CBCS SCHEME

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17AE46

Fourth Semester B.E. Degree Examination, Feb./Mar. 2022
Turbomachines

Time: 3 hrs. Max. Marks: 100

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

Module-1

1 a. Performance of a turbomachine depends on the following variables, discharge (Q) speed (N), size (D), energy per unit mass flow (gH), power (p), density of fluid (ρ), dynamic viscosity of fluid (μ), using the dimensional analysis, obtain π-numbers. **(10 Marks)**

b. A quarter-scale turbine model is tested under a head of 30 m. the full-scale turbine is required to work under a head of 130 m and to run at 450 rpm. Calculate:
(i) The speed of the model if it produces 130 KW when the discharge is 0.6 m^3/sec.
(ii) The power produced by the prototype if its efficiency is 6% more than that of the model. **(10 Marks)**

OR

2 a. For the velocity triangle $U_1 > V_{w_1}$, obtain components of energy transfer, $U_1 \rightarrow$ tangential velocity of the rotor at inlet and $V_{w_1} \rightarrow$ tangential component of the absolute velocity V_1 at inlet. **(10 Marks)**

b. If U_I and U_R are blade speed of impulse turbine and 50% reaction turbine respectively.
(i) Show that $E_I = \frac{2U_I^2}{g_c}$ and $E_R = \frac{U_R^2}{g_c}$, for same blade speed.
(ii) Show that $U_R = 1.414\ U_I$ for same energy transfer.
(iii) Show that $U_R = 2U_I$, for V_1 and α_1 same in both machines. **(10 Marks)**

Module-2

3 a. Obtain infinitesimal stage efficiency for compression process and show that, polytropic efficiency $\eta_p = \left(\frac{\gamma-1}{\gamma}\right)\left(\frac{n}{n-1}\right)$ for irreversible adiabatic compression process with polytropic index as 'n'. **(10 Marks)**

b. Air at STP and at 14 m/s is accelerated isentropically in a nozzle to 225 m/sec, find:
(i) The change in temperature (ii) Change in pressure
(iii) Change in density (iv) Change in stagnation pressure
(v) Change in stagnation temperature **(10 Marks)**

OR

4 a. Show that the index n of polytropic expansion in a turbine of infinitesimal stage efficiency η_p is related as $n = \frac{\gamma}{\gamma-(\gamma-1)\eta_p}$. **(10 Marks)**

b. The overall pressure ratio across a three stages 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:
(i) Pressure ratio in each stage (ii) Polytropic efficiency (iii) Stage efficiency (iv) Reheat factor (v) Exit temperature (vi) Total power output for a mass flow rate of 50 kg/sec. Assume for the gas $C_p = 1.005$ kJ/kg °K and $\gamma = 1.4$. **(10 Marks)**

Module-3

5 a. For centrifugal compressors, explain the following:
(i) Actual characteristics (ii) Slip and slip coefficient **(10 Marks)**

b. A centrifugal compressor rotor has inlet radius of 30 cm and exit radius of 60 cm. Entry is radial with a component of 60 m/sec which is constant throughout. The compressor requires 700 KW of power to handle 20 kg of air per second. Find the blade angles at inlet and outlet, if the compressor runs at 5100 rpm. Calculate the width at inlet and outlet, if specific volumes at inlet and outlet are respectively 0.85 m^3/kg and 0.71 m^3/kg, what is the degree of reaction? **(10 Marks)**

OR

6 a. Calculate the overall pressure rise across a compressor stage and actual work required for axial flow compressor. **(10 Marks)**

b. An axial flow compressor stage, where the absolute velocity entry is axial, has the mean rotor speed of 225 m/sec. The axial velocity is 120 m/sec throughout the stage. A stator downstream of the rotor directs the flow axially at the stage exit. If the rotor blade angle at the exit is 58 and the mass flow rate of air is 13.5 kg/sec. Calculate:
(i) The static pressure rise across the stage, assuming $\eta_{t-t} = 0.86$.
(ii) The power input, assuming mechanical efficiency of 0.98. Assume the inlet air conditions to be standard atmospheric and the work input factor to be 0.86.
(iii) The static pressure rise across the rotor and degree of reaction. **(10 Marks)**

Module-4

7 a. Define degree of reaction and utilization factor, obtain the relation between them. **(08 Marks)**

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

OR

8 a. Explain spouting velocity and stage efficiency for radial turbine. **(10 Marks)**

b. An IFR turbine impulse stage with cantilever blade has a flow coefficient of 0.4 and develops 100 KW with a total-to-total efficiency of 90% at 12000 rpm. If the flow rate of air is 1 kg/sec at an entry temperature of 400 K, determine the rotor diameter and air angles at the entry and exit, the nozzle exit air angle and the stagnation pressure ratio across the stage. Take $d_3 = 0.8\ d_2$, zero exit swirl and constant meridional velocity. **(10 Marks)**

Module-5

9 a. Obtain work done by the centrifugal pump per kg of the water and discuss H-Q curve for centrifugal pump. **(10 Marks)**

b. A centrifugal pump has its impeller diameter 30 cm and a constant area of flow 210 cm^2. The pump runs at 1440 rpm and delivers 90 LPS against a head of 25 m. If there is no whirl velocity at entry, compute the rise in pressure head across the impeller and hydraulic efficiency of pump. The vanes at exit are bent back at 22° with respect to tangential speed. **(10 Marks)**

OR

10 a. Discuss heads and efficiencies of hydraulic turbine. **(10 Marks)**

b. A double jet pelton-wheel is required to generate 7500 KW when the available head at the base of the nozzle is 400 m. 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%. $\eta_o = 80\%$, speed ratio = 0.47. **(10 Marks)**

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