USN | | | | | | | | | | |

15ME53

Fifth Semester B.E. Degree Examination, July/August 2021
Turbo Machines

Time: 3 hrs. Max. Marks: 80

Note:1. ***Answer any FIVE full questions.***
2. ***Use of Thermodynamics Data Hand Book, Steam tables and Mollier chart permitted.***

1 a. Define a turbo machine. Mention any five differences between a turbo machine and a positive displacement machine. **(06 Marks)**

b. Define specific speed of a turbine. Explain its significance. **(03 Marks)**

c. A Francis turbine model is built to a scale of 1 : 5. The data for the model is P = 6 kW, N = 350 rpm, H = 3 m and for prototype H = 9 m. Assuming the overall efficiency of the model as 75%, calculate :
(i) Speed of the prototype (ii) Power of the prototype.
Use Moody's equation. **(07 Marks)**

2 a. Show that the polytropic efficiency for a compression process is given by $\eta_P = \left(\frac{n}{n-1}\right)\left(\frac{\gamma-1}{\gamma}\right)$ where γ is the ratio of specific heats and n is the index of compression. **(08 Marks)**

b. Air flows through an air turbine where its stagnation pressure is decreased in the ratio 5 : 1. Total-to-Total efficiency is 0.8. The air flow rate is 5 kg/s. If the total power output is 500 kW, find : (i) Inlet total temperature (ii) Actual exit total temperature (iii) Actual exit static temperature if the flow velocity is 100 m/s. (iv) Total-to-static efficiency. **(08 Marks)**

3 a. Define degree of reaction. Show that the relationship between the utilization factor $\in$ and the degree of Reaction R for an axial flow turbine is given by $\in = \frac{V_1^2 - V_2^2}{V_1^2 - RV_2^2}$ where V_1 and V_2 are the absolute velocity of fluid at inlet and outlet respectively. **(08 Marks)**

b. At a stage in a 50% degree of reaction axial flow turbine running at 3000 rpm, the blade mean diameter is 68.5 cm. If the maximum utilization factor for the stage is 0.915, calculate the inlet and outlet absolute velocities for the rotor assuming the velocity triangles at inlet and outlet to be symmetric. Find also the power output for a flow rate of 15 kg/s. **(08 Marks)**

4 a. Draw the velocity triangles for an axial flow compressor and show that for an axial flow compressor with no axial thrust, the degree of reaction is given by $R = \frac{V_a}{2u}\left[\frac{\tan\beta_1 + \tan\beta_2}{\tan\beta_1 \tan\beta_2}\right]$ where V_a = Axial flow velocity, u = Blade speed, β_1 and β_2 = Inlet and Outlet blade angles with respect to tangential direction. **(10 Marks)**

b. In a mixed flow compressor handling air at 16000 rpm, the stagnation temperature of air at compressor inlet and outlet are respectively 27˚C and 215˚C. The absolute velocity of air at the rotor inlet is axial while at the exit, the tangential component of absolute velocity is 0.93 times the tangential impeller speed. If the mass flow rate of air through the impeller is 15 kg/s and specific heat is assumed to be constant, find the impeller diameter and total power input. **(06 Marks)**

5 a. What do you mean by compounding of steam turbine? Explain with the help of a schematic diagram, a two row velocity compounded turbine stage. **(06 Marks)**

b. A single stage impulse wheel is supplied with super heated steam at 15 bar and 250°C, expands to 0.5 bar condenser pressure. The rotors are fitted with equi angular blades moving at 450 m/s. If the nozzle angle at the rotor inlet is 16° to the wheel plane, find the specific power output, blade efficiency, grass stage efficiency and direction of exit steam velocity. Assume nozzle efficiency as 94% and assume the relative velocities as equal. **(10 Marks)**

6 a. Show that the maximum blade efficiency of a Parson's reaction turbine is,

$$(\eta_b)_{max} = \frac{2\cos^2\alpha_1}{1+\cos^2\alpha_1}$$

where α_1 = nozzle angle at inlet. **(09 Marks)**

b. The following particulars refer to a Parson's reaction turbine consisting of one ring of fixed blades and one ring of moving blades. The mean diameter of the blade ring is 90 cm and its speed is 3000 rpm. The inlet absolute velocity to the blades is 350 m/s. The blade outlet angle is 20°. The steam flow rate is 7.2 kg/s. Calculate (i) The blade inlet angle (ii) Tangential force (iii) Power developed. **(07 Marks)**

7 a. With suitable velocity triangles, derive an expression for the maximum hydraulic efficiency of a Pelton wheel in terms of blade velocity co-efficient and outlet blade angle. **(08 Marks)**

b. A 137 mm diameter jet of water issuing from a nozzle impinges on the buckets of a Pelton wheel and the jet is deflected through an angle of 165° by the buckets. The head available at the nozzle is 400 m. Assuming coefficient of velocity as 0.97, speed ratio as 0.46 and reduction in the relative velocity while passing through the buckets as 15%, find (i) Force exerted by the jet on the buckets in the tangential direction (ii) theoretical power developed. **(08 Marks)**

8 a. List the functions of a draft tube in a reaction hydraulic turbine. Using Bernoulli's equation, show that the pressure head at the inlet of the draft tube is less than the atmospheric pressure head. **(06 Marks)**

b. The following data is given for a Francis turbine : Net head = 70 m, Speed = 600 rpm, Shaft power = 368 kW, Overall efficiency = 85%, hydraulic efficiency = 95%, Flow ratio = 0.25, Breadth ratio = 0.1, Outer diameter of the runner = 2 × inner diameter of the runner. Velocity of flow is constant at inlet and outlet. The thickness of the vanes occupies 10% of the circumferential area of the runner and the discharge is radial at outlet. Determine : (i) Guide blade angle (ii) Runner vane angles at inlet and outlet. (iii) Diameter of runner at inlet and outlet (iv) Width of the runner at inlet. **(10 Marks)**

9 a. What is Priming? Why priming is required in centrifugal pumps? **(03 Marks)**

b. Derive an expression for minimum starting speed of a centrifugal pump. **(06 Marks)**

c. A 4-stage centrifugal pump has impellers each of 38 cm diameter and 1.9 cm wide at outlet. The outlet vane angle is 45° and the vanes occupy 8% of the outlet area. The manometric efficiency is 84% and overall efficiency is 75%. Determine the head generated by the pump when running at 900 rpm discharging 59 litres/s of water. Also determine the power required. **(07 Marks)**

10 a. Explain the following with appropriate sketches :
(i) Surging (ii) Choking (iii) Pre-rotation. **(09 Marks)**

b. A centrifugal compressor runs at a speed of 15000 rpm and delivers 30 kg/s of air. The exit diameter is 70 cm. The relative velocity at exit is 100 m/s at an exit blade angle of 75°. Assume radial inlet. The inlet total temperature and pressure are 300 K and 1 bar respectively. Determine :
(i) Power required to drive the compressor (ii) Ideal head developed
(iii) Total exit pressure. **(07 Marks)**

* * * * *