DEPARTMENT OF MECHANICAL ENGINEERING
I.I.T. KANPUR

ME – 401A: Energy System II
Assignment #2

Instructor: S. Sarkar

Due Date: 09.10.2018, 5pm

Note: Please submit in time.

1. An axial flow compressor has an overall pressure ratio of 4.0 and mass flow of 3 Kg/s. If the polytropic efficiency is 88% and the stagnation pressure rise per stage must not exceed 25 K, calculate the number of stages required and the pressure ratio of the first and last stages. Assume equal temperature rise in all stages. If the absolute velocity approaching the last rotor is 165 m/s, at an angle of 20^0 from the axial direction, the work done factor is 0.83, the velocity diagram is symmetrical, and the mean diameter of the last stage rotor is 18 cm, calculate 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.

[7; 1.273; 1.178; 414 rev/s; 1.325 cm]

2. A 10 stage axial flow compressor provides an overall pressure ratio of 5:1 with an overall isentropic efficiency of 87%. The temperature of air at inlet is 15^oC. The work is equally divided between the stages. A 50% reaction is used with a blade speed of 210 m/s and a constant axial velocity of 170 m/s. Estimate the blade angles. Assume the value of work done factor as 1.

[$\beta_1 = 41.67^0$, $\beta_2 = 19^0$]

3. Air at 1.0132 bar and 288 K enters an axial flow compressor stage with an axial velocity 150 m/s. There are no inlet guide vanes. The rotor stage has a tip diameter of 60 cm and a hub diameter of 50 cm and rotates at 100rps. The air enters the rotor and leaves the stator in the axial direction with no change in velocity or radius. The air is turned through 30^0 as it passes through rotor. Assuming the constant specific heats and that the air enters and leaves the blade at the blade angles,

(i) Construct the velocity diagram at mean diameter for this stage.
(ii) Mass flow rate.
(iii) Power required.
(iv) Degree of reaction.

[$\dot{m}$ =14.385 kg/s, P = 372.86 kW, R = 0.65]

4. An axial flow air compressor of 50% reaction design has blades with inlet and outlet angles of 45^0 and 10^0 respectively. The compressor is to produce a pressure ratio of 6:1with an overall isentropic efficiency of 0.85 when inlet static temperature is 37^0C. The blade speed and axial velocity are constant throughout the compressor. Assuming a value of 200 m/s for blade speed, find the number of stages required if the work done factor is (i) unity and (ii) 0.87 for all stages.

[(i) 9 Stages, (ii) 10 Stages]

5. Find the polytropic efficiency of an axial flow compressor from the following data:

The total head pressure ratio	:	4
Overall total head isentropic efficiency	:	85 %
Total head inlet temperature	:	290 K

The inlet and outlet air angles from the rotor blades of the above compressor are 45^0 and 10^0 respectively. The rotor and stator blades are symmetrical. The mean blade speed and axial velocity remain constant throughout the compressor. Assuming a value of 220 m/s for blade speed and the work done factor as 0.86, find the number of stages required. Also find the inlet Mach number relative to rotor at the mean blade height of the first stage. Assume R = 284.6 kJ/kg-K.

[η_p = 87.64%, 6 Stages, M_{inlet} = 0.8]

6. A 50 % reaction, aspect ratio 3 and blade height 10 cm, axial compressor cascade was tested and found to have a blade efficiency of 90% and a lift coefficient of 0.80. The mean axial velocity was 200 m/s and the exit and inlet blade angle were 45^0 and 15^0 respectively. Determine the lift and drag forces exerted on the blade, and pressure rise achieved in the stage with the flow coefficient of 0.50. Density of air at inlet is 0.90 kg /m^3.

[(i) 68.47 N (ii) 0.04 N (iii) 0.2 bar]

7. An axial flow compressor takes in 1000 m^3/min of free air at 0.90 bar and 15^0C. The blades are of aerofoil type having projected area and blade length as 19.25 cm^2 and 6.75 cm respectively. The blade ring mean diameter is 60 cm and speed is 6000rpm. On each blade ring there are 50 blades and the blades occupy 10% of the axial area of flow. Values of C_L and C_D are 0.6 and 0.05 respectively at zero angle of incidence. Assuming isentropic compression, calculate the pressure rise per blade ring and the power input per stage. Assume axial inlet.

[P = 227.966 kW, ΔP_{stage} = 1.14 bar]

8. An axial flow compressor stage has blade root, mean, and tip velocities of 150, 200, and 250 m/s. The stage is to be designed for a stagnation temperature rise 20K and an axial velocity of 150 m/s, both constant from root to tip. The work done factor is 0.93. Assuming 50% reaction at mean radius, calculate the stage air angles at root, mean and tip and the degree of reaction at root and tip for a free vortex design.

[(i) 45.76^0 (ii) 17.04^0 (iii) 48.28^0 (iv) 1.133^0 (v) 28.36^0 (vi) 48.16^0]