opening through which the liquid (or) [water] may flow into the vessel (or) out from the vessel.

✓ When the liquid enters the air vessel, the air gets compressed further and when the liquid flows out the vessel, the air will expand in the chamber.

✓ An air vessel is fitted to the suction pipe and to the delivery pipe at a point close to the cylinder of a single-acting Reciprocating pump.

(i) To obtain a continuous supply of liquid at a uniform rate.

(ii) To save a considerable amount of work in overcoming frictional Resistance in the suction and delivery pipes.

(iii) To Run the pump at high speed without separation.

✓ $W.D/sec = \rho g \left[\frac{ALN}{60}\right] \left[h_s + h_d + h_{fs} + h_{fd}\right]$

28

COMPARISON BETWEEN CENTRIFUGAL PUMPS AND RECIPROCATING PUMPS :-

Centrifugal pumps	Reciprocating pumps
① It Roto dynamic pump	① It is positive displacement pump.
② The Discharge is continuous and smooth	② ~~It handl~~ The discharge is fluctuating and pulsating
③ It can handle large quantity of Liquid	③ It handles small quantity of Liquid.
④ It can be used for Lifting highly viscous Liquids	④ It is used only for Lifting pure water (or) Less viscous Liquids.
⑤ It is used for Large Discharge through smaller heads	⑤ It is meant for small Discharge and High heads
⑥ Cost of centrifugal pump is less as compared Reciprocating pump.	⑥ Cost of Reciprocating pump approximately four times the cost of centrifugal pump.
⑦ The operation of centrifugal pump is smooth and without much noise. The maintenance cost is low.	⑦ The operation of Reciprocating pump is complicated and with much noise. The maintenance cost is high.
⑧ Efficiency is high	⑧ Efficiency is low.
⑨ centrifugal pump needs smaller floor area and Installation cost is low.	⑨ Reciprocating pump requires large floor area and Installation cost is high.

Q:-11

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 400 mm. Determine (i) The theoretical discharge of the pump
(ii) Co-efficient of discharge
(iii) slip and percentage of the slip.

Given data:-

Speed of the pump $N = 50$ r.p.m

actual discharge $Q_{act} = 0.01\ m^3/s$

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

$\therefore$ Area $A = \frac{\pi}{4}(0.2)^2 = 0.031416\ m^2$

stroke $L = 400\ mm = 0.40\ m$

(i) Theoretical discharge for single-acting Reciprocating pump is given by the Equation

$$Q_{th} = \frac{ALN}{60} = \frac{0.031416 \times 0.40 \times 50}{60} = 0.01047\ m^3/s$$

(ii) Co-efficient of discharge

$$C_d = \frac{Q_{act}}{Q_{th}} = \frac{0.001}{0.01047} = 0.955$$

(iii) $\text{slip} = Q_{th} - Q_{act} = 0.01047 - 0.01 = 0.00047\ m^3/sec$

$$\text{percentage of slip} = \frac{(Q_{th} - Q_{act})}{Q_{th}} \times 100 = \frac{(0.01047 - 0.01)}{0.01047} \times 100$$

$$= 4.489\%$$

Pb:-12

A double-acting Reciprocating pump, running at 40 r.p.m, is discharging 1.0 m^3 of water per minute. The pump has a stroke of 400 mm. The diameter of the piston is 200mm. The delivery and suction heads are 20m and 5m Respectively. Find the slip of the pump and power Required to drive the pump.

Given data

Speed of pump $N = 40$ R.P.M, Actual discharge $Q_{act} = 1.0\ m^3/min = \frac{1.0}{60} = 0.01666\ m^3/sec$

Stroke, $L = 400mm \Rightarrow 0.40m$

Diameter of piston $D = 200\,mm \Rightarrow 0.20\,m$

$\therefore$ Area $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.2)^2 = 0.031416\,m^2$

Suction head $h_s = 5m$ Delivery head $h_d = 20m$

Theoretical Discharge for double-acting pump is given by Equation

$$Q_{th} = \frac{2ALN}{60} = \frac{2 \times 0.031416 \times 0.4 \times 40}{60} = 0.01675\,m^3/s$$

$$slip = Q_{th} - Q_{act} = 0.01675 - 0.01666 = 0.00009\,m^3/s$$

Power Required to drive the double acting pump

$$P = \rho g \times \frac{2ALN}{60}[h_s + h_d] = 1000 \times 9.81 \times 0.01675 \times [5+20]$$

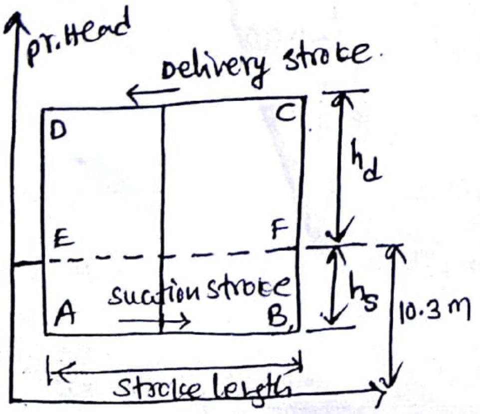
$$\boxed{P = 4.109\,kW}$$

INDICATOR DIAGRAM :-

✓ The Indicator diagram for a Reciprocating pump is defined as the graph between the pressure head in the cylinder and the distance travelled by piston from inner dead centre for one complete revolution of the crank.

