FLUID MECHANICS-II
(6^{Th} Term B.Sc. Civil Engineering)
(Session-2014)
Teacher Incharge: Prof. Dr. Habib-ur-Rehman

Assignment No. 3
(Reaction Turbines)

Solve the following numerical problems.

Q. No.1. An inward flow reaction turbine, having an external dia of 1.50 m runs at 400 r.p.m. The velocity of flow at inlet is 10 m/s. If the guide blade angle is 15°, find (a) the absolute velocity of water (b) the velocity of whirl at inlet (c) the inlet vane angle of the runner (d) the relative velocity at inlet. (38.64 m/s, 37.32 m/s, 59.42°, 11.61 m/s).

Q. No.2. An inward flow reaction turbine has outer and inner diameters of wheel as 1 m and 0.5 m respectively. The vanes are radial at inlet and the discharge is radial at outlet and water enters the vane at an angle of 10°. Assuming the velocity of flow to be constant, and equal to 3 m/s, find (i) the speed of the wheel (ii) the vane angle at outlet. (325 r.p.m, 19.44°).

Q. No.3. An inward flow reaction turbine has external and internal wheel diameters as 1 m and 0.5 m respectively. The water enters the wheel with a velocity of 30 m/s at an angle of 10°. The width of wheel at inlet and outlet is 150 mm and 300 mm respectively. The vane angle is 90° at inlet and 25° at outlet. Determine (a) the tangential velocity of the runner at inlet (b) absolute velocity of water at outlet. (29.54 m/s, 6.33 m/s).

Q. No.4. A Francis turbine working under a head of 14 m, has guide blade angle of 20° and vanes are radial at inlet. The ratio of inlet and outlet diameters is 3 to 2. The velocity of flow of water at exit is 4 m/s. Assuming velocity of flow to be constant, determine the peripheral velocity of water at inlet and the vane angle at outlet. (10.98 m/s, 28.65°).

Q. No.5. A Kaplan turbine operating under a net head of 20 m, develops 50 000 h.p. with an overall efficiency of 86 %. The speed ratio 0.46 and flow ratio is 0.6. The hub diameter of the wheel is 0.35 times the outside diameter of the wheel. Calculate diameter and speed of the turbine. (5.2 m, 19 r.p.m.).

Q. No.6. Prob. 14.3 (Daugherty), (85.80, 3394.11 KW, 212 r.p.m.)

Q. No.7. Prob. 14.4 (Daugherty), (21.6 rn^3/s, 4800 KW, 75 r.p.m.)

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Problem 1

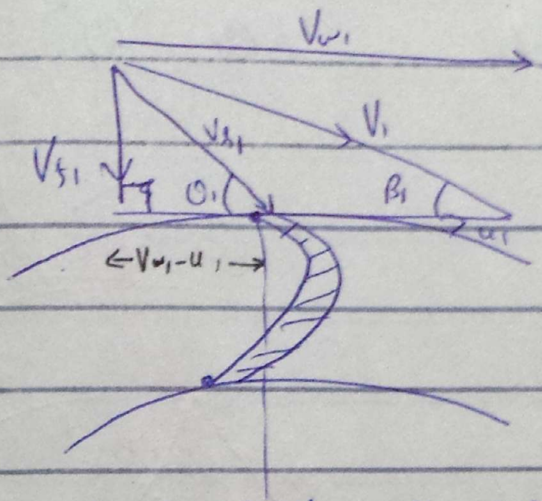
Inward RFRT

Data: $D_1 = 1.5m$ a) $V_1 = ?$

$N = 400$ rpm b) $V_{w1} = ?$

$V_{f1} = 10m/s$ c) $\theta_1 = ?$

$\beta_1 = 15°$ d) $V_{r1} = ?$



Only inlet tip diagram

computing peripheral velocity at inlet tip :

$$\Rightarrow u_1 = \frac{\pi D_1 N}{60} = \frac{\pi(1.5)400}{60} = 31.42m/s$$

$$\Rightarrow V_{f1} = V_1 \sin\beta_1$$

$$10 = V_1 \sin 15$$

$$V_1 = 38.64 m/s \quad \text{Ans}$$

$$\Rightarrow V_{w1} = V_1 \cos\beta_1$$

$$= 38.64 \cos 15 = 37.32 m/s \quad \text{Ans}$$

$$\Rightarrow V_{w1} - u_1 = 5.9 m/s$$

$$\tan\theta_1 = \frac{V_{f1}}{V_{w1} - u_1}$$

$$\theta_1 = 59.46° \quad \text{Ans}$$

$V_{r_1} = \sqrt{V_{f1}^2 + (V_{w_1} - u_1)^2}$

$V_{r_1} = 11.61\ m/s$ Ans

Q=2 Data: Inword flow reaction turbine:

