FLUID M/C

CHAPTER-1 [Application of impulse momentum equation]

- Force = rate of change of linear momentum

Torque = rate of change of angular momentum

$$F = \dot{m}_2\vec{V}_2 - \dot{m}_1\vec{V}_1$$

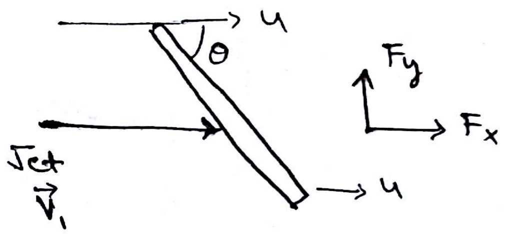
$$F_{jet} = -F_{plate} = \dot{m}_1\vec{V}_1 - \dot{m}\vec{V}_2$$ [here $\dot{m}$ = mass flow rate striking plate]

⇒ Flat plate

$F_x = \rho A (V_1 - u)^2 \sin^2\theta$

$F_y = \rho A (V_1 - u)^2 \sin\theta \cos\theta$

$W.D. = \rho A (V_1 - u)^2 \sin^2\theta \cdot u$

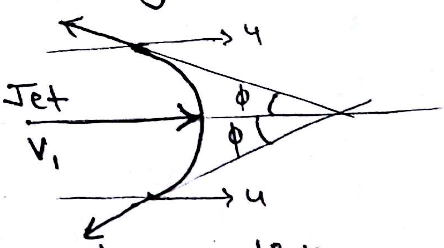


⇒ Symmetric curved plate, jet striking at center

$F_x = \rho A (V_1 - u)^2 (1 + \cos\phi)$

$F_y = 0$

$WD = F_x \cdot u$



⇒ Fixed curved plate, jet entering tangentially

$F_x = \rho A V_1^2 (\cos\theta + \cos\phi)$ here θ = Vane angle at inlet

$F_y = \rho A V_1^2 (\sin\theta - \sin\phi)$ ϕ = Vane angle at outlet

$WD = 0$

⇒ flat plate mounted on wheel

$F_x = \rho A V_1 (V_1 - u)$

$F_y = 0$

$WD = \rho A V_1 (V_1 - u) \cdot u$

$\eta_{max} = 50\%$ at $u = \frac{V_1}{2}$

⇒ Curve plate mounted on wheel, jet at center

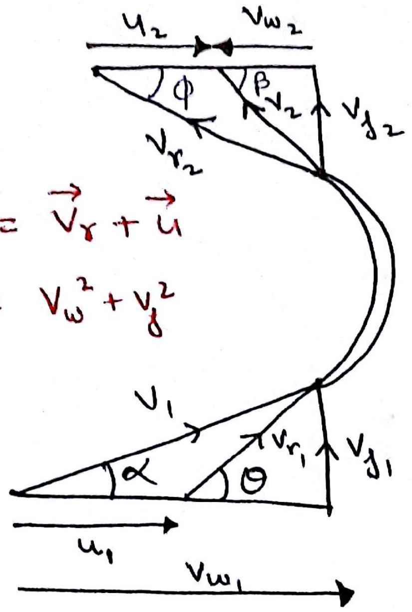
$F_x = \rho A V_1 (V_1 - u)(1 + \cos\phi)$

$F_y = 0$

$WD = F_x \cdot u$

$\eta_{max} = \frac{1 + \cos\phi}{2}$ at $u = \frac{V_1}{2}$

⇒ Curved plat mounted on wheel, jet enters tangentially



it is general diagram for turbine

$u_1 = \dfrac{\pi D_1 N}{60}$; $u_2 = \dfrac{\pi D_2 N}{60}$

$\vec{V} = \vec{V_r} + \vec{u}$

$V^2 = V_w^2 + V_f^2$

V_{r_2}, V_{r_1} ⇒ relative velocities

V_{w_1} & V_{w_2} ⇒ whirl velocities [i.e. tangential component of V_1 & V_2]

