Impulse Turbine:-

Principle:- water is supplied by penstock from reservoir to turbine then enters into the nozzle. Nozzle is use to convert all the available head with water into dynamic head (H)

$$\left(H = \frac{V_1^2}{2g}\right)$$

Then the water leaves the nozzle in the form of ~~Ento~~ jet. As the jet strikes over the rotor vane, it apply large magnitude force over the vane for a small period of time called Impulse due to K.E. of water. This impulse force will rotate the runner therefore these turbines are known as impulse turbine

at rotor

Entry	Exit
KE	KE, V_2 } Min

→ $P_1 = P_2 = P_{atm}$

$V_2 << V_1$

→ Smooth Vane

$V_{r_1} = V_{r_2}$

→ Rough Vane

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

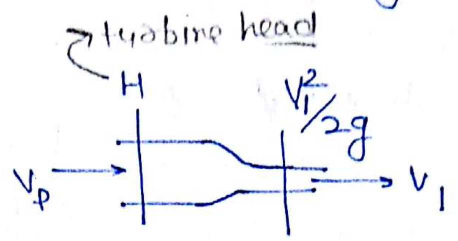
$K \rightarrow$ Coeff. of Vane friction

Pelton wheel turbine

Components used in pelton wheel turbine.

① Casing :- it doesnot have any hydraullic function used to avoid splashing of water.

② Nozzle :-



if no loss in nozzle

$$H = \frac{V_1^2}{2g}$$

$$\boxed{V_1 = \sqrt{2gH}}$$

if loss in nozzle

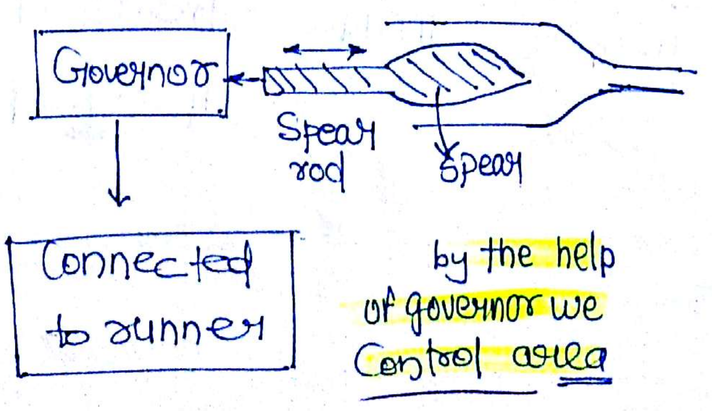
$$\frac{V_1^2}{2g} < H$$

$$\boxed{V_1 = C_v \sqrt{2gH}}$$

C_v - Coeff. of Velocity

$C_v = 0.96 - 0.985$

③ Spear :- To control the discharge through nozzle a spear is provided which can move forward and backward with the help of Governor in order to increase or decrease flow area through nozzle.



$Q = AV$ $\quad V = \sqrt{2gH}$

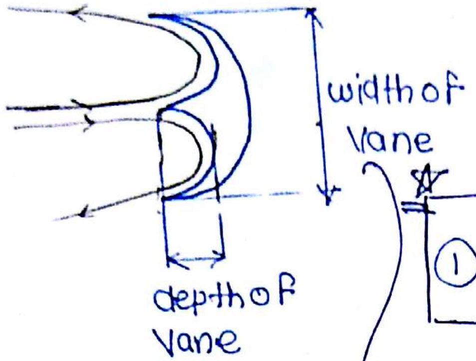
$Q\uparrow, A\uparrow$

$Q\downarrow, A\downarrow$

④ Braking Jet :- used to stop runner.

