Fluid Machinary

Pelton wheel → Tengential Flow machine

Francis turbine → Radial Flow machine (inward Flow)

Kaplan turbine → Axial Flow machine

Centrifugal Pump → Radial Flow M/c

Rotating element → Runner (power producing) / → Impeller (Power Consuming)

V_1 & V_2 → tangential Component (Responsible / → Radial Component / → Axial Component

Euler eqn

$$P = \dot{m}\left(V_{w_1}U_1 - V_{w_2}U_2\right) = \frac{\dot{m}}{2}\left[\left(V_1^2 - V_2^2\right) + \left(U_1^2 - U_2^2\right) + \left(V_{r_2}^2 - V_{r_1}^2\right)\right]$$

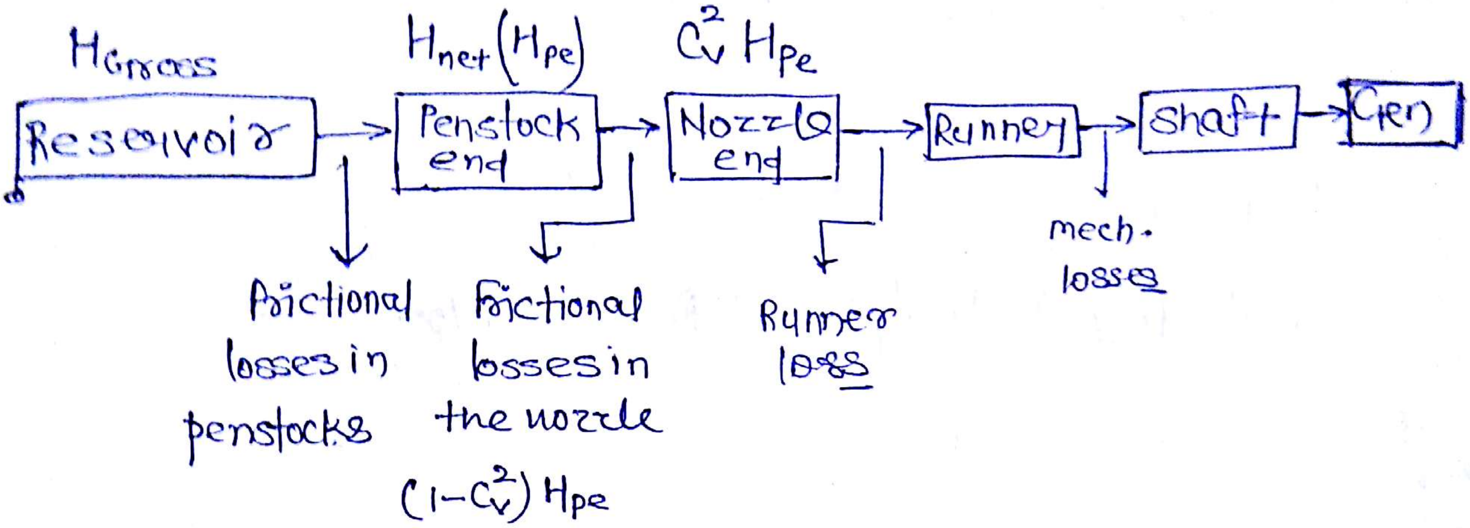
↳ power producing. m/c

$$P = \dot{m}\left(V_{w_2}U_2 - V_{w_1}U_1\right) = \frac{\dot{m}}{2}\left[\left(V_2^2 - V_1^2\right) + \left(U_2^2 - U_1^2\right) + \left(V_{r_1}^2 - V_{r_2}^2\right)\right]$$