V_{f_1} & V_{f_2} ⇒ flow velocity

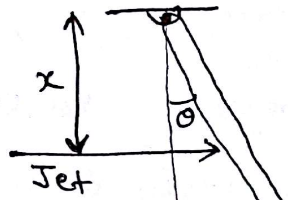
α, β = angle made by absolute velocities @ inlet & exit

θ, ϕ = vane angle @ inlet & exit

$$R.P. = \dot{m}\,(V_{w_1}u_1 + V_{w_2}u_2)$$

⇒ vertically hinged plate

$$\sin\theta = \frac{2 \times \rho A V_1^2 \times x}{W l}$$



CHAPTER - 2 [TURBINES]

⇒ Powers

W.P. = $\rho Q g H$ watt

R.P. = $\rho Q (V_{w_1}u_1 + V_{w_2}u_2)$ watt

S.P. = R.P. − mech. losses

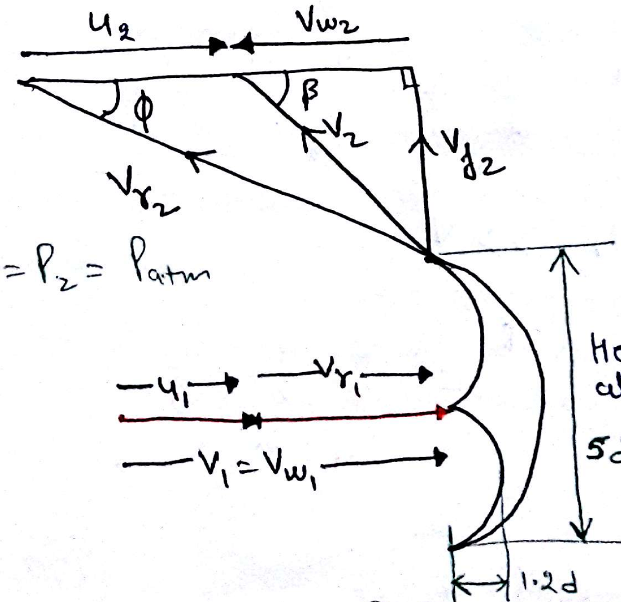
⇒ Efficiencies

$$\eta_v = \frac{Q - \Delta Q}{Q}$$

$$\eta_H = \frac{R.P}{W.P} \; ; \; \eta_{mech.} = \frac{S.P.}{R.P.}$$

$$\eta_o = \eta_H \times \eta_{mech.}$$

A) Impulse turbine [Pelton turbine] (tangential flow)



$P_1 = P_2 = P_{atm}$

⇒ $u_1 = u_2 = \dfrac{\pi D N}{60}$

$V_{r_2} = V_{r_1}$ → smooth vane

$V_{r_2} = K V_{r_1}$ → rough vane

K → coefficient of vane friction

Head available at inlet → $H = \dfrac{V_1^2}{2g}$ ⇒ $V_1 = \sqrt{2gH}$

$V_1 = C_v \sqrt{2gH}$ in case of losses in nozzle

- Jet ratio $= m = \dfrac{\text{Dia of wheel}}{\text{jet dia}} = \dfrac{D}{d}$

no. of vanes $= \dfrac{m}{2} + 15$

- $W.P. = \rho Q g H$

$R.P. = \rho Q\,(V_{w_1} + V_{w_2}) \cdot u$

- $\eta_H = \dfrac{R.P.}{W.P.} = \dfrac{(V_{w_1} + V_{w_2}) \cdot u}{gH}$

- Blade efficiency $= \eta_B = \dfrac{R.P.}{\frac{1}{2}\dot{m}V_1^2}$

$(\eta_H)_{max} = \dfrac{1 + K\cos\phi}{2}$ at $u = \dfrac{V_1}{2}$; $K =$ blade friction coefficient