✓ Distance travelled by the piston is stroke length.

✓ The pressure head is taken as ordinate and stroke length as abscissa



(*) Area of Indicator diagram is

$$AB \times BC = AB \times [BF + FC]$$
$$= L \times [h_s + h_d]$$

so we know the

$$W.D \propto L(h_s + h_d)$$

$\therefore$ Area of Indicator diagram directly proposal to work done.

(28)

30.8.16

UNIT-4 IMPACT OF JETS

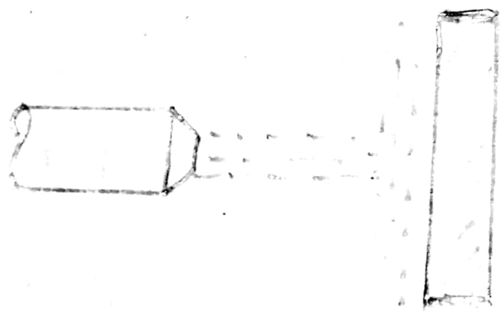
The liquid comes out in the from of the Jet in the Nozzle. which is Fitted to a pipe. through the liquid is through a under pressure.

* Impact of the Jet is classified into 2 types.

1. Force exerted by the plate on a stationary in the
   a) Plate is a vertical to the Jet
   b) " " inclined " " "
   c) " " curved " " "

2. Force exerted by the plate on a moving.
   a) Plate is a vertical to the Jet
   b) " " inclined " "
   c) " " curved " " "

* Force exerted by the Jet on a vertically stationary plate :-



The Jet of water striking to the plate will move along the plate, The plate is Rightangle of Jet the Jet of water striking to the Initil stage veloci

Eq (v). after Striking the velocity will be 0.

F_x = Rate of change of momentum in the direction of Force.

$$= \frac{\text{Initial Momentum} - \text{Final Momentum}}{\text{time}}$$

$$F_x = \frac{m \times V_I - m \times V_F}{T}$$

where after striking velocity = 0

$$\boxed{F_x} = \frac{m \times V_I}{T} = \rho a \cdot V \times V = \boxed{\rho a V^2}$$

1. Find the Force Exerted by the Jet of water

Given data:-

Sol:

$d = 75mm = 0.075m$

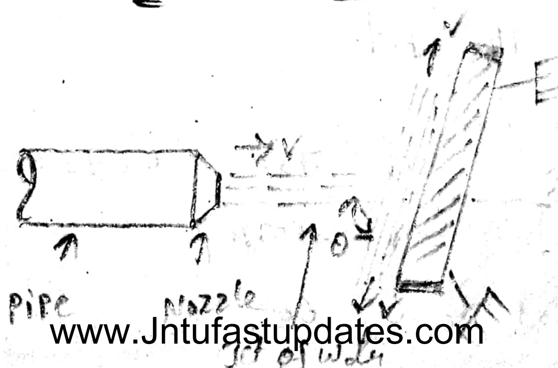
$V = 20 m/s$

$F_x = \rho a V^2 \Rightarrow \rho = 1000 \, kg/m^3, \; V = 20 m/s$.

Area, $(a) = \frac{\pi}{4}(d^2) = 0.0044 m^2$

$F_x = 1000 \times 0.0044 \times 20^2 = \boxed{1760 N.}$

2. Force Exerted by the Jet of a Stationary inclined Flat plate:-



the plate is Moving of Jet of water after striking with a velocity Equal to Initial velocity. There is No loss of Energy due to impact of the Jet.

F_n = mass of Jet striking per second × initial velocity - Final velocity.

$$F_n = \rho a v [v \sin\theta - 0]$$

$$\boxed{F_n = \rho a v^2 \sin\theta}$$

the Force canbe resolve with two components x & y directions.

$$F_x = F_n \times \sin\theta$$

$$= \rho a v^2 \sin\theta \times \sin\theta$$

$$= \rho a v^2 \sin^2\theta$$

$$F_y = F_n \times \cos\theta$$

$$= \rho a v^2 \sin\theta \times \cos\theta$$

$$\boxed{= \rho a v^2 \sin\theta \cdot \cos\theta}$$

2. A Jet of water dia. 75mm Moving with a velocity of 25m/s a Fixed plate in such a way that the angle between the Jet & plate is 60°. Find the Force Exited by the Jet on the plate & also Find the directions of the Jet

