1

$h = 25m$

$Q = 1500\ lpm = \frac{1500}{60}\ lps = 25\ lps$

pipe dia $d = 7.5$ cm.

pipe velocity $= \frac{Q}{\frac{\pi}{4}d^2} = \frac{25 \times 10^{-3}}{\frac{\pi}{4} \times (0.075)^2}\ m/s = 5.66\ m/s$

$h_f = f \frac{l}{d} \frac{v^2}{2g}$ $\quad f = 0.03,\ l = 30m$

$= 0.03 \times \frac{30}{0.075} \times \frac{5.66^2}{2 \times 9.81}$

$= 19.6\ m$

Kinetic head $= \frac{v^2}{2g} = \frac{5.66^2}{2 \times 9.81} = 1.63m.$

$H_m =$ manometric head

$= h + h_f + \frac{v^2}{2g}$

$= 25 + 19.6 + 1.63\ m$

$= \underline{46.23\ m}$ (a)

Power P at exit of impeller

$P = \rho Q g H_m$

$= 10^3 \times 25 \times 10^{-3} \times 9.81 \times 46.23\ W$

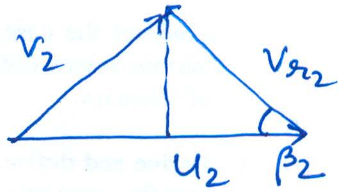
$= 11.337\ kW$

η_h = hydraulic efficiency

$$= \frac{P}{P_r} \quad \text{where } P_r = \text{Power at inlet to rotor}$$

$$\eta_h = 0.94$$

$$\therefore \; P_r = \frac{P}{\eta_h} = \frac{11.337}{0.94} = 12.06 \text{ kw}$$



u_2 = peripheral velocity

$$= \frac{\pi D_2 N}{60} \qquad D_2 = 35 \text{ cm}$$

$$N = 1440 \text{ rpm}$$

$$= \frac{\pi \times 0.35 \times 1440}{60}$$

$$= 26.4 \text{ m/s}$$

Again, $Q = \pi D_2 b_2 V_{n_2}$ $\qquad b_2 = 1$ cm

$$25 \times 10^{-3} = \pi \times 0.35 \times 0.01 \times V_{n_2}$$

$$V_{n_2} = 2.274 \text{ m/s}$$

$$P_r = \dot{m} u_2 V_{u_2}$$

$$12.06 \times 10^3 = \cancel{10^3} \times 25 \times \cancel{10^{-3}} \times 26.4 \times V_{u_2}$$

$$V_{u_2} = 18.27 \text{ m/s}$$

$$\tan\beta_2 = \frac{V_{n_2}}{u_2 - V_{u_2}} = \frac{2.274}{26.4 - 18.27} = 0.28$$

$$\underline{\beta_2 = 15.64^\circ} \quad (e)$$

Engineering specific speed

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} \quad \text{Here } N \text{ in rpm}$$

$$= \frac{1440 \times \sqrt{25\times10^{-3}}}{46.23^{3/4}}$$

$$= \underline{12.84} \quad (c)$$

Non-dimensional specific speed

$$N_s = \frac{\frac{1440\times2\pi}{60} \times \sqrt{25\times10^{-3}}}{(9.81\times46.23)^{3/4}} \quad \text{Here } N \text{ in rad/sec.}$$

$$= \underline{0.243} \quad (d)$$

P_s = Shaft power

$= P_r +$ mechanical losses

$= 12.06 + 0.2$

$= \underline{12.26 \text{ kW}}$ (b)

$\therefore$ Mechanical efficiency $\eta_m = \frac{P_r}{P_s} = \frac{12.06}{12.26} = 0.984$

$= \underline{98.4\%}$ (f)

2. Kaplan turbine.

$H = 42\ m,$

$Q = 6.5\ m^3/s$

$\eta_h = 0.94$

$N = 800\ rpm.$

$D_h/D_t = 0.6$

$\phi = 1.25$

$V_1 = \sqrt{2gH}$

$= \sqrt{2 \times 9.81 \times 42}$

$= 28.7\ m/s$

$\frac{U}{V_1} = 1.25$

$U = 1.25 \times V_1$

$= 1.25 \times 28.7$

$= 35.88\ m/s$

At tip, $\frac{\pi D_t N}{60} = U$

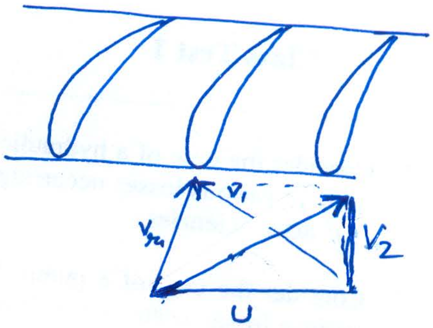
$$\frac{\pi \times D_t \times 800}{60} = 35.88$$

$$D_t = \frac{35.88 \times 60}{\pi \times 800}\ m$$

$$\left.\begin{array}{l} = \underline{0.86\ m} \\ D_h = \underline{0.52\ m.} \end{array}\right\} (a)$$

$$Q = \frac{\pi}{4}(D_t^2 - D_h^2) \times V_{n_1}$$

$$= \frac{\pi}{4}(0.86^2 - 0.52^2) \times V_{n_1}$$



$$V_{n_1} = \frac{6.5 \times 4}{\pi(0.86^2 - 0.52^2)}$$

$$= 17.6 \text{ m/s}$$

$$\eta_h = \frac{u V_{u_1}}{gH} \quad \text{at tip.}$$

$$u V_{u_1} = \eta_h g H$$

$$V_{u_1} = \frac{\eta_h g H}{u}$$

$$= \frac{0.94 \times 9.81 \times 42}{35.88}$$

AT TIP

$$= 10.8 \text{ m/s}$$

$$\tan\beta_1 = \frac{V_{n_1}}{u - V_{u_1}}$$

$$= \frac{17.6}{35.88 - 10.8}$$

$$= 0.702$$

$$\beta_1 = 35.07^\circ$$

(b)

