Registration no:

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HTPE207

Second Semester Examination – 2013
GAS TURBINE
Time: 3 Hours
Max marks: 70

Answer Question No.1 which is compulsory and any five from the rest.

The figures in the right hand margin indicate marks.

1. Answer the followings: [2X10]

   i. The compressibility of a liquid is usually expressed in terms of bulk modulus of compression, $\beta = \rho \dfrac{dp}{d\rho}$, show that $c = \sqrt{\beta / \rho}$,where c is the velocity of sound.

   ii. Define propulsive efficiency (Froude efficiency).

   iii. Draw the P-V and T-S diagram of the basic cycle governing gas turbine propulsion.

   iv. What is surging in centrifugal air compressor?

   v. Explain the impotence of de Haller number in design of axial flow compressor. Write its limiting value for axial flow compressor.

   vi. Define flow co-efficient in axial flow compressor.

   vii. Define combustion intensity.

   viii. How impulse stage of turbine is defined?

   ix. Write four limiting factors in turbine design.

   x. Define momentum thrust and pressure thrust.

2. **(a)** An axial flow compressor has an overall total head pressure ratio of 4.0 and mass flow rate 180 kg/min. If polytropic efficiency is 88% and the stagnation temperature rise per stage must not exceed 25oC, calculate the number of stages required and the pressure ratio of first and last stage. Assume equal temperature rise in all stages. [5]

   (b) If the absolute velocity approaching the last rotor is 165 m/s at an angle of 20oC from the axial direction, the work done factor is 0.83, the velocity diagram is symmetrical nad the mean diameter of the last rotor is 180mm, compute the rotational speed and the length of the last stage rotor blade at inlet to the stage. Ambient conditions are 1.01 bar and 288 K.[5]

3. At design speed following data refers to a gas turbine set:

Total head isentropic efficiency of each compressor :	0.80
Total head pressure ratio of each compressor:	2:1
Total head pressure loss on each side of heat exchanger:	0.105 kg/cm^2
Total head pressure loss in intercooler:	0.07 kg/cm^2
Thermal ratio or effectiveness of heat exchanger:	0.75
Total head pressure loss in combustion chamber:	0.14 kg/cm^2
Combustion efficiency:	0.98
Total head isentropic efficiency of compressor and turbine:	0.87
Mechanical efficiency:	0.99
Total head pressure loss in re-heater:	0.105 kg/cm^2
Combustion efficiency of re-heater:	0.98
Total head isentropic efficiency of power turbine:	0.80

   Calculate the net power output, specific fuel consumption and overall thermal efficiency under following conditions:

   Ambient air temperature and pressure 15o C and 1.03 kg/cm^2

   Maximum cycle temperature: 1000 K

   Air mass flow rate: 22.7 kg/s

   Take Cp=0.24 and Yair=1.4 during compression

   Cpgas=0.276 and Ygas=1.33 during heating and expansion

   Heating value of fuel= 10,300 Kcal/kg. [10]

4. The following data apply to a twin-spool turbofan engine, with fan driven by the LP turbine and the compressor by HP turbine. Separate hot and nozzles are used.

Overall pressure ratio:	20.0
Fan pressure ratio:	1.62
Bypass ratio:	4.0
Turbine Inlet temperature:	1550 K
Fan, compressor, turbine, polytropic efficiency:	0.90
Isentropic efficiency of each propelling nozzle:	0.95
Mechanical efficiency of each spool:	0.99
Combustion pressure loss:	1.5 bar
Total mass flow:	215 kg/s

Calculate the total thrust produced by the turbofan engine. [10]

5. Following data are suggested as basis for design of a single sided centrifugal compressor

Power input factor ψ	1.04
Slip ratio σ	0.9
Rotational speed N	290 rev/s
Overall diameter of impeller	0.5m
Eye tip diameter	0.3 m
Eye root diameter	0.15 m
Air mass flow m	9 kg/s
Inlet stagnation temperature T01	295 K
Inlet stagnation pressure Po1	1.1 bar
Isentropic efficiency	0.78

(a) Determine the pressure ratio of the compressor and power required to drive it assuming the velocity of air at inlet is axial. Also, calculate the inlet angle of impeller vanes at the root and tip radii of eye, assuming the axial inlet velocity is constant across the eye annulus. [5]

(b) Estimate the axial depth of the impeller at the periphery of the impeller. [5]

6. The exhaust gases from a rocket engine have molecular mass of 14. They can be assumed to behave as perfect gas with specific heat ratio of 1.25.These gases are accelerated through a nozzle. At some point in the nozzle where the cross-sectional area of the nozzle is 0.7 m2, the pressure is 1000 kPa, the temperature is 500oC and velocity is 100 m/s.

(a) Find the mass flow rate trough the nozzle and the stagnation pressure and temperature. Also find the highest velocity that could be generated by expanding this flow. [5]

(b) If the pressure at some other point in the nozzle is 100 kPa, find the temperature and velocity at this point in the flow assuming the flow to be one-dimensional and isentropic. [5]

7. Following data apply to a single-stage turbine designed on free vortex theory.

Mass flow	36 kg/s
Inlet temperature T01	1200 K
Inlet pressure P01	8.0 bar
Temperature drop ΔT_{013}	150 K
Isentropic efficiency η	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 blade height and radius ratio of the annulus from the outlet condition.

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 nozzle is 346 m/s. Thence calculate the inlet Mach number relative to rotor blade at root radius. [10]

8. **(a)** Describe the factor affecting combustion chamber performance [5]

(b) Describe the factor affecting combustion chamber design. [5]