Sol: G.D:- $d = 75m = 0.075m$

$v = 25m/s$

$\theta = 60°$

$F_n = \rho a v^2 \sin\theta$

Area $(a) = \frac{\pi}{4} d^2 = \frac{\pi}{4}(0.075)^2 = 0.0044 m^2$

$F_n = 1000 \times 0.0044 \times 25^2 \times \sin 60$

$\boxed{F_n = 2381.6 N}$

$F_x = F_n \times \sin\theta$

$F_x = \rho a v^2 \sin^2\theta = 2381.6 \times \sin 60 = \boxed{2062.5 N}$

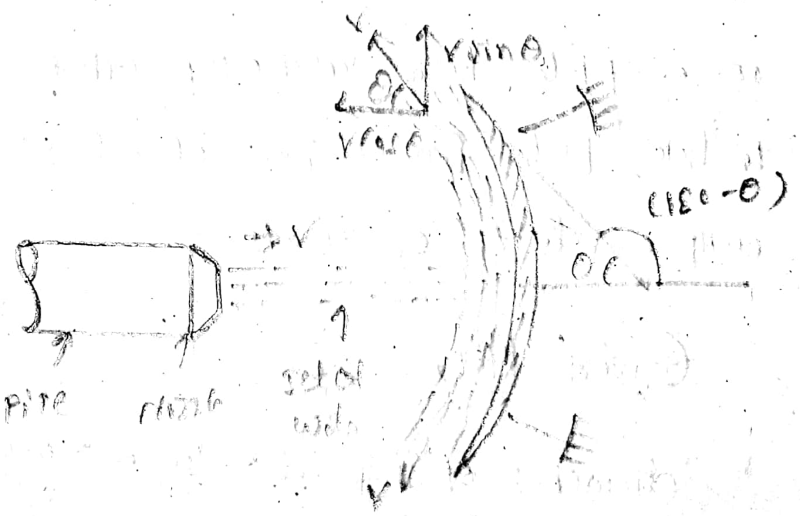
$F_y = F_n \times \cos\theta$

$= \rho a v^2 \sin\theta \cos\theta = 1190.3 N$

NOTE:- Force Exected by the stationary inclined Flat plate

$F_n = 2381.6 N$ $F_x = 2062.5 N$, $F_y = 1190.3 N$

* Force Exerted by the Jet of a stationary Curved plate:-



The Jet After striking the plate comes out to the with same velocity. if the plate is there is no loss of Energy due to Impact of Jet.

$F_x = \rho a v[(v - (-v\cos\theta))]$

$= \rho a v[v + v\cos\theta] = \rho a v^2(1 + \cos\theta)$

$F_y = -\rho a v^2 \sin\theta$

3. A Jet of water dia. 50mm. Moving with a velocity 40 m/s. striking a curved fixed plate at the centre. Find the Force Exerted by the Jet of the water if the Jet is deflected through a an angle of 60° out-let of the curved plate.

Sol: G.D:- $d = 50mm = 0.050m$, $V = 40m/s$

$a = 0.0019 m^2$

$F_x = \rho a v^2 (1+\cos\theta)$

$= 1000 \times 0.0019 \times 40^2 [1 + \cos 60°] = 4560N$

$F_y = -\rho a v^2 \sin\theta$

$= -1000 \times 0.0019 \times 40^2 \sin 60 = -2632.7N$

(Neglected)

* A Jet of diameter 40mm strikes Horizontally on a Plate held vertically. What Force is required to hold plate for a Flow of oil of Spe-gravity 0.8 with a velocity of 30 m/s.

Sol:

Given that,

diameter of jet, $d = 40mm = 0.04m$

Specific gravity of oil, $S_o = 0.8$

Density of oil, $\rho_o = 0.8 \times 1000 = 800 kg/m^3$

velocity of oil, $V = 30 m/sec$.

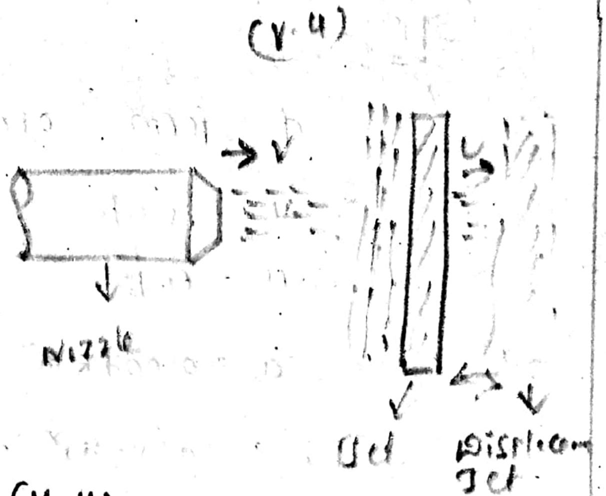
The expression for Force exerted by the Jet on a Stationary vertical plate is given by

$F = \rho_0 a v^2 = 800 \times \frac{\pi}{4} \times (0.04)^2 \times (30)^2 = 904.778 N.$

Force exerted by Jet on a Moving Flat plate :–

A Jet of water striking vertical plate moving with a uniform velocity . a way from the Jet

where,



Relative velocity of Jet (V-u).

mass of water striking the plate per second. F(x)

= ρ × Area of Jet × velocity in strike on the plate

= $\rho a (V-u)$

Force exerted by the inclined plate

$f(x) = \rho a (V-u)(V-u-0)$

$= \rho a (V-u)^2$

Workdone per second by the Jet of the plate

$$= \frac{\text{Force} \times \text{Displacement Moving by Jet}}{\text{Time}}$$

$= F_x \times u$

$= \rho a (V-u)^2 \times u$

1. A Jet of water diameter 10cm strikes a Flat Plate Normal with a velocity of 15m/sec. The plate is Moving with a velocity of 15m/s. 4 6m/s. in the direction of the jet. Find the workdone per second by the Jet of the plate?