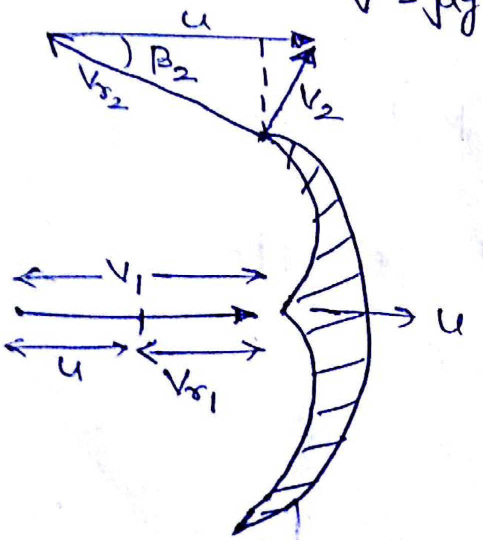
↳ Power Consuming m/c

$$\boxed{\vec{V}_r = \vec{V} - \vec{u}}$$

Pelton Turbine



$$V = \sqrt{2g\,H_{pe}}$$



Case ① $\quad V_{r_2}\cos\beta_2 < u$

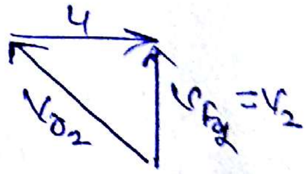
$$V_{w_2} = u - V_{r_2}\cos\beta_2$$

$$\dot{P} = \dot{m}\left(V_{w_1} - V_{w_2}\right)$$

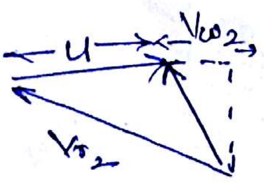
Case ② $\quad V_{r_2}\cos\beta_2 = u$

$$\therefore V_{w_2} = 0$$

$$P = \dot{m}\left(V_{w_1}\right)$$



Case ③



$$u < V_{r_2}\cos\beta_2$$

$$V_{w_2} = V_{r_2}\cos\beta_2$$

$$P = \dot{m}\left(V_{w_1} + V_{w_2}\right)$$

$$H = \frac{1}{2g}\left[(V_1^2 - V_2^2) + (V_{r_2}^2 - V_{r_1}^2)\right]$$

$$H_r = \frac{V_1^2}{2g} - \frac{V_2^2}{2g} - \underbrace{\left[\frac{V_{r_1}^2 - V_{r_2}^2}{2g}\right]}_{h_L}$$

$$h_f = \frac{V_{r_1}^2 - V_{r_2}^2}{2g}$$ loss in runner

↓

Valid for pure impulse turbine

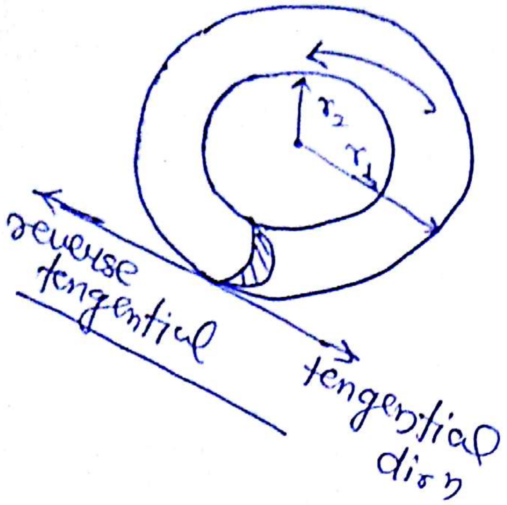
$$f = \frac{PN}{120}$$ → No of poll

$$f = \frac{PN}{60}$$ → pair of poll

Francis turbine

Reservoir → Penstock end → Guide Vane inlet → Runner → Shaft → Genr.

- Penstock end → Guide Vane inlet: losses in Volute casing + Guide Vane
- Guide Vane inlet → Runner: runner losses
- Runner ↓ Draft tube inlet ↓ Draft tube exit
- Draft tube inlet → Draft tube exit: losses in draft tube



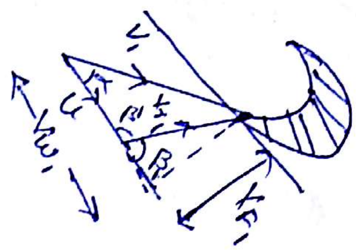
$$U_1 = r_1 \omega = \frac{\pi D_1 N}{60}$$

$$U_2 = r_2 \omega = \frac{\pi D_2 N}{60}$$

V_{w_1} & V_{w_2} → tengential Component

V_{r_1} & V_{r_2} → Radial Component.

