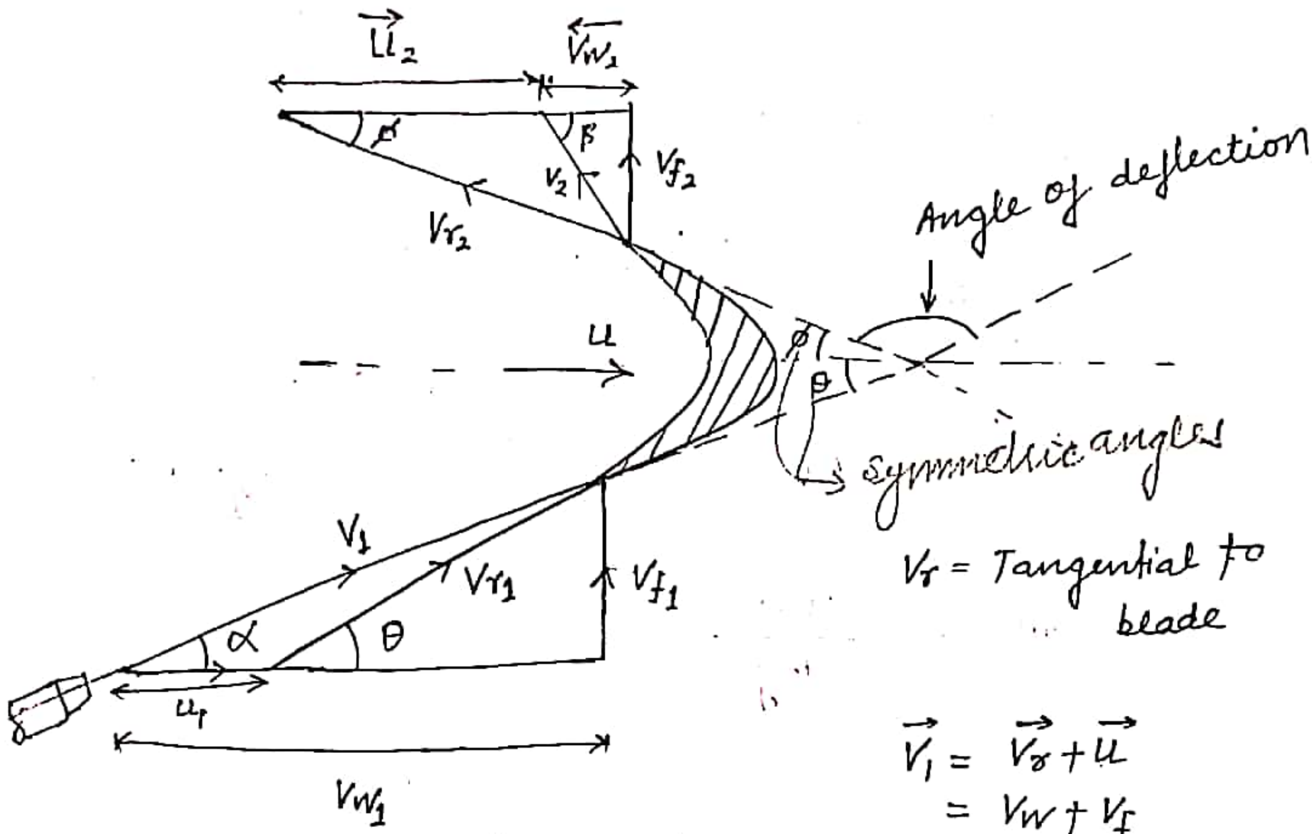
[TURBINE]

convert pressure en. into mechanical en.
(In the form of rotation of runner)



V_r = Tangential to blade

$$\vec{V_1} = \vec{V_r} + \vec{u}$$
$$= \underbrace{V_w + V_f}_{\perp^r}$$

α = Nozzle angle or guide vane angle or absolute velocity angle at inlet OR fixed blade outlet angle

β = diffuser angle

θ & ϕ = Blade angle or vane - angle

$$F_x = (\rho a V_{r_1})\,[V_{w_1} + V_{w_2}] \quad [\text{when } \beta \text{ is acute angle}]$$

न्यूनतम कोण

$$F_x = (\rho a V_{r_1})\,[V_{w_1}] \quad [\text{when } \beta = 90^\circ]$$

$$F_x = (\rho a V_{r_1})\,[V_{w_1} - V_{w_2}] \quad [\text{when } \beta \text{ is } \cancel{\text{acute}} \text{ obtuse angle}]$$