Sol:-

$d = 10cm = 0.1m$

$V = 15m/s$

$u = 6m/s$

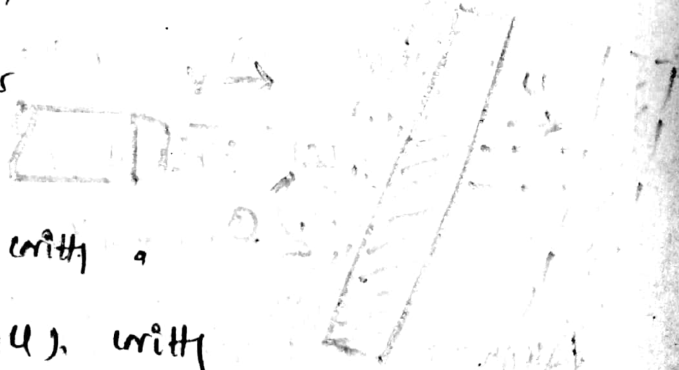
$a = 0.0078 m^2$

$F_x = \rho a (V-u)^2 = 631.8 N$

$W/s = F_x \times u = 3790.8 Nm/s.$

2. Force Exerted by the Jet on a moving inclined plate:-

The plate is Move 4 loss of Energy due to Impact of the Jet is always



⊙. if inclined plate with a velocity equal to (V-u), with Respect of Angle b/w Jet 4 plate.

The Force Exerted by Jet of water with n direction

$F_n = \rho a (V-u)\left[(V-u)\sin\theta\right] = \rho a (V-u)^2 \sin\theta.$

The Normal Force Resolve the x 4 y direction

$F_x = F_n \sin\theta = \rho a (v-u)^2 \sin\theta \times \sin\theta = \rho a (v-u)^2 \sin^2\theta$

$F_y = F_n \cos\theta = \rho a (v-u)^2 \sin\theta \cdot \cos\theta$

A 7.5 cm Dia Jet having a velocity of 30m/sec. Strikes a inclined plate at 45°. Find the Normal pressure of the plate, when the plate is moving with a velocity of 15m/s, when the plate is stationary, Determine the power & efficiency of the jet

Given

$d = 7.5 cm = 0.075 m. \quad a = 0.00441 m^2$

$V = 30 m/s.$

$\theta = 45°$

Normal pressure $F_n = \rho a v^2 \sin\theta$

$= 1000 \times 0.00441 \times 30^2 \times \sin 45$

$= 2800.14 N$

II $u = 15 m/s$

moving inclined plate $F_n = \rho a (v-u)^2 \sin\theta$

$= 1000 \times 0.00441 \times (30-15)^2 \sin 45$

$= 701.6 N$

$F_x = F_n \times \sin\theta = 496.12 N$

$F_y = F_n \times \cos\theta = 496.12 N$

IV Condition Power $= \dfrac{\text{workdone/sec}}{1000}$

$w/s = F_x \times U = 496.12 \times 15 = 7441.8 \text{ N m/sec}$

$P = \dfrac{w}{1000} = \dfrac{7441.8}{1000} = 7.4418 kW.$

V Efficiency of the jet $= O/I = \dfrac{\text{workdone/sec}}{\text{Kinetic energy}}$

$K.E = \frac{1}{2} m v^2 = \frac{1}{2} \rho a v (v^2)$

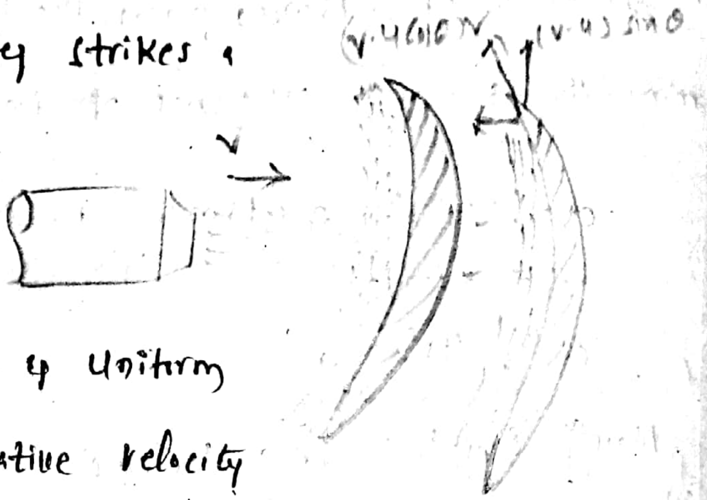
$= \frac{1}{2} \times 1000 \times 0.00441 \times 30 \times 30^2$

$= 59535.$

$\eta_{eff} = \frac{7441.8}{59535} = 0.1249 = 12.4\%.$

Force Exerted on a moving Curved plate:-

A Jet of water strikes a Centre of the plate which is moving a absolute velocity of uniform velocity. The relative velocity of Jet $(V-u)$.



The direction of Flow with Respect to X-Axis is $(V-u) \sin\theta$.