Case-1



$V_{w_1} > U_1$ (low speed Francis turbine)

$$\left.\begin{array}{l} U_1 < V_{w_1} \\ \beta < 90^\circ \end{array}\right\}$$ अगर यह Cond^n satisfied हो रहा हो तो angle tengential dir^n से लिया है

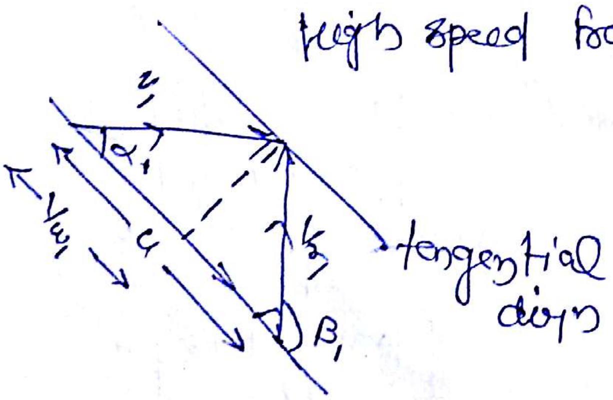
β_1 - from tengential dir^n

β_1' - Reverse tengential dir^n

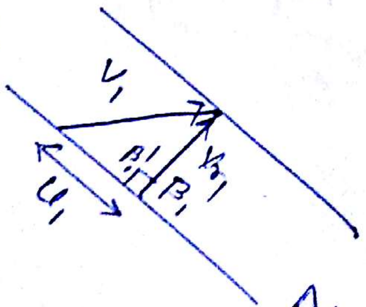
Case-2

$$\left.\begin{array}{l} U > V_{w_1} \\ \beta_1 > 90' \end{array}\right\}$$ अगर यह satisfield हो तो β_1 from reversedir^n

High speed francis turbine



Case-3



$U = V_{w_1}$

$\beta_1 = \beta_1' = 90^\circ$ from both dir^n

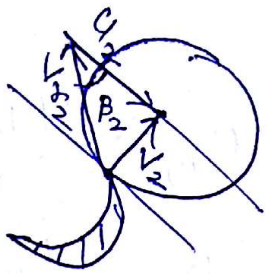
Imp $\left\{\begin{array}{l} \text{radial discharge} \\ \alpha_1 = 90^\circ \quad V_{w_1} = 0 \end{array}\right\}$

★ Radial discharge at outlet
or
water leaves the runner without whirl
or
Axial discharge

$\Big\}\ V_{w_2} = 0$

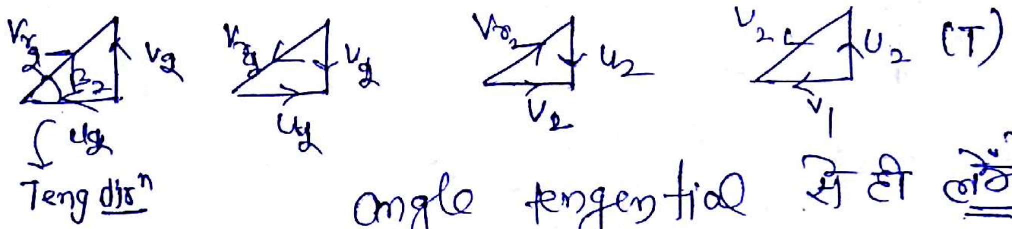
⇒ we can also assume radial discharge at outlet if Not Given.

At Outlet Velocity triange



$$\vec{V}_{r_2} = \vec{V}_2 - \vec{u}_2$$

समकोण त्रिभुज का of relative velocity



angle tengential से ही लेंगे

$$H_{pe} = (h_L)_{\text{Guide vane}} + H_r + (h_L)_{\text{runner}} + H_{\text{at inlet}}$$

Assumption

(i) No frictional losses.
(ii) radial discharge.
(iii) No draft tube
(iv) turbine at tailrace level

$$H_{pe} = H_r + \frac{V_2^2}{2g}$$

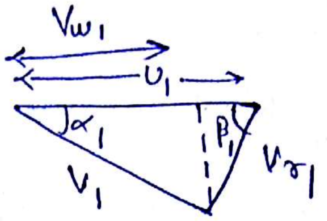
$$\boxed{H_{pe} = \frac{V_{w_1} V_1}{g} + \frac{V_2^2}{2g}}$$

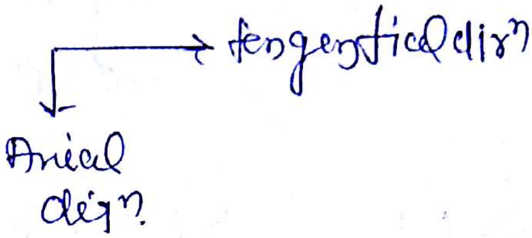
exit पर यह discharge करेगा

Kaplan turbine

Inlet velocity triangle of same as high speed Francis turbine (99.99% Case)