अधिकतम कोण

$$\boxed{W.D./\text{sec} = F_x \times u}$$

$$W.D./\text{sec} = (\rho a V_{r_1})\,[V_{w_1} \pm V_{w_2}] \times u$$

- Formel

$$\eta = \frac{W.D}{K.E.} = \frac{(\rho a V_{r_1})\,[V_{w_1} \pm V_{w_2}] \times u}{\frac{1}{2}(\rho a V_1)\, V_1^2}$$

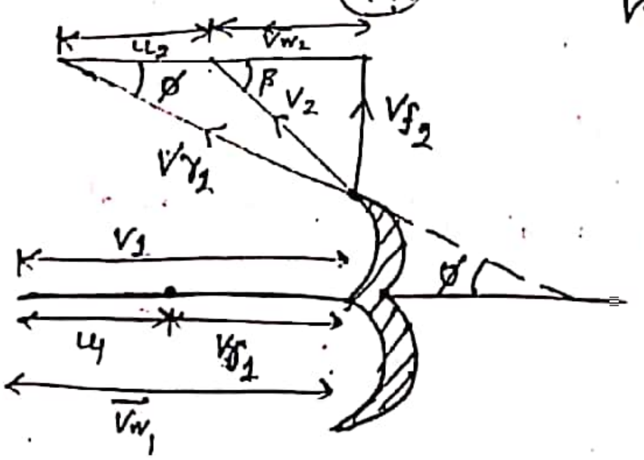
$$W.D/\text{wt.} = \frac{W.D.}{mg}$$

PELTON WHEEL → (Tangential flow) L.A. PELTON

$$\boxed{V_{r_2} = K V_{r_1}} \quad (K < 1)$$

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

$$V_{r_2} = K V_{r_1}$$



$\alpha = 0$
$\theta = 0$

For slow speed runner —— β = acute angle

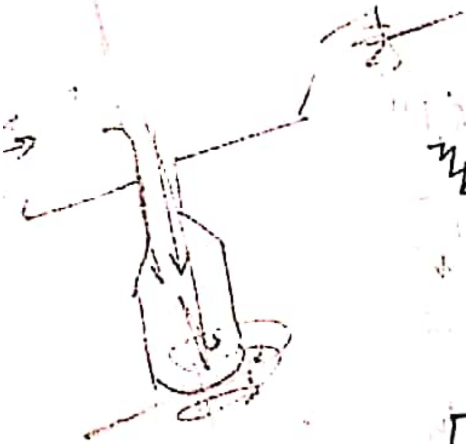
- Medium " —— $\beta = 90^\circ$ $(V_2 = V_{f_2})(V_{w_2} = 0)$

— High —— β = obtuse angle

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

W.D. per second = power = $F \times u$

$$\text{Blade efficiency } (\eta_b) = \frac{\text{power developed by blad}}{\text{power given to blade}}$$



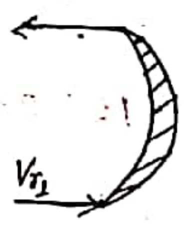
$$\eta_b = \frac{(\rho a V_1)(V_{w_1} + V_{w_2}) \cdot u}{\frac{1}{2}\dot{m} V_1^2}$$

$(\rho \cdot a \cdot V_1)$

$$\boxed{u = \frac{V_1}{2}}$$

$$\boxed{\eta_b = \frac{1 + K\cos\phi}{2}}$$

for best design of bucket the blade should be smooth $K = 1$ & $\phi = 0$



$$\eta_b = \frac{1+1}{2} = 100\%$$

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Hydraulic eff. →

$$\eta_H = \frac{R.P.}{W.P.} = \frac{(\rho a V_1)(V_{w_1} \pm V_{w_2}) \times u}{\rho g Q H}$$

Mechanical eff →

$$\eta_m = \frac{S.P.}{R.P.} = \frac{P}{(\rho a V_1)(V_{w_1} \pm V_{w_2}) \times u}$$

Overall eff. →

$$\eta_o = \frac{S.P.}{W.P.} = \frac{P}{\rho Q g H}$$

$$\boxed{\eta_o = \eta_H \times \eta_m \times \eta_V}$$

$$\text{Head loss in nozzle} = \frac{V_{th}^2}{2g} - \frac{V_1^2}{2g}$$

$$V_1 = C_v V_{th}$$

$$= \frac{V_1^2}{2g}\left[\frac{1}{C_v^2} - 1\right]$$

Jet Ratio $(m) = \frac{D}{d}$ (D → dia of wheel, d → jet dia)