The direction of Flow with Respect to Y-Axis is $(V-u) \cos\theta$

The Normal Force Acting on the Moving Curved plate.

F_n -

when F_n = Negligible

$F_x = \rho a (V-u)^2 (1+\cos\theta)$

$F_y = \quad " \quad (1+\sin\theta)$

workdone per second $F_x \times u$

$w/s = \rho a (V-u)^2 (1+\cos\theta) \times u$

$= \rho a (V-u)^2 \times u (1+\cos\theta).$

A Jet of water dia. 7.5cm & strikes a curved plate at a velocity 20m/sec. The plate moving with a velocity 8 m/sec. The jet deflected through an angle of 165°. Find Force Exerted on the plate & Power of the Jet & Efficiency of Jet

$d = 7.5cm = 0.075m$, $a = 0.00441 m^2$

$V = 20 m/s$

$u = 8 m/s$

Deflected angle $\theta = 180 - 165 = 15°$

I $F_x = \rho a (V-u)^2 (1+\cos\theta)$

$= 1000 \times 0.00441 \times (20-8)^2 (1+\cos 15) = 1248.44N.$

workdone/sec $= F_x \times u = 1248.44 \times 8 = 9987.52 N$

II. Power $= \frac{\text{workdone/sec}}{1000} = \frac{9987.52}{1000} = 9.98752 KW$

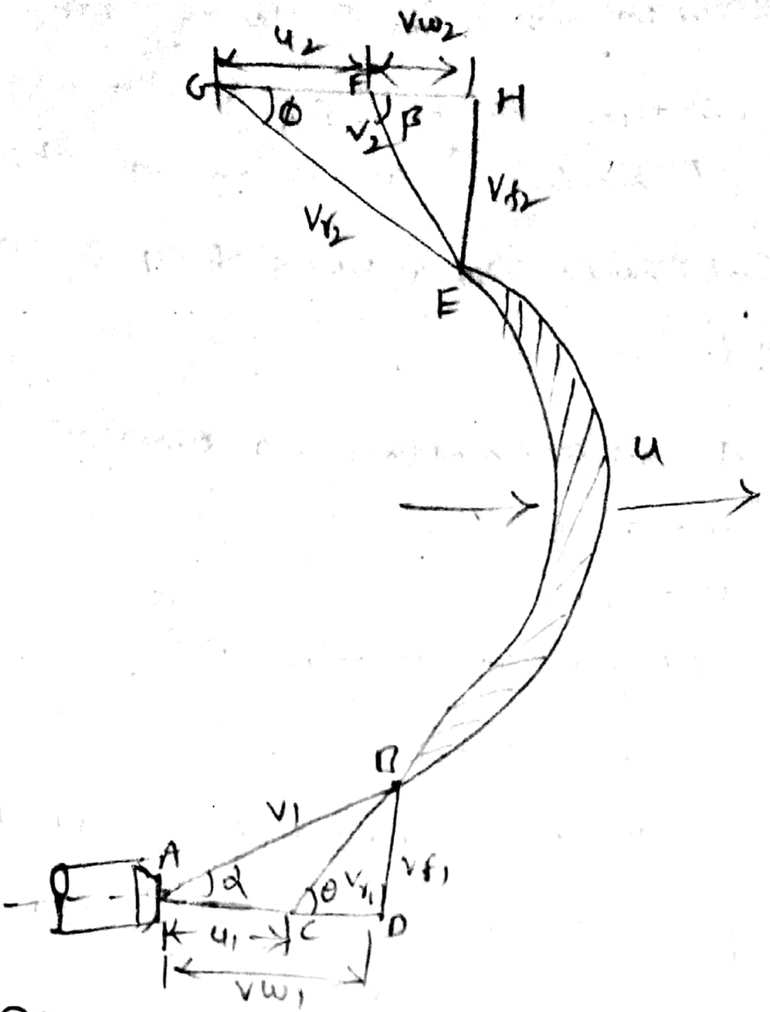
$\eta = O/I = \frac{w/s}{K.E} = \frac{9.98752}{\frac{1}{2}\rho a v^3} = \frac{1}{2} \times 1000 \times 0.00441 \times 20^3$

$= 17640 = 0.566 = 56.6\%$.

Force Exerted by the Jet of a water at unsymmetrically Moving Curved plate :- when Jet strikes at Tangentially one of the Tip:-

* A Jet of water striking a Moved curved plate is Tangentially is one of the tip. the Jet strikes Tangentially. the loss of Energy due to impact of the Jet will be zero. The velocities of water strikes to the Jet is Equal to Relative Velocity

* The Relative Velocity of inlet should be Equal to the



- Difference of velocity at inlet.

* TERMS:-

V_1 - Velocity of the Jet at inlet

u_1 - Velocity of the plate at inlet

Vr_1 - Relative velocity of Jet at inlet

Vw_1 - Velocity of whirl at inlet

Vf_1 - velocity of flow at inlet

α - Angle b/w the direction of the Jet & direction of the Motion of the plate.
(Guide blade angle)

θ = Angle made by the Relative velocity with the Direction of Motion

V_2 - Velocity of Jet leaving the vane (outlet velo).

u_2 - velocity of the vane at out let

V_{r_2} - Relative velocity at outlet

V_{w_2} - velocity of wirror at outlet

V_{f_2} - velocity of flow at outlet

θ - Angle made by the velocity at outlet.