$\boxed{U_1 > V_{w_1}}$ — Always Check





In axial flow turbine

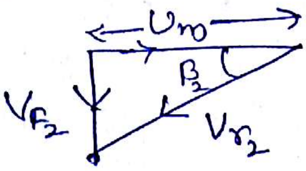
$V_{f_1} = V_{f_2}$ Always

$$Q = \frac{\pi}{4}\left(D_o^2 - D_h^2\right) \times V_f$$

$$U_m = \frac{\pi D_m N}{60}$$

$$D_m = \frac{D_o + D_h}{2}$$

at outlet



$$(\eta)_{\text{draft tube}} = \frac{\left\{\frac{V_2^2}{2g} - \frac{V_3^2}{2g}\right\} - h_L}{\left(\frac{V_2^2}{2g}\right)}$$

Centrifugal pump

Francis की उल्टा

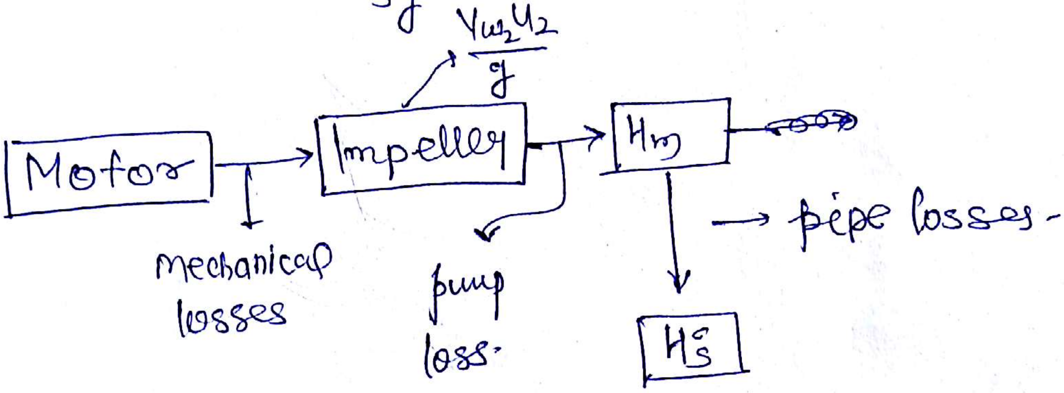
$$H_s + h_{LS} + h_{LD} = H_m$$

- H_s → static head
- h_{LS} → losses in suction pipe
- h_{LD} → losses in discharge pipe
- H_m → Manometric head

$$H_m = \left(\frac{P_D}{\rho g} + \frac{V_D^2}{2g} + Z_D\right) - \left(\frac{P_c}{\rho g} + \frac{V_c^2}{2g} + Z_c\right)$$

$Z_D \simeq Z_c$ (can also assume $V_D = V_c$)

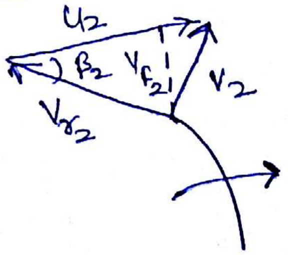
$$H_m = \frac{P_D - P_c}{\rho g}$$



$$\frac{V_{w_2} U_2}{g} = H_m + \text{Pump loss}$$

$$H_m = H_s + \text{pipe losses.}$$

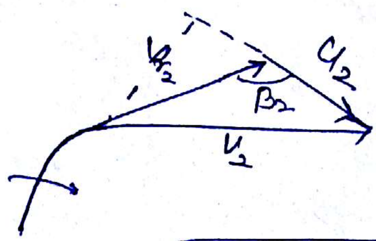
Backward curved Vane



$$V_{w_2} = U_2 - V_{f_2} \cot \beta_2 \qquad \beta_2 < 90^\circ \text{ (Always)}$$

$$U_2 > V_{w_2}$$

Forward Curved Vane



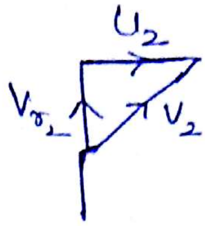
$$V_{w_2} > U_2$$

$$V_{w_2} = U_2 - V_{f_2} \cot \beta_2$$

$$\beta_2 > 90 \quad \cot \beta_2 < 0$$

$$\boxed{V_{w_2} > U_2}$$

radial vane

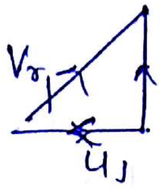


$U_2 = V_{w_2}$

$\beta_2 = 90°$

$\cot 90° = 0$

Velocity Δ at inlet



V_1 = Radial discharge at inlet

$V_{r_1} = V_1 - u_1$