⑤ Runner/Rotor :-

double - Hemispherical shape Vane / buckets



→ Design parameter for runner

$$\boxed{① \text{ Jet Ratio}(m) = \frac{D}{d}}$$

② No. of Vane $= \frac{m}{2} + 15$

③ width of Vane $= 5d$

④ depth of Vane $= 1.2d$

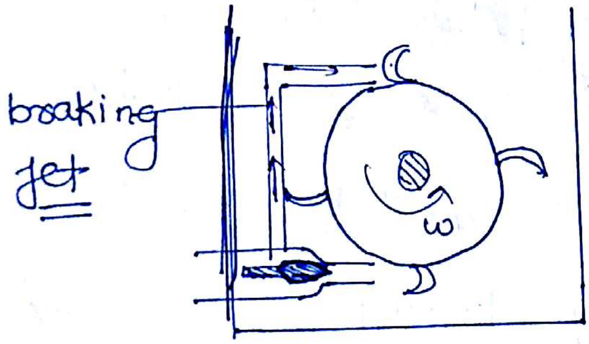
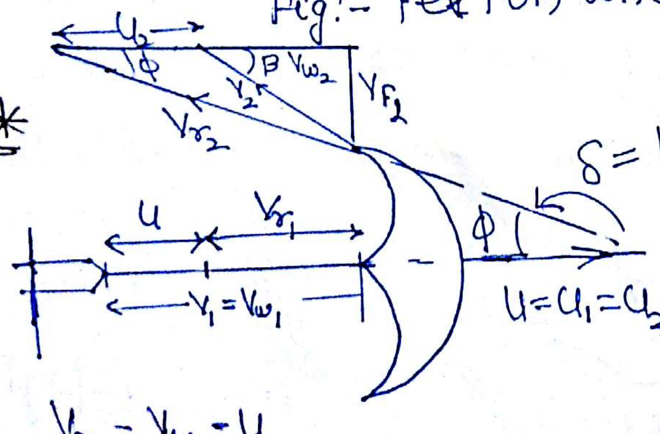


Fig:- Pelton wheel turbine

*



$\delta = 180 - \phi$

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

D = dia. of wheel

N = Speed (rpm)

$V_{r_1} = V_{w_1} - u$

→ Discharge

$$Q = AV_1 = \frac{\pi}{4} d^2 . V_1$$

→ Power

$$\boxed{WP/HP = \rho g Q H} \text{ watt}$$

$$RP = F_x \times u$$

$$F_x = \dot{m} \times V_{w_1} - \left[\frac{\dot{m}}{2} \times (-V_{w_2}) + \frac{\dot{m}}{2}(-V_{w_2}) \right]$$

$$F_x = \dot{m} \times V_{w_1} + \dot{m} V_{w_2}$$

$$F_x = \dot{m}(V_{w_1} + V_{w_2})$$

$$\boxed{RP = \rho Q (V_{w_1} + V_{w_2}) u} \text{ watt}$$

→ SP = RP − mech. loss

Efficiency

→ $\eta_{vol.} = \dfrac{Q - \Delta Q}{Q}$

→ $\eta_H = \dfrac{RP}{WP} = \dfrac{(V_{w_1} + V_{w_2}) u}{gH}$

→ $\eta_M = \dfrac{SP}{RP}$

→ $\eta_o = \dfrac{SP}{WP} = \eta_H \times \eta_M$

Hydraulic efficiency & blade eff. are not same

Blade efficiency

$$\eta_{blade} = \frac{\frac{1}{2} m V_1^2 - \frac{1}{2} m V_2^2}{\frac{1}{2} \dot{m} V_1^2} = \frac{RP (= \rho Q (V_{w_1} + V_{w_2}) u)}{\frac{1}{2} \dot{m} V_1^2}$$

For max. WP eff.

$$\Rightarrow \eta_H = \frac{RP}{WP} = \frac{\rho Q (V_{w_1} + V_{w_2}) \cdot u}{\rho g Q H}$$

if No loss in Nozzle.

$$\rho g Q H = \frac{1}{2} \dot{m} V_1^2$$

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

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

$$\rightarrow V_{w_1} = V_1$$

$$\rightarrow \cos\phi = \frac{u_2 + V_{w_2}}{V_{r_2}}$$

$$V_{r_2} = K V_{r_1} = K (V_1 - u_1)$$

$$V_{w_2} = K (V_1 - u_1) \cdot \cos\phi - u_2$$

So

$$\eta_H = \frac{2 (V_1 + K (V_1 - u_1) \cos\phi - u_2)}{V_1^2}$$

$$\because (u_2 = u_1)$$

$$\eta_H = \frac{2 (V_1 - u_1)(1 + K \cos\phi) \cdot u}{V_1^2}$$

$\rightarrow \eta_H = f(V_1, u)$

for a const. V_1

$$\frac{d\eta}{du} = 0$$

$$\frac{d}{du}\left[\frac{2(V_1 - u_1)(1 + k\cos\phi) \cdot u}{V_1^2}\right] = 0$$