ϕ - The vane Angle at outlet

Velocity Tringle at inlet,

The Tringle ABD is given for inlet velocity Triangle

where A→B - velocity at inlet

B→D - velocity of flow at inlet

A→D - velocity of wirror at inlet

B→C - Relative velocity at inlet.

Velocity Tringle at outlet,

From ⌊GEH is given for outlet velocity trinsle

where G→F - velocity of vane at outlet

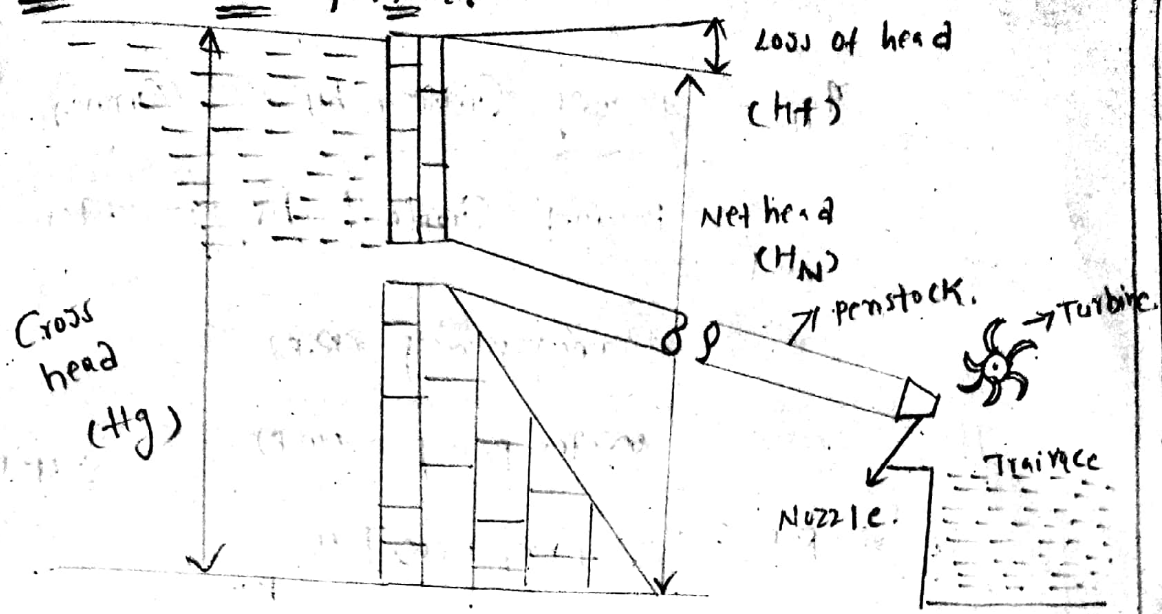
G→E - Relative Velocity of outlet

H→E - velocity of flow at outlet

F→H - velocity of wirror at outlet

F→E - velocity of Jet at outlet.

Layout of Power Plant:-



$$H_N = H_g - h_f.$$

Gross Head:- The diff b/w Head race level & Tail race level when the no water is flowing is known as Gross & H_g.

Net Head:- The difference b/w Gross Head & Loss of head.

$$H_N = H_g - h_f.$$

Efficiency of Turbines:-

They are Four types of efficiency is Mostly Turbines.

1. Hydraulic efficiency. (η_h)
2. Mechanical efficiency.
3. Volumetric efficiency
4. Overall efficiency.

1:- The Ratio of power given by water to the Runner of a turbine to the power supplied by the water at the inlet of the turbine.

$$\eta_H = \frac{\text{Power Supplied by the Runner}}{\text{Power Supplied by the water.}}$$

$$= \frac{\text{Runner power (R.P)}}{\text{water power (W.P).}}$$

$\because u = u_1 = u_2$

$$\therefore R.P = \frac{\frac{w}{g}[v_{w_1} \pm v_{w_2}]u}{1000} \text{ KW}$$

$$= \frac{\frac{w}{g}[v_{w_1}u_1 \pm v_{w_2}u_2]}{1000} \text{ KW}$$

W.P = Power supplied by the water at inlet to turbine

$$= \frac{W \times H_N}{1000} \text{ KW}$$

$W = \rho \times g \times Q$

$\because \rho = 1000$

$$W.P = \frac{\rho \times g \times Q \times H_N}{1000} \text{ KW}$$

2:- The Power Delivered by the water is TransmiT to the shaft of the turbine.

$$\eta_m = \frac{\text{Power Supplied by the shaft}}{\text{Power Supplied by the water to the runner}}$$

$$= \frac{\text{Shaft power (S.P)}}{\text{Running power (R.P)}}$$

3:- THe Volume of the water Striking the Runner of a turbine is Slightly Less than the Volume of water

Supplied to the Turbine.

$\eta_v =$

The ratio b/w mech. efficiency to the hydraulic efficiency.