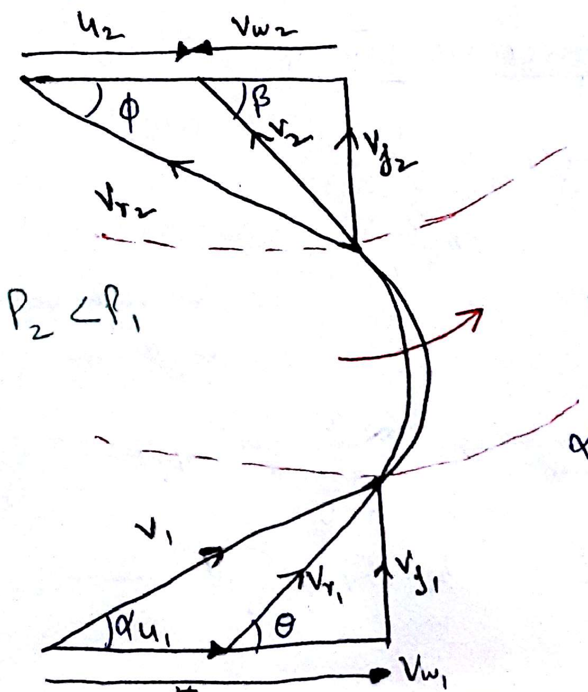
- $\delta =$ angle of deflection $= 180 - \phi$
- Above analysis is for single nozzle, for multinozzle :

$n =$ no. of jet $= \dfrac{\text{Total discharge from Penstock}}{\text{Discharge through 1 jet}}$

$(\text{Power})_{total} = n \times (\text{Power})_{1\,jet}$ [$n \not> 6$ for one rotor]

- Speed ratio $K_u = \dfrac{u_1}{\sqrt{2gH}}$

Impulse - Reaction Turbine [



$H \neq \dfrac{V_1^2}{2g}$

$H = \dfrac{V_1^2}{2g} + \dfrac{P_1}{\rho g}$

$\boxed{V_{r_2} >> V_{r_1}}$

$\alpha =$ guide blade angle or absolute velocity angle at inlet

$u_1 \neq u_2$

- $A_{f_1} = \pi d_1 b_1$; $A_{f_2} = \pi d_2 b_2$

$Q = A_{f_1} V_{f_1} = A_{f_2} V_{f_2}$

$Q = (\pi d - nt) b . V_f = K \pi d . b . V_f$
↳ coefficient of vane thickness

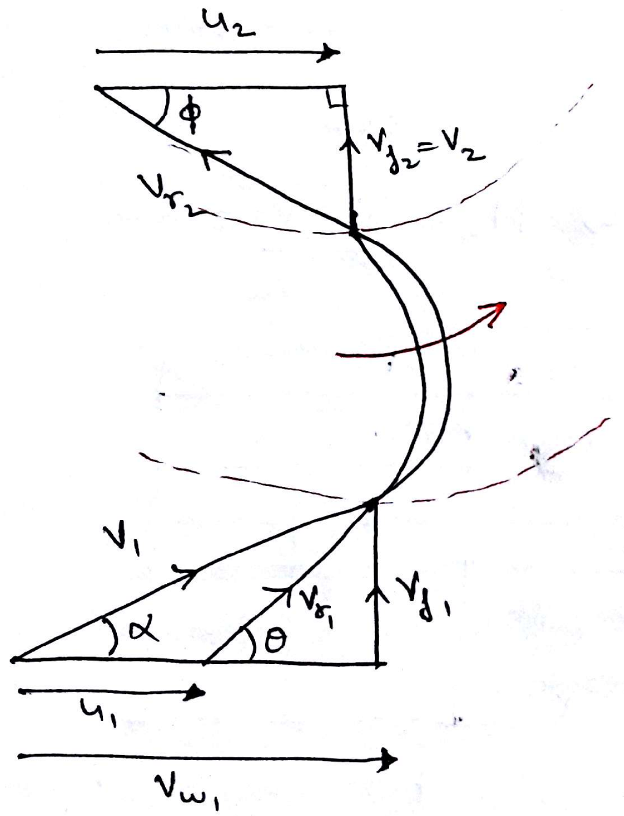
- Speed ratio $= \dfrac{u_1}{\sqrt{2gH}}$

flow rato $= \dfrac{V_{f_1}}{\sqrt{2gH}}$

- Degree of reaction $= R = \dfrac{\text{Contribution of Pr. E in } \frac{R.P}{mg}}{\text{total (KE + P.E) in } \frac{R.P.}{mg}}$

$$R = 1 - \frac{(V_1^2 - V_2^2)}{2g\left(\frac{R.P.}{mg}\right)}$$

B) <u>Impulse reaction turbine</u> (<u>Francis turbine</u>) [Radial flow]