$$\frac{d}{du}\left((V_1 - u)\,u\right) = 0$$

$$V_1 - 2u = 0$$

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

$$\rightarrow (\eta_H)_{max} = \frac{2\left(V_1 - \frac{V_1}{2}\right)(1 + k\cos\phi) \cdot \frac{V_1}{2}}{V_1^2}$$

$$\boxed{(\eta_H)_{max} = \frac{(1 + k\cos\phi)}{2}}$$

for $k = 1$, $\phi = 15^\circ$

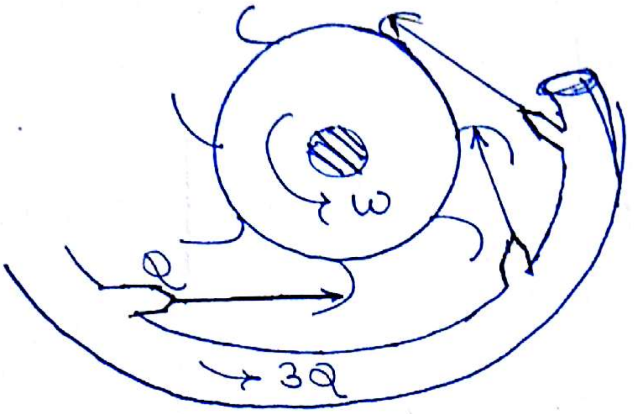
$\eta_H = 98.29\ \%$

$\Rightarrow$ Angle of Deflection

$\delta = 180 - \phi$

$\delta = 160^\circ - 170^\circ$

* Multijet Pelton wheel :-



$$n = \text{no. of Jet} = \frac{\text{total Discharge supplied by penstock}}{\text{Discharge from one jet.}}$$

(Not more than 6)

Speed Ratio :-

$$\boxed{k_u = \frac{u_1}{\sqrt{2gH}}}$$

Frequency (Hz) $\boxed{F = \frac{PN}{120}}$

P - no. of poles 2, 4, 6 - -
Always even

Q.9

$H_G = 300m$

$L = 400m$ $V = 5 m/s$ $f' = 0.0098$

$D = 1 m$ $k = 0.0098$ $4f'$

$H = H_G - H_F$

$h_f = \frac{fLV^2}{2gd}$

$= 300 - \cancel{\frac{V^2}{2g}}$

$h_f = \frac{0.0098 \times 400 \times 25}{2 \times 9.81 \times 1}$

$H = 300 - 4.99$

$H = 295m$ $h_f = 4.99$

Q.9

$N = 630$ rpm

$\cancel{V} = Q = 3 m^3/s$

$Ku = \frac{u}{\sqrt{2gH}}$ $\cancel{\phi} = 0.48$

$Q = AV$

$V = \frac{3}{\frac{\pi d^2}{4}}$

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

$\cancel{0.48 \times \frac{3 \times 4}{\pi d^2} \Rightarrow \frac{\pi d \times 630}{60}}$