$\eta_o =$

Peton Turbine:-

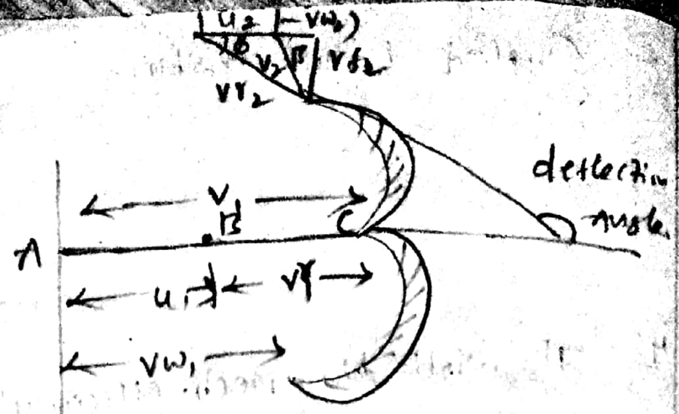
it is a impulse Turbine. which is used to Tangential ~~Axial~~ Flow. The buckets is Tangentially to the runner. The Pressure Head inlet & outlet of the turbine is Atmosphere. By using only K.E they are Four main parts

1. Nozzle 2 Runner 3 Casing 4. Breaking Jet

Casing is used it is preventing the Flashing of water and to discharge the water to Trail race. it is also using For safety clock against of accidents

in Breaking Jet Nozzle is completely closed by moving the speary in the Forword direction. To stop the runner. In a soft time. & snow Nozzle is privided which directs the jet of water on the back of the vanes.

Velocity Triangle of pelton wheels:-



* The velocity Triangle at inlet $V_1 = \sqrt{2gH}$
* Moving velocity. $u = u_1 = u_2 = \frac{\pi DN}{60}$.
* Relative velocity $V_{r_1} = V_1 - u_1$
* $V_{w_1} = V_1$

⇒ When θ & α is zero. With respect V_{f_1}.

* The force exerted by the jet of water $F_x = \rho a v (V - 0) u$.

$= \rho a V_1 (V_{w_1} \pm V_{w_2})$

* Net workdone by the jet on the runner per second.

$F_x \times u = \rho a V_1 (V_{w_1} \pm V_{w_2}) u$

$= \rho a V_1 (V_{w_1} u_1 \pm V_{w_2} u_2)$.

* Power of Net/workdone $= P = F_x \times u$ Nm/s

$= \frac{F_x \times u}{1000}$ kW

$= \frac{\rho a V_1 (V_{w_1} \pm V_{w_2}) u}{1000}$ kW

* Workdone per second per unit weight of water striking per second. $\frac{W/s}{W/water} = \frac{\rho a V_1 ((V_{w_1} \pm V_{w_2}) u)}{\rho a V_1 \times g}$

$= \left(\frac{V_{w_1} \pm V_{w_2}}{g}\right) u$

Workdone per second by K.E of Jet per second.

$$\eta_{Hyd} = \frac{R.P}{IN.P} = \frac{\rho a V_1 [V_{w_1} \pm V_{w_2}] u}{\frac{1}{2} \rho a V_1 \times V_1^2}$$

$$= \frac{2 (V_{w_1} \pm V_{w_2}) u}{V_1^2}.$$

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

$$= (V_1 - u) \cos\phi - u$$

$$\frac{2 (V_1 \pm (V_1 - u) \cos\phi - u) u}{V_1^2}.$$

NOTE:-

velocity of the Jet at inlet $V_1 = \sqrt{2gH}$ / $C_v \cdot \sqrt{2gH}$.

if C_v = Coefficient of velocity (0.98/0.99). if C_v not given.

The Moving velocity of the Jet $u = \frac{\pi D N}{60}$ / $\phi \cdot \sqrt{2gH}$

where $\phi = (0.43 - 0.48)$. when ϕ not given time.

Jet ratio :- The Rate of Pitch dia. (D). & wheel diameter of the Jet (d). $m = \frac{D}{d}$. (Mostly using 12 vanes).

No. of buckets m & Rurmg $Z = 15 + \frac{D}{2d}$.

19.9.15

6

A pelton wheel has a mean bucket speed 10m/s with a jet of water flowing at the 700 m/s under a head of 30m. The buckets deflected the angle 160°. calculate the power given by water to the runner and hydraulic efficiency of the turbine. Take, co-efficient of velocity 0.98.

Sol:

Given data:-

$u = u_1 = u_2 = 10 m/s$.

$Q = 700$ lit/sec $= 0.70 m^3/sec$

$H = 30m$

$\phi = 180 - 160 = 20°$

$\therefore$ I.P $= \frac{\rho a V_1 [V_{w1} + V_{w2}] \cdot u}{1000}$

$\eta_H = \frac{2[V_{w1} + V_{w2}] u}{V_1^2}$

$C_V = 0.98$.

$V_1 = C_V \cdot \sqrt{2gH}$

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

$= 23.77$ m/s

$V_{r1} = V_1 - u$

$= 23.77 - 10 = 13.77$ m/s.

$V_{w1} = V_1 = 23.77$ m/s.

