Exam Date & Time: 08-May-2024 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

Program Elective II
Turbomachinery Aerodynamics

TURBOMACHINERY AERODYNAMICS [AAE 4034]

Marks: 50 **Duration: 180 mins.**

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Answer all the questions. Section Duration: 180 mins

1A) Draw the outlet velocity triangle for the radial vane centrifugal compressor with and without slip conditions. (2)

1B) Draw an ideal Joule-Brayton cycle for a gas turbine engine and explain various processes involved in it. (3)

1C) An axial flow compressor is required to deliver 50 kg/s of air at a stagnation pressure of 500 kPa. At inlet to the first stage the stagnation pressure is l00 kPa, the stagnation temperature is 23°C and static temperature is 17°C. The hub and tip diameters at this location are 0.436 m and 0.728 m. At the mean radius, which is constant through all stages of the compressor, the reaction is 0.50 and the absolute air angle at stator exit is 28.8° for all stages. The speed of the rotor is 8000 rev/min. Determine the number of similar stages needed assuming that the polytropic efficiency is 0.89 and that the axial velocity at the mean radius is constant through the stages and equal to 1.05 times the average axial velocity. (5)

2A) With the help of a neat sketch, explain the jet impingement cooling for an axial flow turbine. (2)

2B) Explain the significance of work-done factor in axial flow compressors. Why it is not employed in axial flow turbine stages? (3)

2C) An axial compressor stage has the following data:

Temperature at entry = 300 K, pressure at entry = 1 bar, degree of reaction = 50%, mean blade ring diameter = 36 cm, rotational speed = 18,000 rpm, blade height at entry = 6 cm, air angles at rotor entry and stator exit = 25°, axial velocity = 180 m/s, work-done factor = 0.88, stage efficiency = 85%, mechanical efficiency = 96.7%. Determine (i) air angles at the rotor exit and stator entry (ii) the mass flow rate of air (iii) power required to drive the compressor (iv) the stage loading coefficient and (v) the pressure ratio developed by the stage. Assume the static and stagnation conditions are the same at the compressor inlet. (5)

3A) Explain the term, ‘power input factor’ in case of centrifugal compressors. (2)

3B) Derive an expression for the stage pressure ratio for a centrifugal compressor. (3)

3C) A centrifugal compressor stage with radial vanes has the following data: Entry pressure = 1.05 bar, Entry temperature = 306 K, Speed = 17,000 rpm, Impeller tip diameter = 48 cm, Eye tip diameter = 24 cm, Eye hub diameter = 12 cm, Mass flow rate = 8 kg/s, Slip factor = 0.92, Stage efficiency = 0.77. Assume static and stagnation conditions are the same at the compressor inlet. Determine (i) the air angles at the hub, mean and tip of the eye (ii) total pressure ratio developed and (iii) power required to drive the compressor. (5)

4A) The number of stages for an axial flow turbine are significantly lower than the axial flow compressor. Justify it. (2)

4B) Draw the enthalpy-entropy diagram for an axial flow turbine and explain various processes involved in it. (3)

4C) The following data apply to a single-stage axial flow gas turbine. (5)

Inlet stagnation temperature = 1400 K

Inlet stagnation pressure = 8 bar

Stage stagnation temperature drop = 150 K

Isentropic stage efficiency = 0.9

Mass flow rate = 36 kg/s

Mean blade speed = 320 m/s

Outlet velocity = 400 m/s

Assuming that the stage outlet velocity is axial, calculate:

(i) the stage specific work

(ii) the blade and flow angles at stage inlet and outlet and

(iii) the stage pressure ratio.

5A) Define and explain the term, 'total-to-static efficiency' for an axial flow turbine. (2)

5B) For an axial flow compressor, prove that (4)

$$R_x = 1 - \frac{C_a}{2U}(\tan \alpha_1 + \tan \alpha_2)$$

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5C) With the help of a neat sketch, explain the construction and working of a radial flow turbine. (4)

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