$u_1 = 0.48 \times \sqrt{2 \times 9.81 \times 256}$

$u_1 = \frac{\pi . D\, 630}{60}$

$D = 1.03\ \underline{m}$

Q.63

$Q_{total} = 40 \ m^3/s$ $\quad C_v = 0.985$

$H = 250 \ m$

turbine = 5
total runner = 10
total Nozz = 40

(s) n = 40

$V = C_v\sqrt{2gH}$

$V = 0.985\sqrt{2 \times 9.81 \times 250}$

$V = 68.98 \ m/s$

$Q = n A V$

$$40 = 40 \times 68.98 \times \frac{\pi d^2}{4}$$

$d = 0.13586$

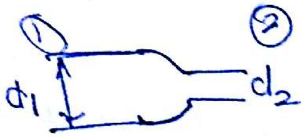
$d = 135 \ mm$

Q.62

$H = 400 m$ $\quad f = 0.008$

$d_p = 1m$ $\quad d = 150mm$ $\quad \theta = 165°$

$L = 4000m$ $\quad \phi = 15°$



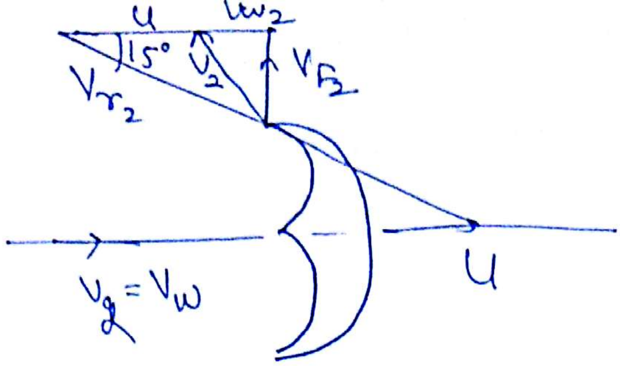
~~$V_{r_2} = 0.15 V_{r_1}$~~

$V_{r_2} = 0.85 V_{r_1}$

V_p - penstock velocity

$\frac{u}{V_1} = 0.45$

$\eta_m = 85\%$



(i) $V_1 = \sqrt{2gH} = \sqrt{2 \times 9.81 \times 400}$

$V_1 = 88.588$ m/s

$\cancel{A_1 V_1 = A_2 V_2}$

$\cancel{V_2 = \frac{d_1^2}{d_2^2} V_1}$

$\cancel{V_2 = 3937.28 \text{ m/s}}$

$\cancel{\frac{V_2^2}{2g} = H_G - h_f = 400 - \frac{f_1 L V^2}{2g}}$

$\cancel{\frac{V_2^2}{2g} = 400 - \frac{0.008 \times 4000 \times (88.588)^2}{2 \times 9.81}}$

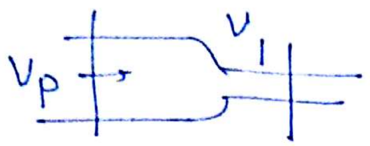
(a) $RP = \rho Q(V_{w_1} + V_{w_2}) \cdot u$

$Q = \frac{\pi}{4} d^2 \cdot v_1$

$v_1 = \sqrt{2gH}$

$H = H_G - H_f$

$H = 400 - \frac{4 \times f \times L \times V_p^2}{2 \times 9.81 \times 1}$



$$\frac{\pi}{4} D_p^2 \times V_p = \frac{\pi}{4} d^2 \times v_1$$

$$V_p = 0.15^2 \, v_1$$

$$V_p = 0.022 F \sqrt{2gH}$$

$$H = 400 - \frac{(4\times0.008)\times4000\times\left(0.0225\sqrt{2gH}\right)^2}{2\times9.81\times1}$$

$$H = 400 - 0.0648 H$$

$$H = 375.65$$

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

$$V_{w_1} = V_1 = 85.85 \text{ m/s.}$$

$$Q = \frac{\pi}{4} \times 0.15^2 \times 85.85$$

$$Q = 1.51 \text{ m}^3/\text{s}$$

$$u = 38.63 \text{ m/s}$$

$$V_{r_1} = 47.21 \text{ m/s.}$$

$$V_{r_2} = 40.13 \text{ m/s}$$

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

$$40.13 \cos 15 = 38.63 + V_{w_2}$$

$$V_{w_2} = 0.1326 \ m/s.$$

$$RP = 1000 \times 1.51 \times (85.85 + 0.1325) \times 38.63$$

$$RP = 5.015 \ MW$$

$$\eta_M = \frac{SP}{RP}$$

$$0.85 = \frac{SP}{5.015} \qquad SP = 4.26 \ MW$$

$$\eta_H = \frac{(V_{w_1} + V_{w_2}) \cdot u}{gH} = \frac{RP}{WP} = \frac{5.015 \times 10^6}{1000 \times 9.81 \times 1.51 \times 375.65}$$

$$= \frac{(85.85 + 0.1326) \times 38.63}{9.81 \times 40} \quad \eta_H = 90.13\%.$$

$$\cancel{\eta_H = 0.84}$$

$$\eta_{ove} = 0.85 \times 0.\cancel{84}\ 90.13$$

$$= 76.6\%$$