$V_{w2} = V_{r2} \cos\phi - u$

$V_{r2} = V_{r1}$

$V_{w2} = 13.77 \cos 20 - 10 = 2.931$ m/s

$= \frac{\rho Q V [V_{w_1} + V_{w_2}] u}{1000}$ (here V_{w_1} + V_{w_2})

Because V_{w_1} is more than V_{w_2} value

$= \frac{1000 \times 0.70 (23.77 + 2.93) 10}{1000}$

$= 186.90$ kw.

$\eta_H = \frac{2(V_{w_1} + V_{w_2}) u}{V_1^2} = \frac{2(23.77 + 2.931)}{(23.77)^2} \times 10$

$= 0.945 = 94.5\%$

Pelton wheel is to be design Following specification.

Shaft Power 11772 kw

Head 380 m.

Speed 750 RPM.

Overall efficiency 86%.

Jet diameter is 1/6 of wheel diameter. Determine the ... of the Jet. & No of Jets & wheel diameter

Given:- S.P = 11772 kw.

head (H) = 380 m

Speed (N) = 750 rpm.

$\eta_0 = 86\% = 0.86$

$\frac{d}{D} = 1/6$

$\therefore d = ?$

$D = ?$

$N_j = ? = \frac{Q}{q}$

we have to Find out : $V_1 = C_V \sqrt{2gH}$

$= 0.98 \sqrt{2 \times 9.81 \times 380}$

$= 84.61$ m/s.

$u = u_1 = u_2$

$u = \phi \sqrt{2gH}$

$= 0.45 \sqrt{2 \times 9.81 \times 380}$

$= 38.85$ m/s

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

$$38.85 = \frac{\pi \times D \times 750}{60} \Rightarrow D = 0.989\ m.$$

$$\frac{d}{D} = \frac{1}{6}$$

$$d = \frac{1}{6} \times 0.989 = 0.16\ m.$$

one Jet discharge

$$q = a \times V_1$$

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

$$= \frac{\pi}{4} (0.165)^2 \times 84.61 = 1.70\ m^3/sec.$$

$$\eta_0 = \frac{S.P}{WP} \Rightarrow \frac{S.P}{\frac{\rho \times g \times Q \times H}{1000}}$$

$$\therefore 0.86 = \frac{11772}{\frac{1000 \times 9.81 \times Q \times 380}{1000}} \Rightarrow Q = 3.671\ m^3/sec$$

Total discharge.

$$\therefore \text{No. of Jet } N_j = \frac{Q}{q} = \frac{3.671}{1.70} = 2.15 \Rightarrow 2\ \text{Jets}.$$

20.9.16

3. A pelton wheel is Having a Mean dia. 1m. & it is running at 1000 rpm. The Net head on the pelton wheel is 700m. C

Sol: G.D:-

$D = 1m$

$N = 1000\ rpm.$

$H = 700m$

$\phi = 15^0$

$Q = 0.1 m^3/sec.$

$$P = \frac{WP}{1000} = \frac{\rho g H Q}{1000}\ kW$$

$$\eta_H = \frac{2(V_{w_1} + V_{w_2})u}{V_1^2}$$

$V_1 = C_V \cdot \sqrt{2gH} = 0.98 \sqrt{2 \times 9.81 \times 700} = 114.84$ m/s.

$u = \frac{\pi D N}{60} = \frac{\pi \times 1.0 \times 1000}{60} = 52.35$ m/s.

$$P = \frac{1000 \times 9.81 \times 0.1 \times 700}{1000}$$

$= 686.7$ kW.

$$\eta_h = \frac{2(V_1 + (V_1 - u)(\cos\phi - u))}{V_1^2}$$

$$= \frac{2(114.84 + (114.84 - 52.35)(\cos 15^\circ - 52.35))52.35}{114.84^2}$$

$= 0.97 = 97\%$.

A Jets strikes the bucket of a peton wheel which is having S.P - 15450 kW. The dia of the Each Jet is 200mm. If the Net head of Turbine 400m. Find the overall Efficiency. Coefficient of velocity is 1.

Given:- $C_v = 1$

$S.P = 15450$ kW

Dia $= 200$mm $= 0.2$m

Head $H = 400$m.

Discharge $Q = AV$.

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

$= \frac{\pi}{4}(0.2)^2$

$= 0.0314$ m².

$V = C_v \sqrt{2gH}$

$= 1 \times \sqrt{2 \times 9.81 \times 400}$

$= 88.58$ m/s.

Q = 2 times

2 Jets of $Q = AV \Rightarrow 2(A \times V)$

$= 0.314 \times 88.58 = 2.78$ m³/sec

$= 2.7 \times 2$

$= 5.56$ m³/s

$$\eta_o = \frac{15450}{\frac{1000 \times 9.81 \times 5.56 \times 400}{1000}} = 0.708 = 70\%.$$

5 Determine the power given by the jet of water to the runner of a which is having moving velocity 20 m/s. the net head of turbine 150m. a discharge through the jet of water 0.03 m³/sec. the clearance angle of side is 150°. Take Cv = 0.97.

Sol: G.D:

$H = 150m$

$Q = 0.03 m^3/sec.$

$u = 20 m/sec.$