No. of buckets $= 15 + \frac{D}{2d} = 15 + 0.5m$

blade to jet speed ratio = $\frac{u}{V_1}$

$a = \frac{\pi}{4} d^2$, Jet dia

$U = \frac{\pi D N}{60}$ wheel dia

specific speed → (N_s)

$$\eta_o = \frac{S.P.}{W.P.} = \frac{P}{\frac{\rho g Q H}{1000}}$$

$$P = \eta_o \times \frac{\rho g Q H}{1000}$$

$\boxed{P \propto QH}$ { η_o & ρ are const. }

$$u = \frac{\pi D N}{60} \qquad u \propto \sqrt{H}$$

$$u \propto DN$$

$$\sqrt{H} \propto DN$$

$$D \propto \frac{\sqrt{H}}{N}$$

$$Q = \text{Area} \times \text{velocity}$$

$$Q = (\pi B D) \times \sqrt{2 g H}$$

$$Q \propto BD \times H^{1/2}$$

$$B = D$$

$$Q \propto D^2 H^{1/2}$$

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$$Q \propto \left(\frac{\sqrt{H}}{N}\right)^2 \times \sqrt{H}$$

$$Q \propto \frac{H^{3/2}}{N^2}$$

$$P \propto Q H$$

$$P \propto \frac{H^{3/2}}{N^2} \cdot H$$

$$P \propto \frac{H^{5/2}}{N^2}$$

$$P = K \frac{H^{5/2}}{N^2} \qquad \left[\text{where } K \text{ is const}\right]$$

if $P = 1$, $H = 1$, the speed N = specific speed N_s

$$1 = K \times \frac{1^{5/2}}{N_s^2}$$

$$N_s^2 = K$$

$$P = N_s^2 \frac{H^{5/2}}{N^2}$$

$$N_s^2 = N^2 \frac{P}{H^{5/2}}$$

$$\boxed{N_s = N \frac{\sqrt{P}}{H^{5/4}}}$$

$$Q = \text{Area} \times \text{Velocity} = A \times V_1$$

Unit Quantities → Turbine working under unit Head

$$N_u = \frac{N}{\sqrt{H}}$$

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

These formula used when dia is not given

$$P_u = \frac{P}{H^{3/2}}$$

Model →

$$\frac{H}{N^2 D^2} = C$$

$$\frac{D_m}{D_p} = D_r$$

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

$$\frac{P}{N^3 D^5} = C$$

FRANCIS TURBINE → Mixed flow

Degree of Rxn :-

$$R = \frac{\text{change in pressure en. inside the runner}}{\text{change of Total en. inside the runner}}$$

$$= \frac{\text{contribution of moving part}}{\text{Total energy}}$$

$$= \frac{T.E. - K.E.}{T.E.}$$

$$R = 1 - \frac{K.E}{T.E.}$$

$$R = 1 - \frac{(V_1^2 - V_2^2)}{(V_1^2 - V_2^2) + (u_1^2 - u_2^2) + (V_{r_2}^2 - V_{r_1}^2)}$$

$$\boxed{R = 1 - \frac{\cot\alpha}{2(\cot\alpha - \cot\theta)}}$$

for pelton wheel

$$u_1 = u_2$$
$$V_{r_1} = V_{r_2}$$

$$R = 1 - \frac{(V_1^2 - V_2^2)}{(V_1^2 - V_2^2) + 0 + 0}$$

$$\boxed{R = 0}$$

$$\text{Head } (H) = \frac{W.D/sec}{wt.}$$

$$H = \frac{\cancel{(\rho a V_1)} (V_{w_1} + V_{w_2}) u}{\cancel{(\rho a V_1)} g}$$

$$\boxed{H = \frac{1}{g}(V_{w_1} + V_{w_2}) u}$$

Speed ratio $\phi = \frac{u_1}{\sqrt{2gH}} = 0.6 \text{ to } 0.9$

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flow ratio $K_f = \frac{V_{f_1}}{\sqrt{2gH}}$ (0.15 to 0.3)

Q = Area × velocity of flow
or
V_{Radial}

$$\boxed{Q = \pi D_1 B_1 \times V_{f_1}}$$

$$Q = K_f \; \pi D_1 B_1 V_{f_1}$$

K_f = blade thickness factor or blade thickness coefficient.

$$Q = \underbrace{(\pi D_1 B_1 - n t B_1)}_{Area} V_{f_1}$$

n = no. of blades

KAPLAN TURBINE → Axial flow {Vanes on the hub are adjustable}

Propeller Turbine → similar to Kaplan but vanes are fixed on hub.

$$A = \frac{\pi}{4}(D_0^2 - D_b^2)$$

$$Q = A \times V_f$$

$$\boxed{u_1 = u_2 = u}$$

$$\boxed{V_{f_1} = V_{f_2} = V_f}$$