ENGINEERING TRIPOS PART IIB

Friday 29 April 2005 9 to 10.30

Module 4A11

TURBOMACHINERY II

*Answer not more than **two** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of the question is indicated in the right margin.*

There are no attachments.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

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1. (a) A 2-D turbine cascade operating with air has an inlet flow angle of 0° and inlet Mach number 0.24. When the exit Mach number is 0.85 the exit flow angle is 65°. Calculate the stagnation pressure loss coefficient of the cascade. [20%]

(b) If the Zweifel coefficient of the cascade at the above condition is 0.9, calculate the pitch to axial chord ratio of the cascade. [20%]

(c) When the exit isentropic Mach number increases to 1.2, there is no variation in the inlet flow conditions but the exit flow angle decreases to 60°, Assuming that the stagnation pressure loss coefficient remains constant, calculate the Zweifel coefficient at this new condition. [30%]

(d) Sketch, qualitatively, the surface static pressure distributions of the cascade at the above two flow conditions. [15%]

(e) Discuss the physical cause(s) for the calculated variation of the Zweifel coefficient for the above two flow conditions. [15%]

2. (a) Discuss the difference between the concept of "unique incidence" in a transonic compressor cascade and the relationship linking the inlet flow angle and Mach number for a choked high subsonic compressor cascade. [20%]

(b) Describe the concept of the "throat" in a transonic compressor cascade with supersonic relative inlet Mach number. Explain why the throat is not defined at the minimum flow area in the blade passage. A 2-D transonic compressor cascade is designed for inlet Mach number 1.4 and inlet flow angle 65°. It is known the flow angle at the throat is 61.2°. Calculate the Mach number and the tangential blade blockage t/S at the throat. [40%]

(c) Describe the definition of the critical area ratio A/A^* for high subsonic compressor blade and discuss the significance of this parameter for the blade design. A 2-D compressor cascade is choked at an inlet Mach number of 0.85 with an inlet flow angle of 28°. How much must the flow incidence change from this condition as the inlet Mach number increases to 0.90? [40%]

3 (a) Discuss the cause and consequences of the secondary flow in a highly loaded compressor cascade with particular emphasis on the effects of the incoming boundary layer thickness on the secondary flow. [20%]

(b) Using velocity triangles, analyse typical relative endwall flows entering compressor and turbine rotors with upstream stators. Discuss the implications of the difference in the relative flows for the secondary flows of the compressor and turbine rotors. [20%]

(c) It is suggested that using a cantilever blade with a small tip (hub) gap between the blade tip and the end wall can relieve the damage due to the secondary flow. Comment on the possible mechanism for this. [20%]

(d) The finite volume method is now commonly used for solving Euler or Navier-Stokes equations in conservative form for turbomachinery flows. Discuss the advantages of this approach in comparison with more traditional non-conservative finite difference methods favoured in external flow CFD. [20%]

(e) Describe the boundary conditions required for solving the 3-D Euler equations for steady flows in a turbomachinery blade passage at subsonic speeds. How should the boundary conditions change if the flow is supersonic at both inlet and exit? [20%]

END OF PAPER