INDIAN INSTITUTE OF TECHNOLOGY

Date 26th April,2001 FN/AN- Time 3 Hrs. Full Marks 60 No. of Students 16

Spring Semester, 2001 Deptt. Aerospace Engineering Sub. No. 113006

Third Yr. B.Tech. (H) Sub. Name Theory of Jet Propulsion

Instruction ANSWER ANY FIVE QUESTIONS

1. Define radial equilibrium flow and explain vortex flow theory applied to axial turbo machines. Derive the basic equation for vortex flow theory and find out necessary conditions for radial equilibrium.

2. (a) Explain cascade nomenclature.
   (b) Determine expressions for the cascade forces in terms of X, Y and Lift, Drag components and provide relationship for lift and drag coefficients.

3. Discuss application of vortex theory for axial flow turbines and explain free vortex design method for axial turbine blades.

4. The overall pressure loss factor of a combustion chamber may be assumed to vary with the temperature ratio according to the law

$$\frac{\Delta p_o}{m^2 / 2\rho_1 A_m^2} = K_1 + K_2\left[\frac{T_{02}}{T_{01}} - 1\right]$$

For a particular chamber having an inlet area of 0.0389 m^2 and a maximum cross-section area A_m of 0.0975 m^2, cold loss tests show that K_1 has the value 19.0. When tested under design conditions the following readings were obtained.

Air mass flow m	9.0 kg/s
Inlet stagnation temperature T_{01}	475 K
Outlet stagnation temperature T_{02}	1023 K
Inlet static pressure p_1	4.47 bar
Stagnation pressure loss Δp_o	0.27 bar

Estimate the pressure loss at a part load condition for which m is 7.40 kg/s, T_{01} is 439K, T_{02} is 900 K and p_1 is 3.52 bar.
Also, for these two operating conditions compare the values of (a) the velocity at inlet to the chamber and (b) the pressure loss as a fraction of the inlet stagnation (i.e. compressor delivery) pressure, and comment on the result.

5. The first stage of an axial compressor is designed on free vortex principal, with no inlet guide vanes. The rotational speed is 6000 rev/min and the stagnation temperature rise is 20 k. The hub-tip ratio is 0.60, the work done factor is 0.93 and the isentropic efficiency of the stage is 0.89. Assuming an inlet velocity of 140 m/s and ambient conditions of 1.01 bar and 288 K, calculate :
   (a) The tip radius and corresponding rotor air angles β_1 and β_2, if the Mach number relative to the tip is limited to 0.95.
   (b) The mass flow entering the stage.
   (c) The stage stagnation pressure ratio and power required.

(d) The rotor air angles at the root section.

6. The following data apply to a single stage turbine on free-vortex theory.

Mass flow	36 kg/s
Inlet temperature T_{01}	1200 K
Inlet pressure p_{01}	8.0 bar
Temperature drop ΔT_{013}	150 K
Isentropic efficiency η_t	0.90
Mean blade speed U_m	320 m/s
Rotational speed N	250 rev/s
Outlet velocity C_3	400 m/s

The outlet velocity is axial. Calculate the blade height and radius ratio of the annulus from the outlet conditions.

The turbine is designed with a constant annulus area through the stage, i.e. with no flare. Assuming a nozzle loss coefficient λ_N of 0.07, show that continuity is satisfied when the axial velocity at exit from the nozzle is 326 m/s. Thence calculate the inlet Mach number relative to the rotor blade at the root radius.