⇓

$V_{w_2} = 0 \Rightarrow V_2 = V_{f_2}$
$\Rightarrow \beta = 90°$

$R = 1 - \dfrac{V_{w_1}}{2u_1}$ [when $V_{f_1} = V_{f_2}$]

$W.P. = \rho Q g H$

$R.P. = \rho Q (V_{w_1} u_1 + V_{w_2} u_2)$

$R.P. = \rho Q V_{w_1} u_1$

$\eta_H = \dfrac{R.P.}{W.P.} = \dfrac{V_{w_1} u_1}{gH}$

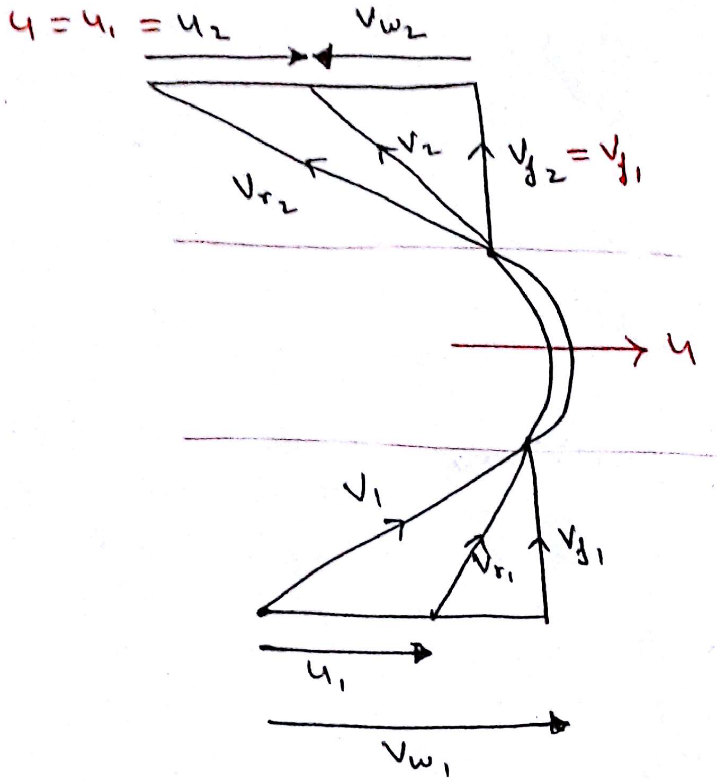
⇒ when $V_{w_2} = 0$; turbine gives maximum efficiency

⇒ Approximate eqn

$$H = \frac{V_2^2}{2g} + \frac{V_{w_1} u_1}{g}$$

[- when question get stucked
- when no friction
- when $V_{w_2} = 0$]

c) Impulse - Reaction turbine [Propeller or Kaplan] [Axial flow]



$$u = u_1 = u_2 = \frac{\pi D N}{60}$$

D = taken where analysis is done

$$\text{Ar of flow} = \frac{\pi}{4}\left(D_o^2 - D_h^2\right)$$

$$\left.\begin{array}{l} A_{f_1} = A_{f_2} \\ V_{f_1} = V_{f_2} \end{array}\right] \Rightarrow \text{always}$$

Rest calculations are same as Francis.

Propeller ⇒ blades are fixed

Kaplon ⇒ blades are adjustable so it give max. η at variable loads among all turbine.

