Ex/ME/T/425L/2017(old)

BME Final year Examination 2017

Sub: **Gas Turbine (Elective iii)**

Full Marks = 100; Time: Three hours; Answer any ***four*** questions

1. A simple turbojet is operating with a compressor pressure ratio of 8.0, a turbine inlet temperature of 1200 K. The mass flow rate is 15 kg/sec when the aircraft is flying at 260 m/sec at an altitude of 7000 m where the ambient conditions are 243K, 0.357 bar. Polytropic efficiencies of compressor and turbine are 87% each. Isentropic efficiencies of intake and propelling nozzle are 95% each. Mechanical transmission efficiency is 99%. Combustion chamber pressure loss is 6% of the compressor delivery pressure. Calculate the propelling nozzle area and the net thrust produced. (25)
2. a) Explain the significance of ***optimum*** by-pass ratio in a turbofan engine.
   b) Sketch a typical ram jet engine with emphasis on the compression process. No description is needed.
   c) A simple gas turbine with heat exchanger has a compressor and turbine having respective isentropic efficiencies η_c and η_t. Show that the combined effect of small pressure drops ΔP_g (in gas side of heat exchanger) and ΔP (total in combustion chamber and air side of heat exchanger) is to reduce the specific work output by an amount given by
   $$[(\gamma-1)/\gamma].[C_p.T_3.\eta_t/r^{(\gamma-1)/\gamma}.p_1].[\Delta P_g+\Delta P/r]$$
   where T_3 = turbine inlet temperature, p_1 = compressor inlet pressure and 'r' is the compressor pressure ratio. Assume C_p and γ are constant throughout the cycle. (4+8+13)
3. A mean diameter design of a turbine stage having equal inlet and outlet velocities leads to the following data:
   Mass flow rate = 20 Kg/sec; Inlet stagnation temperature = 1000K; Inlet stagnation pressure = 4.0 bar; axial velocity (constant through the stage) C_a = 260 m/sec; Blade speed (U) = 360 m/sec; Nozzle efflux angle = 65^0; Stage exit swirl angle = 10^0.
   Determine the rotor blade gas angles (β_2 and β_3), degree of reaction, temperature drop co-efficient and power output.

Assuming a nozzle loss co-efficient λ_N of 0.05, calculate the nozzle throat area required (ignore the effect of friction on critical condition). (10+15)

4. a) Sketch an 'annular' type and a tubular type of combustion chamber. What are their respective advantages and disadvantages? (5+5)

   b) The overall pressure loss across the combustion chamber is given by the following relationship:

   $\Delta P_0 / [\dot{m}^2 2\rho_1, A_m^2] = K_1 + K_2[(T_{02}/T_{01}) - 1]$

   For a particular chamber having an inlet area of 0.0389m^2 and a maximum cross-sectional area of A_m of 0.0975 m^2, cold loss tests show that K_1 has a value of 19.0. When tested under ***design conditions***, the following readings were obtained: m = 9.0kg/sec; T_{01} = 475K; T_{02} =1023K; inlet static pressure, P_1 = 4.47 bar; and stagnation pressure loss, $\Delta P_0 = 0.27 bar$. Estimate the pressure loss at a part load condition for which m = 7.4kg/sec; T_{01} = 439K; T_{02} =900K; inlet static pressure, P_1 = 3.52 bar. (15)

5. a) State the important differences between a compressor cascade and a turbine cascade with the help of an appropriate sketch. (4)

   b) Name the different sources of losses in a compressor stage. (3)

   c) An axial flow compressor stage has blade root, mean and tip velocities of 150.200 and 250 m/sec. The stage is to be designed for a stagnation pressure rise of 20K and an axial velocity of 150 m/sec, both constant from root to tip. The work done factor is 0.93. Assuming 50% reaction at the mean radius, calculate the stage air angles at root mean and tip and the degree of reaction at the root and tip for a ***free vortex design***. (18)

6. a) The following data refer to the ***eye*** of a single-sided impeller of a centrifugal compressor:

   Inner radius = 6.5 cm; Outer radius = 15.0 cm; Mass flow rate = 8kg/sec; ambient conditions = 1.00 bar, 288K, Speed = 270 Rev/sec.

   Assuming no pre-whirl and no losses in the intake duct, calculate the blade angle at root and tip of the eye and the Mach number at the tip of the eye. (15)

   b) State the important non-dimensional quantities that are used for the construction of performance curves of a rotary compressor. (4)

   c) State briefly the role of vaneless space in a centrifugal compressor. (6)