$$\tan\beta_2 = \frac{V_{n_1}}{u}$$

$$= \frac{17.6}{35.88}$$

$$= 0.49$$

$$\beta_2 = 26.1^\circ$$

Free vortex design

UV_u = constant at hub and tip

$$U_h = 0.6 \times U_{tip}$$

$$= 0.6 \times 35.88$$

$$= 21.53 \text{ m/s}.$$

At inlet

$$(UV_u)_t = (UV_u)_h$$

AT HUB

$$35.88 \times 10.8 = 21.53 \times V_u$$

$$V_u = 18 \text{ m/s}$$

$$\tan\beta_1 = \frac{V_n}{U - V_u}$$

$$= \frac{17.6}{21.53 - 18}$$

$$= 4.98$$

$$\beta_1 = 78.65^\circ \quad (c)$$

$$\tan\beta_2 = \frac{V_n}{U}$$

$$= \frac{17.6}{21.53}$$

$$= 0.817$$

$$\beta_2 = 39.25^\circ.$$

$\eta_o = 0.88$

$P_s = \rho Q g H \times \eta_o$

$= 10^3 \times 6.5 \times 9.81 \times 42 \times 0.88 \quad W$

$= 2356.7 \, kW$

Engineering specific speed $N_s = \dfrac{N\sqrt{P}}{H^{5/4}}$

$$N_s = \frac{800 \times \sqrt{2356.7}}{42^{5/4}}$$

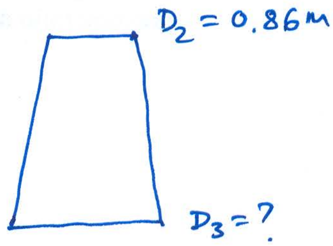
$$= 363 \qquad (d)$$

Non-dimensional specific speed

$$N_s = \frac{2\pi N}{60} \times \frac{\sqrt{P}}{\rho^{\frac{1}{2}} (gH)^{5/4}}$$

$$= \frac{\frac{2\times\pi\times 800}{60} \times \sqrt{2356.7\times\cancel{10^3}}}{\sqrt{1\cancel{000}} \times (9.81\times 42)^{5/4}}$$

$$= 2.19$$



$\tan 4 = \dfrac{D_3 - D_2}{2\times H}$

$0.07 = \dfrac{D_3 - 0.86}{2\times 3}$

$D_3 = 0.07\times 2\times 3 + 0.86$

$= 1.28 \, m$

$V_2 = \dfrac{Q}{\frac{\pi}{4}\times D_2^2} = \dfrac{6.5}{\frac{\pi}{4}\times (0.86)^2} = 11.2 \, m/s$

$V_3 = \dfrac{Q}{\frac{\pi}{4}\times D_3^2} = \dfrac{6.5}{\frac{\pi}{4}\times 1.28^2} = 5.0 \, m/s$

$$\text{Gain in head} = (3-0.5) + 0.9 \times \frac{11.2^2 - 5^2}{2 \times 9.81}$$

$$= 7.11\,\text{m}$$

$$\text{Gain in power} = \rho Q g H_{gain} \eta_o$$

$$= 10^3 \times 6.5 \times 9.81 \times 7.11 \times 0.88$$

$$= 399\,\text{kW} \qquad (e)$$

3. $H = 150\,m$

$Q = 2\ m^3/s$

$C_v = 0.98$

$C_b = 0.975$

$\beta_2 = 20^0$

$N = 600\ rpm$

$\eta_o = 0.88$

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

Here, $P = \rho Q g H \eta_o$

$$= 10^3 \times 2 \times 9.81 \times 150 \times 0.88$$

$$= 2590\ kW$$

$$N_s = \frac{600 \times \sqrt{2590}}{150^{5/4}}$$

$$= \underline{58.2} \quad (b)$$

So multi-jet Pelton turbine.

Assuming to be $\underline{4\ \text{jet turbine}}$. (d)

PS: You may choose other numbers. Then d will come different.

$$\eta_h = \frac{1 + C_b \cos\beta_2}{2}$$

$$= \frac{1 + 0.975 \times \cos 20}{2}$$

$$= \underline{0.958} \quad (a)$$

Jet velocity $V_1 = \sqrt{2gH} \times C_v$

$= \sqrt{2 \times 9.81 \times 150} \times 0.98$

$= 53.2\,m/s$

$\frac{U}{V_1} = 0.5$

$\therefore U =$ Peripheral velocity

$= 26.6\,m/s$

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

$26.6 = \frac{\pi \times D \times 600}{60}$

D = Pelton wheel diameter

$= 0.847\,m$ (c)

Water flow per jet $= \frac{Q}{4} = \frac{2}{4} = 0.5\,m^3/s$

$\therefore$ $0.5 = \frac{\pi}{4} d^2 \times V_1$ where d = jet diameter.

$d = \left(\frac{0.5 \times 4}{\pi \times 53.2}\right)^{\frac{1}{2}}$

$= 0.11\,m$ (e)

New jet specific speed

$N_s = \frac{600 \times \sqrt{2590/4}}{150^{5/4}}$

$= 29.1$ (b)