- $$\eta_{DT} = \frac{\frac{V_2^2}{2g} - \frac{V_3^2}{2g} - h_f}{\frac{V_2^2}{2g}}$$

- Specific speed of turbine ⇒ $N_s = \frac{N \sqrt{P}}{H^{5/4}}$ (N → rpm, P → kW, H → m)

Specific speed	turbine	H	Q
0 – 60	Pelton	High	low
60 – 300	Francis	medium	medium
300 – 600 600 – 900	Prepeller Kaplan	low	High

- Model - Prototype relations [valid for both turbine & Pump]

$$\frac{H}{D^2 N^2} = K \qquad \frac{P}{D^5 N^3} = K$$

$$\frac{Q}{D^3 N} = K$$

- Unit Quantities [Used for a single turbine]

$$N_u = \frac{N}{\sqrt{H}} \qquad P_u = \frac{P}{H^{3/2}}$$

$$Q_u = \frac{Q}{\sqrt{H}}$$

- Performance Curve [main characteristic curve (H = const)]

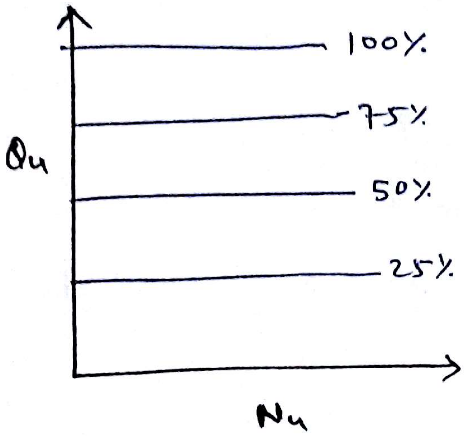


Fig => Impulse

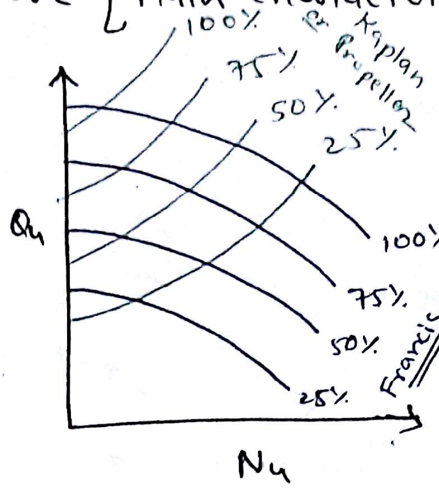


Fig:- Reaction

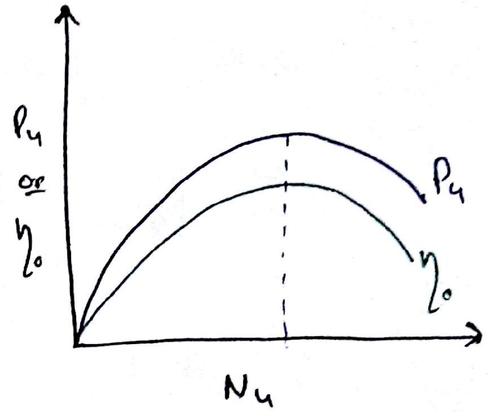
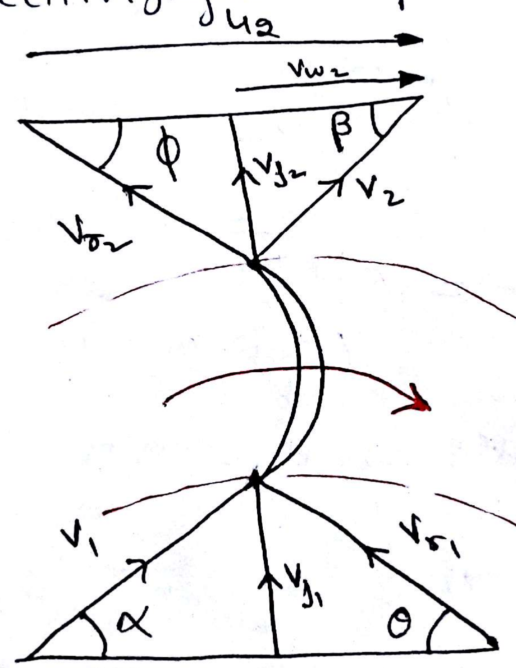


