Exercises

PROBLEMS AND SOLUTIONS FOR CYCLE, CENTRIFUGAL, AXIAL COMPRESSORS

[For all the Exercises, assume R=287J/kg K and γ = 1.4 for air]

1. Determine the pressure ratio developed and the specific work input to drive a centrifugal air compressor having an impeller diameter of 0.5 m and running at 7000 rpm. Assume zero whirl at the entry and T_{1f} = 288 K.

(1.47,33.58 kJ/kg)

2 A centrifugal compressor develops a pressure ratio of 4:1. The inlet eye of the compressor impeller is 0.3 m in diameter. The axial velocity at inlet is 120 m/s and the mass flow rate is 10 kg/s. The velocity in the delivery duct is 110 m/s. The tip speed of the impeller is 450 m/s and runs at 16,000 rpm with a total head isentropic efficiency of 80%. The inlet stagnation temperature and pressure are $101 kN/m^2$ and 300 K. Calculate (a) the static temperatures and pressures at inlet and outlet of the compressor, (b) the static pressure ratio, (c) the power required to drive the compressor.

Ans. (T_1 = 292.8 K, T_2 = 476.45 K, p = 93 kN/m 2 , p_2 = 386.9 kN/m 2 , p_2/p_1 = 4.16, p = 1.83 MW)

3. The following results were obtained from a test on a small single-sided centrifugal compressor

Compressor delivery stagnation pressure 2.97 bar
Compressor delivery stagnation temperature 429 K
Static pressure at impeller tip 1.92 bar
Mass flow 0.60 kg/s
Rotational speed 766 rev/s
Ambient conditions 0.99 bar 288 K
Determine the isentropic efficiency of the compressor.
The diameter of the impeller is 0.165 m, the axial depth of the vaneless diffuser is 0.01m and the number of impeller vanes is 17. Making use of the Stanitz equation for slip factor, calculate the stagnation pressure at the impeller tip.

Ans. (0.76, 3.13 bar)

4. A single sided centrifugal compressor is to deliver 14 kg/s of air when operating at a pressure ratio of 4:1 and a speed of 200 rev/s. The inlet stagnation conditions are 288 K and 1.0 bar. The slip factor and power input factor may be taken as 0.9 and 1.04 respectively. The overall isentropic efficiency is 0.80. Determine the overall diameter of the impeller.

Ans. (0.69m)

PROBLEMS ON AXIAL COMPRESSORS

5. Each stage of an axial flow compressor is of 50% degree of reaction and has the same mean blade speed and the same value of outlet relative velocity angle $\beta_2 = 30^o$. The mean flow coefficiency V_f / U is constant for all stages at 0.5. At entry to the first stage, the stagnation temperature is 290 K, the stagnation pressure is 101 kPa. The static pressure is 87 kPa and the flow area is $0.38\ m^2$. Determine the axial velocity, the mass flow rate and the shaft power needed to derive the compressor when there are 6 stages and the mechanical efficiency is 0.98.

Ans. (135.51 m/s, 56.20 kg/s, 10.68 MW)

6. 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 of 20 K and an axial velocity of 150 m/s, both constant from root to tip. The work done factor is 0.93. Assuming degree of reaction 0.5 at mean radius, determine the stage air angles at root mean and tip for a free vortex design where the whirl component of velocity varies inversely with the radius

$Ans.\ (\alpha_1 = 17.04^o (= \beta_2),\ \beta_1 = 45.75^o (= \alpha_2)\ at\ mean\ radius\ \alpha_1 = 13.77^o,\ \beta_1 = 54.88^o,\ \beta_2 = 40.36^o,$
$at\ tip; \alpha_1 = 22.10^o,\ \beta_1 = 30.71^o,\ \beta_2 = -19.95^o,\ \alpha_2 = 53.74^o\ at\ root)$

7. An axial compressor has the following data:

Temperature and pressure at entry 300 K, 1.0 bar
Degree of reaction 50%
Mean blade ring diameter 0.4 m
Rotational speed 15,000 rpm
Blade height at entry 0.08 m
Air angles at rotor and stator exit 25°
Axial velocity 150 m/s
Work done factor 0.90
Isentropic stage efficiency 85%
Mechanical efficiency 97%

Determine (a) air angles at the rotor and stator entry (b) the mass flow rate of air (c) the power required

to derive the compressor, (d) the pressure ratio developed by the stage (e) Mach number (based on relative velocities) at the rotor entry.

Ans. [(a) 25° , 58.44° (b) 17.51 kg/s, (c) 0.89 MW, (d) 1.58, (e) 0.83]

8 An axial flow compressor stage has a mean diameter of 0.6 m and runs at 15,000 rpm. If the actual temperature rise and pressure ratio developed are 30°C and 1.36 respectively, determine (a) the power required to derive the compressor while delivering 57 kg/s of air. Assume mechanical efficiency of 86% and an initial temperature of 35°C (b) the isentropic efficiency of the stage and (c) the degree of reaction if the temperature at the rotor exit is 55°C.

Ans. [(a) 2 MW, (b) 94.2%, (c) 66.6%]

Previous Next