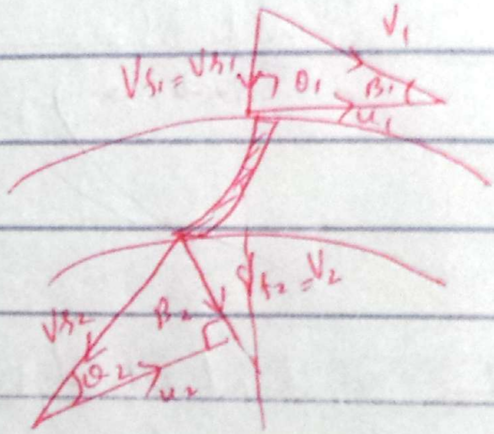
$D_1 = 1m$ $D_2 = 0.5m$

$V_{f_1} = V_{f_2} = 3m/s$ $\beta_1 = 10^\circ$

i) N ?

ii) $\theta_2 = ?$

Sol:



i) $N = \frac{60u}{\pi D_1}$

$= \frac{60 \times (17.01)}{\pi (1)}$

N = 325

As $\tan\beta_1 = \frac{V_{f1}}{U_1}$

$U = \frac{V_{f1}}{\tan\beta_1}$

$U = 17.01\ m/s$

ii) $\tan\theta_2 = \frac{V_{f2}}{u_2}$

$u_2 = \frac{N\pi D_2}{60}$

$= 8.5\ m/s$

$\theta_2 = \tan^{-1}\frac{3}{8.5}$

$\theta_2 = 19.44^\circ$

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Q=3

Data: Inward R F R T

$D_1 = 1m$ $D_2 = 0.5m$

$V_1 = 30 m/s$ $b_1 = 150mm$

$\beta_1 = 10°$ $b_2 = 300mm$

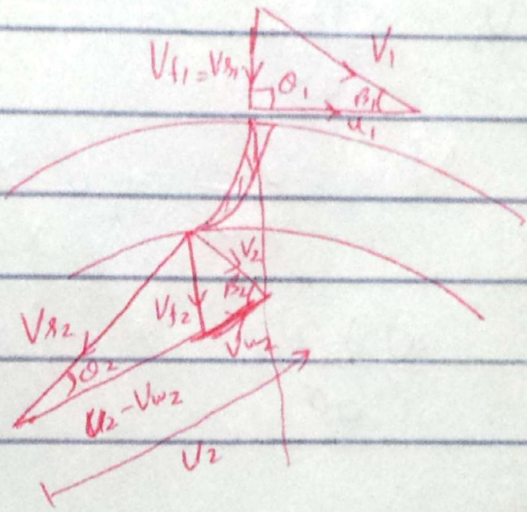
$\theta_1 = 90°$

$\theta_2 = 25°$

a) $u_1 = ?$

b) $V_2 = ?$

Sol:



a) $\cos\beta_1 = \frac{u_1}{V_1}$

$u_1 = 29.54 m/s$

b) $\sin\beta_1 = \frac{V_{f1}}{V_1}$

$V_{f1} = 30 \sin 10 = 5.209 m/s$

Applying continuity equation

$0.15 \times 1 \times 5.209 = 0.3 \times 0.5 \times V_{f2}$

$V_{f2} = 5.209 m/s$

$\pi \times D_1 \times b_1 V_{f1} = \pi D_2 b_2 V_{f2}$

~~$H_2 = 50m$~~

$$u_1 = \frac{\pi D_1 N}{60}$$

$$N = \frac{60 u_1}{\pi D_1} = \frac{60 \times 29.54}{\pi \times 1} = 564.25 \text{ rpm}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.5 \times 564.25}{60} = 14.77 \text{ m/s}$$

$$\tan\theta_2 = \frac{V_{f_2}}{u_2 - V_{w_2}}$$

$$u_2 - V_{w_2} = \frac{5.209}{\tan 25} = 11.17 \text{ m/s}$$

$$u_2 - V_{w_2} = 11.17$$

$$V_{w_2} = 14.77 - 11.17 = 3.6 \text{ m/s}$$

$$V_2 = \sqrt{V_{w_2}^2 + V_{f_2}^2}$$

$$= \sqrt{3.6^2 + 5.209^2} = 6.33 \text{ m/s}$$

Q = 4

Francis turbine:

Data:

$H = 14\,m$ ~~90m~~

$\frac{D_1}{D_2} = \frac{3}{2}$

$\beta_1 = 20^\circ$

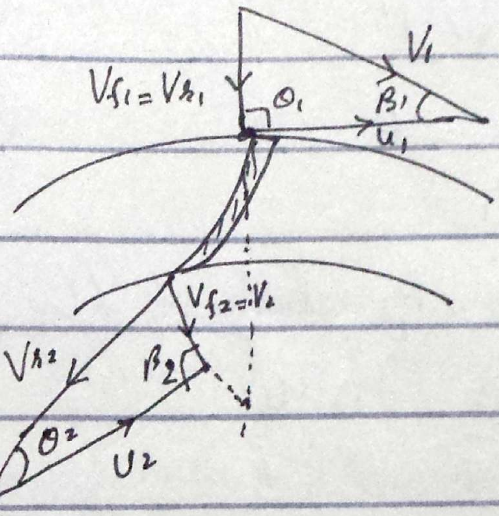
Vanes are radial at inlet

$V_{f1} = V_{f2} = 4\,m/s$

i) $u_1 = ?$

ii) $\theta_2 = ?$

Sol:



i) $\tan\beta_1 = \frac{V_{f1}}{u_1}$

$u_1 = \frac{4}{\tan 20} = 10.989\,m/s$

ii) $u_1 = \frac{\pi D_1 N}{60}$ $\qquad D_1 = \frac{3}{2} D_2$

$u_1 = \frac{\pi\left(\frac{3}{2} D_2\right) N}{60}$

$\frac{2}{3} u_1 = \frac{\pi D_2 N}{60}$

$\frac{2}{3} u_1 = u_2$

$u_2 = \frac{2}{3}(10.989) = 7.326\,m/s$

$\theta_2 = \tan^{-1}\frac{V_{f2}}{u_2}$

$\theta_2 = \tan^{-1}\left(\frac{4}{7.326}\right) = 28.63^\circ$

Prob. 5

Kaplan turbine

$H = 20m$

$P_o = 50000\ hp = 50000 \times 746 = 37.3 \times 10^6$ Watt

$\eta_o = 86\%$

$\frac{U}{\sqrt{2gH}} = 0.46$ $\frac{V_f}{\sqrt{2gH}} = 0.6$

$D_b = 0.35D$ $D = ?$ $N = ?$

Sol:

Computing velocity of flow from given relationship

$\frac{V_f}{\sqrt{2gH}} = 0.6$

$V_f = 0.6\sqrt{2 \times 9.81 \times 20} = 11.88\ m/s$

Using overall efficiency equation

$\eta_o = \frac{P_o}{\gamma Q H}$

$0.86 = \frac{37.3 \times 10^6}{9810 \times Q \times 20}$

$Q = 221.06\ m^3/s$

As

$Q = \frac{\pi}{4}[D^2 - D_b^2]V_f$

$221.06 = \frac{\pi}{4}[D^2 - (0.35D)^2]V_f$

$D = 5.2\ m$ Ans

$u = \frac{\pi D N}{60}$, $\frac{u}{\sqrt{2gH}} = 0.46$

$9.11 = \frac{\pi (5.2)(N)}{60}$ $u = 9.11 m/s$

$N = 33.46$ rpm Ans

Prob. 9

Problem 14.~~9~~3 of Daugherty

Data:

$N_1 = 150$ rpm a) $\eta_{01} = ?$

$Q_1 = 5.7$ cumecs b) $N_2 = ?$

$P_{01} = 1200$ KW c) $Q_2 = ?$

$H_1 = 25m$ d) $P_{02} = ?$ if $H_2 = 50m$

Sol:

$$\eta_{01} = \frac{P_{01}}{\gamma Q H} = \frac{1200,000}{9810 \times 5.7 \times 25} = 85.84\%$$ Ans

Applying similarity law #2

$$\frac{N_2}{150} = \sqrt{\frac{50}{25}} \left(\frac{D_1}{D_2} \right)$$ $D_1 = D_2$ Since same turbine.

$N_2 = 212.13$ rpm Ans

Apply ① law

$$\frac{Q_2}{5.7} = (1)^2 \sqrt{\frac{50}{25}}$$

$Q_2 = 8.06 \ m^3/s$ Ans

Apply ④ law

$$\frac{P_{o2}}{1200000} = (1) \left(\frac{50}{25}\right)^{3/2}$$

$P_{o2} = 3.39$ MWatt

Problem 7

14.4

$D_2 = 2D_1$ Same data as above but Runner of twice dia

$N_2 = ?$ $Q_2 = ?$ $P_2 = ?$

$H_1 = 25m$ $H_2 = 25m$

⇒ $N_2 = 75$ rpm $(150 \times \frac{1}{2})$

⇒ $Q_2 = 22.8 m^3/s$

⇒ $P_2 = 2400$ kw