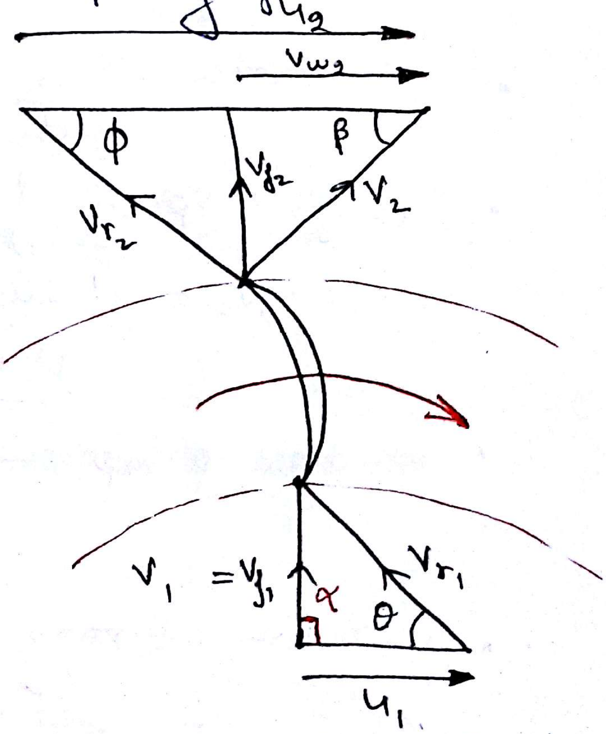
Fig:- All turbine

CHAPTER-3 [Pump]

- $\Delta P \propto \omega^2$
- centrifugal Pump works on Principle of forced vortex



General Pump



Centrifugal Pump

- H_m = manometric Head [Head required to pump the water]

- $I.P. = \rho Q (V_{w_2} u_2 - V_{w_1} u_1)$

$I.P. = \rho Q (V_{w_2} u_2) \longrightarrow$ for centrifugal

$\eta_{mano} = \dfrac{W.P.}{I.P.}$; $\eta_v = \dfrac{Q}{Q + \Delta Q}$

$W.P. = \rho Q g H_m$

- $\eta_o = \eta_{mano} \times \eta_{mech.}$; $\eta_{mech} = \dfrac{I.P.}{S.P.}$

$I.P. = S.P. -$ mech. losses

- $Q = A_{f_1} V_{f_1} = A_{f_2} V_{f_2}$

$A_f = \pi d b$

- Speed ratio $= K_u = \dfrac{u_2}{\sqrt{2gH_m}}$;

flow ratio $= K_f = \dfrac{V_{f_2}}{\sqrt{2gH_m}}$

- Dia ratio $= \dfrac{d_1}{d_2} \simeq 0.5$ generally

- Specific speed of Pump

$$N_s = \frac{N \sqrt{Q}}{H^{3/4}} = \frac{N\sqrt{Q}}{(gH)^{3/4}}$$

$N \rightarrow$ rpm, $Q \rightarrow m^3/s$, $H \rightarrow m$; dimensionless

- multiple pump $\longrightarrow$ Series $\Rightarrow$ $H_m = nH$
  $Q = Q_1 = Q_2$ ----

  Parallel $\Rightarrow$ $Q = Q_1 + Q_2 + Q_3$ ----
  $H_m = H_1 = H_2 = H_3$ ----

- minimum starting speed

$$\frac{2\pi N}{60} = \omega \geq \sqrt{\frac{2gH_m}{r_2^2 - r_1^2}}$$

- NPSH $= h_a - h_v - h_f - h_s$ $\rightarrow$ height above sump level

- Cavitation factor $= \sigma = \dfrac{NPSH}{H_m} \geq \sigma_c$ for no cavitation