CBCS SCHEME

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18ME54

Fifth Semester B.E. Degree Examination, Jan./Feb. 2023
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 a turbine. Derive an expression for specific speed of a turbine. **(08 Marks)**

b. A model of a centrifugal pump absorbs 5kW at a speed of 1500rpm. Pumping water against a head of 6m. The large prototype pump is required to pump water to a head of 30m. The scale ratio of diameter is 4. Assuming some efficiency and similarities, find the speed, power of prototype and ratio of discharge of prototype and model. **(08 Marks)**

c. For power generating turbomachines, define
i) Total – to – total efficiency
ii) Total – to – static efficiency. **(04 Marks)**

OR

2 a. With usual notations, derive an expression for infinitesimal stage efficiency during compression process with an aid of T-S plot. **(08 Marks)**

b. An air compressor has eight stages of equal pressure ratio 1.3. The flow rate through the compressor and its overall efficiency are 45Kg/s and 80% respectively. If the conditions of air at entry are 1 bar and 35°C, determine,
i) State of air at compressor exit
ii) Polytropic efficiency **(06 Marks)**

c. Compare the turbomachine with positive displacement machines. **(06 Marks)**

Module-2

3 a. Derive alternate form of Euler's turbine equation and explain the significance of each energy component. **(10 Marks)**

b. At a stage of an axial flow impulse turbine, the mean blade diameter is 80cm and the speed is 3000 rpm. The absolute velocity of the fluid at inlet is 300m/sec and is inclined at 20° to the plane of the wheel. If the utilization factor is 0.85 and the relative velocity at rotor exit is equal to that at inlet, determine
i) Inlet and exit blade angles
ii) Power output for a mass flow rate of 1Kg/sec. **(10 Marks)**

OR

4 a. Define degree of reaction for an axial flow machine. Prove that degree of reaction for an axial flow device assuming constant velocity of flow is given by

$$R = \frac{Va}{2u}[Cot\beta_1 + Cot\beta_2]$$ **(10 Marks)**

b. In a turbine stage with 50% reaction the tangential blade speed is 98.5 m/sec. The steam velocity at the nozzle exit is 155 m/sec and the nozzle angle is 18°. Assuming symmetric inlet and outlet velocity triangles. Compute the inlet blade angle for the rotor and power developed by the stage assuming a steam flow rate of 10Kg/sec. Also find the utilization factor. **(10 Marks)**

Module-3

5 a. Draw the inlet and exit velocity triangle for a single stage impulse steam turbine and prove that maximum blade efficiency is given by

$\eta_{b\,max} = \cos^2 \alpha_1$

Assume $v_{r_1} = v_{r_2}$ and $\beta_1 = \beta_2$ **(10 Marks)**

b. The following particular refer to a stage of a Parson's steam turbine. The mean diameter of the blade ring is 70cm, the steam velocity at the inlet of moving blades is 160m/sec, the outer blade angle of moving blade β_2 is 20°. The steam flow through the blades is 7Kg/sec, Speed 1500rpm and η_{st} is 0.8. Draw the velocity diagrams and find the following :

i) Blade inlet angle
ii) Power developed in the stage
iii) Available isentropic enthalpy drop. **(10 Marks)**

OR

6 a. Define and explain nozzle efficiency and stage efficiency. **(04 Marks)**

b. With a neat sketch, explain the velocity compounding. **(06 Marks)**

c. In a stage of an impulse turbine provided with single row wheel, the mean diameters of the blade ring is 80cm and the speed of rotation is 3000rpm. The steam issues from the nozzle with a velocity of 300m/sec and the nozzle angle is 20°. The rotor blades are equiangular and blade velocity coefficient is 0.85. What is the power developed in the blades when the axial thrust on the blade is 140N? **(10 Marks)**

Module-4

7 a. Derive an expression for force, power and efficiency of a Pelton turbine assuming no frictional losses with the help of velocity triangles. **(10 Marks)**

b. The following data is given for a Francis turbine net head = 70m, Speed = 600rpm, Shaft power = 368kW, η_0 = 86%, η_h = 95%, flow ratio = 0.25, breadth ratio = 0.12, outer diameter of runner = 2 times inner diameter of runner, velocity of flow is constant at inlet and outlet, the thickness of vanes occupies 10% of the circumferential area of the runner and discharge is radial at outlet. Determine :

i) Guide blade angle
ii) Runner vane angles at inlet and outlet
iii) Diameters of runner at inlet and outlet
iv) Width of the wheel at inlet **(10 Marks)**

OR

8 a. Draw the cross sectional views of a Kaplan turbine and explain its working with a neat sketches of velocity triangles at inlet and outlet of Kaplan turbine runner. **(10 Marks)**

b. A three – jet Pelton wheel is required to generate 10,000kW under a head of 400m. The blade angle at outlet is 15° and reduction in relative velocity over the bucket is 5%. If the overall efficiency is 80%, C_v = 0.98 and speed ratio = 0.46. Find

i) Diameter of jet
ii) Total flow in m^3/sec
iii) Force exerted by a jet on the buckets **(10 Marks)**

Module-5

9 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,

$(P_2 - P_1) = \rho/2\ [vf_1^2 + u_2^2 - vf_2^2 \text{Co}\sec^2 \beta_2]$

Where, vf_1 = Velocity of flow at inlet

vf_2 = Velocity of flow at exit

β_2 = Blade angle at exit

u_2 = Blade speed at exit

ρ = density of fluid

P_1 and P_2 = Static pressure at inlet and exit **(08 Marks)**

b. The outer diameter of the impeller of a centrifugal pump is 40cm and width of the impeller at outlet is 5cm. The pump is running at 800rpm and is working against a total head of 15m. the vane angle at outlet is 40° and manometric efficiency is 75%. Determine :

i) Velocity of flow at outlet
ii) Velocity of water leaving the vane
iii) Angle made by the absolute velocity at outlet with the direction of motion at outlet
iv) Discharge **(08 Marks)**

c. Explain the phenomenon of surging in compressor. **(04 Marks)**

OR

10 a. Define the following for a centrifugal compressor

i) Slip and slip coefficient
ii) Energy transfer
iii) Power input factor
iv) Overall pressure ratio
v) Loading coefficient **(10 Marks)**

b. A 4 –stage centrifugal pump has impellers each of 38cms diameter and 1.9cms wide at outlet. The outlet vane angle is 49° and 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 900rpm discharging 59 litres/second. Also determine the power required. **(10 Marks)**

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