Turbines

Reading :

DGS sections 22.1–22.4, 23.1–23.4, 23.15, 23.16

Questions :

Q.1. Use the Buckingham-Π theorem to show that for an impeller

$$\left(\frac{P}{N^3D^5\rho}\right) = \mathcal{F}\left[\left(\frac{Q}{ND^3}\right), \left(\frac{gH}{N^2D^2}\right), \left(\frac{\mu}{ND^2\rho}\right), \left(\frac{K}{N^2D^2\rho}\right), \left(\frac{\varepsilon}{D}\right)\right]$$

Q.2. Show that the type number for pumps is independent of the machine size, and develop a formula for it in terms of N, Q and H. Repeat this for turbines (now N, P and H are the relevant parameters).

Q.3. In order to predict the behaviour of a small oil pump, tests are to be made on a model using air. The oil pump is to be driven by a 37 W motor at 1800 RPM, and 186 W motor is available to drive the air pump at 600 RPM. Using oil of specific gravity 0.912 and air of constant density at 1.23 kg/m^3, what size model should be built?

Q.4. A small-scale hydroelectric turbine generates 29.2 kW of electricity running off a head of 35 m of water at a flow rate of 0.1 m^3/s. Calculate the overall efficiency, If the mechanical losses ammount to 1 kW, calculate the hydraulic and mechanical efficiencies.

Q.5. A reaction turbine 500 mm in diameter, when running at 600RPM, developed brake power of 195 kW when the flow was 0.74 m^3/s. The pressure head at entrance to the turbine was 27.9 m, and the elevation of the turbine casing above tailrace level was 1.91 m. The water enters the turbine with a velocity of 3.66 m/s. Calculate a. the effective head, b. the efficiency, c. the speed expected under a head of 68.6 m, d. the brake power and discharge under the 68.6 m head.

Q.6. A centrifugal turbine with inside diameter (ID) 40 cm and outside diameter (OD) 1 m rotates at 200 RPM and discharges 0.8 m^3/s of water. The blade height is 10 cm, and the water inlet imparts a swirl velocity v_{w1} of 1.45 m/s.

Draw a vector triangle for the inlet velocities. Calculate the relative and absolute inlet velocities. What angle should the blades be set at for the no shock condition to hold?

If the blades sweep around to an angle $\beta_2 = 40°$, what are the flow velocities (absolute and relative) at the outlet?

Q.7. A centrifugal fan supplies air at a rate of 4.5 m^3/s and total head of 100 mm of water. The outer diameter of the impeller is 50 cm and the outer width is 18 cm. The blades are backwards inclined and of negligible thickness. If the fan runs at 1800 RPM, determine the blade angle at outlet. Assume zero whirl at inlet and take air density as 1.23 kg/m^3.

Q.8. A centrifugal water pump with 6 backward facing blades (angle $\beta_2 = 30°$ to the tangent) can deliver 0.35 m^3/s with a head of 25 m. The radial outflow velocity is 3 m/s and the pump runs at 900 RPM. Consider the ideal case (no shock)

a. Find the type number for this design

b. Draw the exit velocity diagrams if the hydraulic efficiency is 85%. State any assumptions you make in the analysis.

c. Find the outside diameter and the exit blade height

d. Find the ideal power.

Q.9. If a particular wind turbine can generate 100 kW of power when the wind is blowing at 10 km/hr, how much power can it generate when the wind is blowing at 15 km/hr?

Q.10. B. A helicopter has 4 blades of length 4 m and width 10 cm. If the lift coefficient is constant along the length of the blade at a value of $C_L = 0.8$, what is the loaded weight of the helicopter if it is hovering with its rotor making 8 revolutions every second?