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| Menoufiya University<br>Faculty of Engineering<br>Shebin El-Kom<br>Final Term Examination<br>Academic Year: 2013-2014 | Minufiya University | Year: Ph -D<br>Department: Mechanical Power Eng<br>Subject: Gas Turbines (MPE 515)<br>Time Allowed: 3 hours<br>Date: 15 /6/2014<br>Total Mark (100) |

Answer the Following Questions

1-a)Explain with sketch the variation of axial velocity when the two discs are regarded as isolated and when they are combined .

b) Derive the radial equilibrium equation for an incompressible fluid flowing with axisymmetric swirl through an annular duct.

c) An axial-flow turbine stage is to be designed for free-vortex conditions at exit from the nozzle row and for zero swirl at exit from the rotor. The gas entering the stage has a stagnation temperature of 1000 K, the mass flow rate is 32 kg/s, the root and tip diameters are 0.56m and 0.76m respectively, and the rotor speed is 8000 rev/min. At the rotor tip the stage reaction is 50% and the axial velocity is constant at 183 m/s. The velocity of the gas entering the stage is equal to that leaving.

Determine: (i) the maximum velocity leaving the nozzles; (ii) the maximum absolute Mach number in the stage; (iii) the root section reaction; (iv) the power output of the stage; (v) the stagnation and static temperatures at stage exit.

(Take R = 0.287 kJ/(kg°C) and Cp = 1.147 kJ/(kg°C).) (20Mark)

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2- a) Draw the overall characteristic of a compressor showing the surge line. Define the surge and show its effect on machine.

b) Discuss the various losses in a compressor stage. Draw the compressor stage efficiency with flow coefficient showing the effect of various losses on it.

c) An axial flow compressor stage is designed to give free-vortex tangential velocity distributions for all radii before and after the rotor blade row. The tip diameter is constant and 1.0 m; the hub diameter is 0.9m and constant for the stage. At the rotor tip the flow angles are as follows

Absolute inlet angle, $\alpha_1 = 30^0$. Relative inlet angle, $\beta_1 = 60^0$.

Absolute outlet angle, $\alpha_2 = 60^0$. Relative outlet angle, $\beta_2 = 30^0$.

Determine, (i) The axial velocity; (ii) The mass flow rate ;( iii) The power absorbed by the stage; (iv) The flow angles at the hub; (v) The reaction ratio of the stage at the hub. (20Mark)

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3- a) Describe various methods of cooling gas turbine blades. Why is air cooling preferred to liquid cooling in aero engines?

b) What is creep? How does it affect the operation of gas turbine stages at elevated temperatures? Show with sketch the development of creep in gas turbine blades. What are the five most important properties which the high temperature blade material must have?

c) Explain with sketch the effect of high inlet temperatures on specific power output, specific thrust, plant and turbine stage efficiencies.

d) With sketch draw the variation of blade and coolant temperature along the blade height.

(20Mark)

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4- a) For a turbine stage define: the total to total efficiency – total to static efficiency – degree of reaction and prove that: $R = \frac{c_a}{2u}(\tan\beta_3 - \tan\beta_2)$.

b) Define the secondary loss. Discuss how the secondary loss can be eliminated in turbine blades cascade. Explain how secondary loss can be estimated.

c) A single – stage gas turbine operates at design condition with an axial absolute flow velocity at entry and exit from stage. The absolute flow angle at nozzle angle exit is $70^0$. At stage entry the total pressure and temperature are 311 kPa and $850^0$C respectively. The exhaust static pressure is 100 kPa, the total- to- static efficiency is 0.87 and the mean blade speed is 500 m/s.

Assuming constant axial velocity through stage, determine: i – The specific work done, ii – The mach number leaving the nozzle, iii- The axial velocity, iv – The total –to- total efficiency, v – The stage reaction. (20Mark)

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5- a) Drive the non-dimensional groups that are normally used in the testing of gas turbines and compressors.

b) With the aid of sketch draw and explain the variation in profile loss and gas outlet angle with incidence for impulse and reaction blades .

c) The rotor blades of an axial-flow turbine stage are 100 mm long and are designed to receive gas at an incidence of 3 deg from a nozzle row. A free-vortex whirl distribution is to be maintained between nozzle exit and rotor entry. At rotor exit the absolute velocity is 150 m/s in the axial direction at all radii. The deviation is 5 deg for the rotor blades and zero for the nozzle blades at all radii. At the hub, radius 200 mm, the conditions are as follows: Nozzle outlet angle 70 deg, rotor blade speed 180 m/s, gas speed at nozzle exit 450 m/s. Assuming that the axial velocity of the gas is constant across the stage. Determine: (i) the nozzle outlet angle at the tip; (ii) the rotor blade inlet angles at hub and tip; (iii) the rotor blade outlet angles at hub and tip; (iv) the degree of reaction at root and tip. Why is it essential to have a *positive* reaction in a turbine stage?

(20Mark)

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