CBCS SCHEME

USN 17ME53

Fifth Semester B.E. Degree Examination, Jan./Feb. 2021
Turbomachines

Time: 3 hrs. Max. Marks: 100

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

Module-1

1 a. Define specific speed of turbine and hence derive an expression for specific speed of turbine. **(06 Marks)**

b. A Pelton wheel is running at a speed of 200rpm and develops 5200KW when working under a heat of 220m with an overall efficiency of 80%. Determine its unit speed, unit flow, unit power and specific speed. Find the speed, flow and power when its operating condition changes to a head of 140m. **(08 Marks)**

c. A full scale centrifugal pump running at 500rpm delivers $5m^3/s$ against a head of 100m. A model of the pump delivers $0.3m^3/s$ with a power input of 100KW at an efficiency of 90%. Calculate the speed of the model and scale ratio. **(06 Marks)**

OR

2 a. Applying First law of thermodynamics to turbomachines, prove that the work transfer is numerically equal to the change in total enthalpy between inlet and outlet of the machine. **(06 Marks)**

b. With the help of h-s diagram define the following with respect to turbines :
i) Total–to–total efficiency
ii) Total–to–static efficiency. **(06 Marks)**

c. Liquid water flows through pump from an elevation of 1m at the inlet to an elevation of 2m at the exit from the centre of the pump respectively. The static pressure increases from 10cm to 150cm of mercury between the inlet and exit. The inlet and exit velocities are 5m/s and 10m/s respectively. Evaluate the isentropic enthalpy increase across the pump. Also find the power required to drive the pump and the actual change in enthalpy if the total – to – total isentropic efficiency of the pump is 75%. The mass flow rate of water in pump is 100kg/min. **(08 Marks)**

Module-2

3 a. Define degree of reaction and utilization factor. Obtain the general equation for utilization factor in terms of degree of reaction, absolute velocities at inlet and outlet of the turbine. **(08 Marks)**

b. At a stage of an impulse turbine, the mean blade diameter is 0.75m, its rotational speed being 3500rpm. The absolute velocity of fluid exiting from a nozzle inclined at 20° to the wheel tangent is 275m/s. If the utilization factor is 0.9 and the relative velocity at rotor exit is 0.9 times that at inlet, find the inlet and exit rotor angles. Also find the power output from the stage for a mass flow rate of 2 kg/s and axial thrust on the shaft. **(12 Marks)**

OR

4 a. Prove that the degree of reaction for an axial flow compressor is given by

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

Where V_a = Axial component or flow velocity, U = tangential velocity of rotor, β_1 and β_2 are the rotor angles at inlet and exit measured with reference to tangential direction. **(10 Marks)**

b. A single stage axial flow blower with no inlet guide vanes, operates at 3600rpm. The tip and hub diameters of the rotor are 20cm and 12.5cm respectively. The air flow through the stage is 0.45kg/s. The air turned through an angle of 20° towards the axial direction during the passage through the rotor at the mean diameter. Assuming the inlet conditions of pressure of 1 bar and 25°C, constant axial velocity and no losses in the rotor, compute :
i) The power input in KW ii) degree of reaction. **(10 Marks)**

Module-3

5 a. Derive the condition for maximum blade efficiency with equip-angular blades in an impulse steam turbine. **(08 Marks)**

b. In a Curtis stage with two rows of moving blades, the rotors are equiangular. The first rotor has angle of 29° each while second rotor has angle of 32° each. The velocity of steam at the exit of nozzle is 530m/s and blade coefficients are 0.9 in the first moving row, 0.95 in the stator and in the second moving row. If the absolute velocity at the stage exit should be axial, find :
i) Mean blade speed
ii) The rotor efficiency
iii) The power output for a steam flow rate of 1kg/s. **(12 Marks)**

OR

6 a. Prove that the maximum blade efficiency in a Parason's reaction steam turbine is given by :

$$\eta_{b,max} = \frac{2\cos^2\alpha_1}{1+\cos^2\alpha_1}.$$

(08 Marks)

b. At a stage of a turbine with Parasons's blading deliver dry saturated steam at 2.7 bar form fixed blades at 90m/s. The mean blade height is 40mm, and the moving blade exit angle is 20°. The axial velocity of steam is ¾ times the blade velocity at the mean radius. Steam is supplied to the stage at the rate of 9000kg/h. The effect of blade tip thickness on the annulus area can be neglected calculate : i) the wheel speed in RPM ii) the diagram efficiency iii) the diagram power iv) the enthalpy drop of the steam in this stage. **(12 Marks)**

Module-4

7 a. With the necessary velocity triangles, show that the maximum hydraulic efficiency of a Pelton wheel is given by $\eta_{H,max} = \frac{1+c_b\cos\beta_2}{2}$, where $c_b = V_{r2}/V_{r1}$ and β_2 is bucket tip angle. **(08 Marks)**

b. 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) The diameter of each jet ii) total flow iii) force exerted by the jets in the tangential direction. Assume generator efficiency is 95%, overall efficiency is 80% and speed ratio = 0.47. **(12 Marks)**

OR

8 a. For Francis turbine, show that the hydraulic efficiency $= \dfrac{2}{2+\tan^2\alpha_1}$ for the following conditions : i) the component of velocity normal to the tangential direction is constant from inlet to outlet ii) relative velocity at the inlet is radial iii) absolute velocity at the outlet is radial. Where α_1 = flow angle at inlet. Sketch the velocity triangles at inlet and outlet. **(08 Marks)**

b. An inward flow reaction turbine has a runner 0.5m diameter an d7.5cm wide. The inner diameter is 0.35m. The effective area of flow is 93% of the gross area and the flow velocity is constant. The guide vane angle is 23° inlet moving vane angle is 97° and the outlet vane angle is 30°. Assuming radial discharge at the exit, calculate the speed of the wheel so that the water enters without shock and the supply head of 60m. Assume hydraulic friction losses of 10% and mechanical efficiency as 94%. What is the specific speed of the machine? **(12 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 by

$$\frac{1}{2g}\left[V_{f1}^2 + u_2^2 - V_{f2}^2 \operatorname{cosec}^2\beta_2\right].$$

Where V_{f1} and V_{f2} are the flow velocities at inlet and out let of the impeller, u_2 = tangential velocity of the impeller at exit and β_2 = exit blade angle. **(08 Marks)**

b. Derive an expression for minimum speed of CF pump to start the flow. **(04 Marks)**

c. Find the power required to drive the CF pomp which delivers $0.04\,m^3/p$ of water t a height of 20m through a 15cm diameter of pipe and 100m long. The overall efficiency of the pump is 70% and the friction factor is assumed to be 0.015. **(08 Marks)**

OR

10 a. Explain the phenomena of :
Surging
Stalling and
Choking in a centrifugal compressor stage. **(06 Marks)**

b. Show that the H-Q characteristic equation for centrifugal blower is given by

$$H = K_1 - K_2 Q$$

Where $K_1 = u_2^2/g$, $K_2 = \dfrac{u_2 \cot\beta_2}{g, \pi D_2 \cdot b_2}$. **(06 Marks)**

c. An axial flow compressor of 50% reaction design has blades with inlet and outlet angle with reference to axial direction of 45° and 10° respectively. The compressor is to produce a pressure ratio of 6 : 1 with an isentropic efficiency of 0.85 when inlet static temperature is 37°C. The blade speed and axial velocity are constant throughout the compressor. Assuming a blade speed of 200m/s, find the number of stages required if the work done factor is i) unity ii) 0.87 for all stages. **(08 Marks)**

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