Fifth Semester B.E. Degree Examination, Dec.08/Jan.09
Turbomachines

Time: 3 hrs. Max. Marks:100

Note: 1. *Answer any FIVE full questions, selecting at least TWO questions from each part.*
2. *Use of Thermodynamic data handbook is permitted.*

PART – A

1 a. Define Turbomachines. Give at least 4 different classifications of turbomachines. (06 Marks)

b. Define specific speed of pumps. Show that specific speed of pump is given by $N_s = \frac{N\sqrt{Q}}{H^{3/4}}$ (06 Marks)

c. A turbine model of 1:10 develops 2.0 kW under a head of 6mts at 500 rpm. Find the power developed by the prototype under a head of 40m. Also find the speed of prototype and its specific speed. Assume the turbine efficiencies to remain same. (08 Marks)

2 a. Draw the inlet and exit velocity triangles for a radial flow power absorbing turbomachine with (i) Backward curved vane (ii) Radial vane (iii) Forward vane. Assume inlet whirl velocity to be zero. Draw and explain the head-capacity relations for the above 3 types of vanes. (10 Marks)

b. Show that for maximum utilization the work output per stage of an axial flow impulse machine (with equiangular rotor blades) is double that of a 50% reaction stage which has the same speed. Assume that axial velocity remains constant for a 50% reaction machine. (10 Marks)

3 a. Define degree of reaction and utilization factor with mathematical expressions. Show that $\epsilon = \frac{V_1^2 - V_2^2}{V_1^2 - RV_2^2}$ where ϵ is utilization factor. R is degree of reaction and V_1 & V_2 are absolute velocities at the inlet and exit. (10 Marks)

b. Air enters a rotor in an axial flow turbine with a tangential component of absolute velocity equal to 600 m/s in the direction of rotation. At the rotor exit, the tangential component of absolute velocity is 100 m/s in a direction opposite to that of rotation. The tangential blade speed is 250 m/s. Draw inlet & exit velocity triangles. Find
(i) Change in total enthalpy.
(ii) Change in total temperature across the rotor.
(iii) Power in kW for a flow rate of 10 kg/s. (10 Marks)

4 a. Show that polytropic efficiency (infinitesimal stage efficiency) is given by (Draw the T-S diagram) $\eta_p = \left(\frac{n-1}{n}\right)\left(\frac{\gamma}{\gamma-1}\right)$

where n = polytropic process of index n. γ = ratio of specific heat. (10 Marks)

b. A low pressure air compressor develops a pressure 1400 mm of water gauge (WG). If the initial and final states of air are P_1=1.01 bar, T_1=305 K and T_2=320 K, determine compressor and infinitesimal stage efficiencies. (10 Marks)

PART – B

5 a. Explain the surging phenomena in compressors with the help of head-discharge curves. (08 Marks)

b. An axial-flow compressor stage draws air with inlet stagnation condition of 1 bar and 35°C. Assuming a 50% reaction stage with a flow coefficient of 0.52 and the ratio $\Delta V_u/u = 0.25$, find the rotor blade angles at the inlet and exit as well as mean rotor speed. The total-to-total efficiency of the stage is 0.87 when the stage produces a total-to-total pressure ratio of 1.23. Find the pressure coefficient and power input to the system, assuming work input factor to be 0.86. The mass flow rate is 12 kg/s. (12 Marks)

6 a. Applying Bernoulli's equation between the inlet and exit of the impeller of a centrifugal pump, show that the static pressure rise is given by

$$p_2 - p_1 = \frac{\rho}{2}\left[V_{m1}^2 + U_2^2 - V_{m2}^2 \operatorname{cosec}^2\beta_2\right]$$

Where, V_{m1}= velocity of flow at inlet = V_1, V_{m2}= velocity of flow at exit.
β_2= Blade angle at exit, U_2= Blade speed at exit.
ρ = density of fluid, p1 & p2 = Static pressure at inlet & exit. (08 Marks)

b. A centrifugal pump discharges 0.15 m³/sec of water against a head of 12.5m. Speed of impeller is 600 rpm. The outer & inner diameters of impeller are 500mm and 250mm respectively and the vanes are bent back at 35° to the tangent at exit. If the area of flow remains 0.07 m² from inlet to outlet, find (i) Manometric efficiency of pump (ii) Vane angle at inlet (iii) Loss of head at inlet to impeller when discharge is reduced by 40% without changing the speed. (12 Marks)

7 a. For a single stage impulse turbine, prove that the maximum blade efficiency is given by

$$(\eta_b)_{max} = \frac{\cos^2\alpha_1}{2}(1+KC) \quad \text{Where } K = V_{r_2}/V_{r_1} \text{ and } C = \cos\beta_2/\cos\beta_1,\ \alpha_1 = \text{nozzle angle},$$

β_1, β_2 = are rotating blade angles at inlet & exit
V_{r_1}, V_{r_2} are relative velocities at inlet and exit. (08 Marks)

b. The following particulars relate to a two-row velocity compounded impulse wheel.
Steam velocity at nozzle outlet = 650 m/s
Mean blade speed = 125 m/s
Nozzle outlet angle = 16°
Outlet angle of first row of moving blades = 18°
Outlet angle of fixed guide blades = 22°
Outlet angle of second row of moving blades = 36°
Steam flow = 2.5 kg/s
The ratio of relative velocity at outlet to that at inlet is 0.84 for all blades. Determine (i) Axial thrust on blades (ii) Power developed (iii) The efficiency of the wheel. (12 Marks)

8 a. State the functions of a draft tube. Show that the efficiency of draft tube is given by $\eta_d = \dfrac{v_1^2 - v_2^2 - 2gh_f}{v_1^2}$; where v_1 is absolute velocity of water at rotor exit; v_2 is absolute velocity of water at draft tube exit. h_f is loss of head due to friction. (08 Marks)

b. A Kaplan turbine working under a head of 20m develops 11772 kW of shaft power. The outer diameter of runner is 3.5m & hub diameter is 1.75m. The guide blade angle at the extreme edge of the runner is 35°. The hydraulic and overall efficiencies of the turbines are 88% and 84% respectively. If the velocity of whirl is zero at outlet, determine:
(i) Runner vane angle at the inlet & outlet at the extreme edge of the runner.
(ii) Speed of turbine. (12 Marks)

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