USN

10ME56

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

Time: 3 hrs. Max. Marks:100

Note: ***Answer any FIVE full questions.***

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

1 a. Define a Turbomachine. List any five differences between turbomachines and positive displacement machines. **(06 Marks)**

b. Define specific speed of turbine. Derive an expression of specific speed for the same. **(06 Marks)**

c. The quantity of water available for a hydroelectric station is $275 m^3/s$ under a head of 18m. Assuming speed of the turbine to be 150rpm and their efficiency 82%, determine the least number of machines all of same size that will be needed if i) Francis turbine whose specific speed must not exceed 395 ii) Kaplan turbine whose specific speed must not exceed 690 are chosen. What would be the individual output of the units in the two cases? **(08 Marks)**

2 a. For a power generating turbo machine, with h-s diagram, define: i) Total-to-total efficiency ii) Total-to-static efficiency. **(04 Marks)**

b. With h-s diagram, show that the pre heat factor for a multi stage compressor is less than unity. **(08 Marks)**

c. A 16 stage axial flow compressor is to have a pressure ratio of 6.3 and tests have shown that a stage efficiency of 89.5% can be obtained. The intake conditions are 288K and 1 bar. Find: i) Overall efficiency ii) Polytropic efficiency iii) Preheat factor. **(08 Marks)**

3 a. Define utilization factor and degree of reaction. Show that the relationship between utilization factor $\in$ and degree of reaction R for an axial flow turbine is given by $\in = \dfrac{V_1^2 - V_2^2}{V_1^2 - RV_2^2}$. **(10 Marks)**

b. In a turbine stage with 50% reaction, the tangential blade speed is 98.5m/s. The steam velocity at the nozzle exit is 155m/s and the nozzle angle is 18°. Assuming a steam flow rate of 10kg/s, compute: i) Inlet blade angle ii) Power developed iii) Utilization factor. **(10 Marks)**

4 a. A radial outward flow turbomachine has no inlet whirl. The blade speed at exit is twice that at inlet. The radial velocity is constant throughout. Taking the inlet blade angle as 45°, show that the degree of reaction $R = \dfrac{\cot\beta_2 + 2}{4}$ where β_2 = Blade angle at exit with respect to tangential direction. **(10 Marks)**

b. The total power input at a stage of an axial flow compressor with symmetric inlet and outlet velocity triangles with R = 0.5 is 27.85kJ/kg of air flow. If the blade speed is 180m/s throughout the rotor, draw the velocity triangles and compute the inlet and outlet rotor blade angles with respect to tangential direction. Assume axial velocity component = 120m/s. **(10 Marks)**

5 a. Show that for an axial flow impulse turbine, the rotor efficiency is given by $\eta_{rotor} = 2(\phi \cos \alpha_1 - \phi^2)\left(1 + k_b \dfrac{\cos\beta_2}{\cos\beta_1}\right)$ where ϕ = Blade speed ratio, α_1 = Nozzle angle, β_1 = Blade angle at inlet, β_2 = Blade angle at outlet, K_b = Blade velocity coefficient. Further show that $\eta_{rotor(max)} = \cos^2\alpha_1$. **(10 Marks)**

b. A single stage impulse turbine rotor has a diameter of 1.2m running at 3000rpm. The nozzle angle is 18°. The blade speed ratio is 0.42. The blade velocity coefficient is 0.9. The outlet angle of the blade is 3° less than the inlet angle. Steam flow rate is 5kg/s. Draw the velocity triangles and find: i) Blade angles ii) Power developed iii) Axial thrust iv) Blade efficiency. **(10 Marks)**

6 a. Mention the different classification of hydraulic turbines. **(04 Marks)**

b. Explain the functions of a draft tube in a reaction turbine. Prove that the pressure head at the inlet of the draft tube is always less than the atmospheric pressure head. **(06 Marks)**

c. A double jet Pelton wheel is required to generate 7500kW when the available head at the base of the nozzle is 400m. The jet is deflected through 165° and the relative velocity of the jet is reduced by 15% in passing over the buckets. Determine: i) Diameter of each jet ii) Total flow rate iii) Force exerted by the jet in the tangential direction. Assume overall efficiency = 80%, speed ratio = 0.47, coefficient of velocity of the nozzle = 0.97. **(10 Marks)**

7 a. What is Priming? Why it is required? Explain how priming is done in centrifugal pumps. **(04 Marks)**

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

$$P_2 - P_1 = \frac{\rho}{2}\left[v_{f_1}^2 + u_2^2 - v_{f_2}^2 \operatorname{cosec}^2 \beta_2\right]$$

where v_{f_1} = velocity of flow at inlet

v_{f_2} = Velocity of flow at exit

u_2 = Blade velocity at exit

β_2 = Blade angle at exit

ρ = Density of the fluid

P_1 = Static pressure of the fluid at inlet

P_2 = Static pressure of the fluid at exit. **(08 Marks)**

c. A centrifugal pump delivers 50 litres/s of water against a total head of 24m when running at 1500rpm. The velocity of flow is maintained constant at 2.4m/s and blades are curved back at 30° to the tangent at outlet. The inner diameter is half the outer diameter. If the manometric efficiency is 80%, determine: i) Blade angle at inlet ii) Power required to drive the pump. **(08 Marks)**

8 a. Derive an expression for overall pressure ratio for a centrifugal compressor in terms of impeller tip speed, slip, power input factor and isentropic efficiency. **(10 Marks)**

b. An axial flow compressor of 50% reaction has blades with inlet and outlet angles with respect to axial direction as 45° and 10° respectively. The compressor is to produce a pressure ratio of 6:1 with an overall isentropic efficiency of 85% when inlet static temperature is 37°C. The blade speed and axial velocity are constant throughout the compressor. Assuming a value of 200m/s for blade speed, find the number of stages required if the work done factor is i) Unity ii) 0.87 for all stages. **(10 Marks)**

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