CBCS SCHEME

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15AE46

Fourth Semester B.E. Degree Examination, Aug./Sept.2020
Turbo Machines

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define Turbomachines. Give the classifications of Turbomachines. **(06 Marks)**

b. Test on a turbine runner 1.25m in diameter at 30m head gave the following results, power developed 736kW, speed is 180rpm and the discharge is $2.7m^3$/sec. Find the diameter, speed and discharge of a similar runner to operate at 45m head and give 1472kW at the same efficiency. What is the specific speed of both the turbines? **(06 Marks)**

c. Define specific speed of Turbine and specific speed of pump. **(04 Marks)**

OR

2 a. State the assumptions and derive Euler's turbine equation. **(08 Marks)**

b. Define degree of reaction (R). Construct the velocity triangles for
i) $R < 0$
ii) $R = 0$
iii) $R = 0.5$
iv) $R = 1$ **(08 Marks)**

Module-2

3 a. Define Infinitesimal stage efficiency. With a neat h-s diagram show that

$$\eta_p = \frac{\gamma - 1}{\gamma} \frac{n}{n-1}$$ **(08 Marks)**

b. A compressor develops a pressure of 1500mm W.G. If the initial and final states of air are P_1 = 1.02bar, T_1 = 300°K and T_2 = 315°K, determine the compressor and the polytropic efficiencies.
In another compressor, air compresses from P_1 = 1.02 bar, T_1 = 300°K to P_2 = 2.5 bar with an efficiency of 75%. Determine the polytropic efficiency of this compressor. **(08 Marks)**

OR

4 a. Define the following for a Turbine using h-s diagram:
i) Total-to-total efficiency
ii) Polytropic efficiency
iii) Reheat factor. **(08 Marks)**

b. The overall pressure ratio across a three stage gas turbine is 11 and its efficiency is 88%. If the pressure ratio of each stage is the same and the inlet temperature is 1500°K, determine pressure ratio in each stage, polytropic efficiency, stage efficiency, reheat factor, exit temperature and total power output for a mass flow rate of 50kg/sec. (Take: C_p = 1.005kJ/kg°K and γ = 1.4). **(08 Marks)**

Module-3

5 a. For an centrifugal compressor show that

$$H = \frac{U_2^2}{g} - \left[\frac{U_2 \cot\beta_2}{\pi D_2 B_2 g} Q\right]$$

U_2 = tangential velocity at outlet
β_2 = Outlet blade angle
B_2 = Width of impeller at outlet
D_2 = diameter of impeller at outlet. **(08 Marks)**

b. A centrifugal compressor rotor has inlet radius of 30cm and exit radius of 60cm. Entry is radial with a component of 60m/sec which is constant throughout. The compressor requires 700kW of power to handle 20kg of air per-second. Find the blade angles at inlet and outlet if the compressor runs at 5100rpm. Calculate the width at inlet and outlet, if specific volumes at inlet and outlet are respectively 0.85m^3/kg and 0.71m^3/kg. What is the degree of reaction? **(08 Marks)**

OR

6 a. Draw the velocity triangle for an axial flow compressor and show that for an axial flow compressor. The degree of reaction is given by

$$R = \frac{V_a}{2U}\left[\frac{\tan\beta_1 + \tan\beta_2}{\tan\beta_1 \tan\beta_2}\right]$$

V_a = axial flow velocity
U = blade speed
β_1 and β_2 = inlet and outlet blade angles. **(08 Marks)**

b. An axial compressor stage has the following data: Temperature and pressure at entry are 300°K and 1.0 bar, R = 50%, mean blade ring diameter is 36cm, rotational speed 18000rpm, Blade height at entry is 6cm, Air angles at rotor and stator exit 25°, Axial velocity 180m/sec, work done factor 0.88, stage efficiency 85% and mechanical efficiency 96.7%. Determine: Air angles at rotor and stator entry, mass flow rate of air, power required to drive the compressor, pressure ratio developed by the stage and mach number at the rotor entry. **(08 Marks)**

Module-4

7 a. Show that $\in_{max}$ of an axial flow turbine with degree of reaction = $\frac{1}{4}$, the relationship of blade speed U to absolute velocity at rotor inlet V_1, should be $\frac{U}{V_1} = \frac{2}{3}\cos\alpha_1$, where α_1 = nozzle angle at inlet. Assume flow velocity is constant from inlet to outlet. **(08 Marks)**

b. Air enters in an axial flow turbine with a tangential component of the absolute velocity equal to 600m/sec in the direction of rotation. At the rotor exit, the tangential component of the absolute velocity is 100m/sec in a direction opposite to that of rotational speed. The tangential blade speed is 250m/sec. Evaluate: i) The change in total enthalpy of air between the inlet and outlet of the rotor ii) The power in KW if the mass flow rate is 10kg/sec iii) The change in total temperature across the rotor. **(08 Marks)**

OR

8 a. Describe briefly the various aerodynamic losses occurring in an inward flow radial turbine stage. **(06 Marks)**

b. A 90° IFR turbine stage has the following data:

Total-to-static pressure ratio $\frac{P_{01}}{P_3} = 3.5$, exit pressure = 1 bar, stagnation temperature at entry = 650°C, blade-to-isentropic speed ratio $\sigma = 0.66$, rotor diameter ratio $d_3/d_2 = 0.45$, rotor speed N = 16000rpm, nozzle exit air angle = 20°, nozzle efficiency = 0.95, rotor width at entry b_2 = 5cm. Assuming constant meridional velocity, axial exit and that the properties of the working fluid are the same as those of air, determine: the rotor diameter, rotor blade exit air angle, mass flow rate, hub and tip diameter at the rotor exit, power developed, total-to-static efficiency of the stage. **(10 Marks)**

Module-5

9 a. Show that the pressure rise in the impeller of a centrifugal pump when the frictional and other losses in the impeller are neglected is given,

$$\frac{1}{2g}\left[Vf_1^2 + U_2^2 - Vf_2^2 \text{ cosec}^2 \beta_2\right],$$

Where Vf_1 and Vf_2 are the flow velocities at inlet and outlet of the impeller, U_2 = tangential speed of impeller at exit, β_2 = Exit blade angle. **(10 Marks)**

b. With a neat sketch, explain the terminology of centrifugal PUMP. **(06 Marks)**

OR

10 a. Show that the hydraulic efficiency of pelton wheel is maximum when peripheral wheel velocity is half the absolute velocity of jet at inlet. Further deduce that

$$\eta_{b,max} = \left(\frac{1 + K \text{ Cos } \beta_2}{2}\right),$$

where K is friction co-efficient and β_2 is outlet blade angle. **(08 Marks)**

b. An inward flow Francis turbine operates at 486rpm and uses 100m^3/min of water. The draft tube diameter at inlet and outlet are 0.8m and 1.5m respectively. The length of the draft tube is 30m. The available head is 81m. Assuming $\eta_v = 0.98$, $\eta_m = 0.97$ and $\eta_H = 0.92$, find the runner tip diameter, power output and speed ratio if the flow ratio $\psi = 0.2$, the blade at the inlet is inclined 120° to the wheel tip velocity. **(08 Marks)**

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