Kafr elsheikh University
Faculty of Engineering
Mechanical Power Eng. Department
4th Year Power Mechanics
Subject: Turbo-machinery
Examiner: Dr. M.I. Amro and commit

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Final Exam
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يسمح باستخدام جداول و خرائط البخار

Assume any missing data, use schematic diagrams in your answer

Question (1) (25 marks)

1-a) Assigned if the following statements is correct or incorrect and correct the false **(15 marks)**

1- In a reaction turbine, the relative velocity coefficient is less than unity

2- Blade loading coefficient is used to express work capacity of the stage.

3- Radial flow turbine is used in all applications of the gas turbine power plant

4- The axial flow turbine has been used exclusively in aircraft gas turbine engines

5- In an impulse turbine, pressure drop of expansion takes place in the stator as well as rotor

6- It is much more difficult to arrange for an efficient deceleration of flow than it is obtain an efficient acceleration.

7- Speed of turbines must be governing and always the gears box is fixed after its stages.

8- In multi-stages turbine, the same blades shape can be used if the absolute velocity at inlet and outlet of stage is the same; in addition the inlet and outlet flow angle is equally.

9- In a Rateau turbine, every turbine stage has a row of fixed Convergent-Divergent nozzle and the pressure energy is divided between all turbine stages to reduce the turbine velocity.

10- In impulse turbines, the moving blades convert the pressure energy into rotational energy and direct the gases flow to the next stages.

11- The turbine is more efficient than the compressor since the expansion of gases save the boundary layer and does not permits, to the flow separation occurred.

12- In a reaction turbine, the blades passage area varies continuously to allow for the continued expansion of the gas stream over the rotor blades.

13- In case of maximum blade efficiency in a single stage impulse turbine, the steam leaves the blades axially with no axial thrust.

14- In multi-stage steam turbines, the impulse turbine stage is used in last stage and the reaction stages are used where the pressure drop per stage is high.

15- Curtis turbine is a pressure-compound impulse turbine, while Rateau turbine is a velocity-compound impulse turbine.

1-b) At a stage in a reaction turbine, the mean blade ring diameter is 1 m and the turbine runs at a speed of 50rev/s. The blades are designed for 50% degree of reaction with exit angles of 30^O and inlet angles of 50^O. The turbine is supplied with steam at the rate of 600 tons/hr. and the stage efficiency is 85%. Determine:

a) The power output of the stage, and the specific enthalpy drop in the stage,

b) The percentage increase in relative velocity in the moving blades due to expansion in these blades.

Question (2) (20 marks)

2-a) Draw and describe Rateau and Curtis turbines, indicate the velocity and pressure distributions through each turbine. (5 marks)

2-b) Prove that; for the equiangular frictionless blades of impulse turbine; the blade or diagram maximum efficiency is equal to: $\eta_{b,max} = cos^2 \alpha_1$,

Draw the velocity compound diagram at that condition (5 marks)

2-c) A single stage impulse turbine is to be designed that the initial steam conditions are 7 bar and 260^O C and the exhaust pressure is 1 bar. The nozzles angle is to be 15^O to the plane of rotation. Nozzles efficiency is 95 %. Blade exit angle is 30^O and the blade velocity coefficient is 85%. The mean diameter of wheel is 1100mm.

a) What is the blade speed ratio when the wheel speed is 6000 rpm?

b) How much power is delivered to the wheel at this speed of 6000 rpm when the steam flow is 2250 kg/hr.?

c) At what wheel speed would the maximum power be developed?

d) What would be the maximum power? (10 marks)

Question (3) (10marks)

Steam is supplied to a condensing turbine at 17 bar and 330 C^o. Condenser pressure is 0.095 bar. Steam is tapped off at one point for extraction to a certain process, where the extraction pressure equals 1.6 bar. The turbine delivers 2000 kW at full load, with an internal efficiency of 80 %. When there is a steam process available at full load, all the steam is extracted at 1.6 bar.

If the no load steam consumption in both no extraction and extraction cases equals 12 % of the full load consumption, and the mechanical and generation efficiencies are 96.2% and 99 % respectively.

a) Calculate the steam consumption at no load and full load for both cases of no extraction and extraction.

b) Draw Willans line for each case.

c) How much steam will be generated in the boiler for a power output of 1500 kW, if 6500 kg/hr. of steam are extracted from the turbine? (10 marks)

Question (4) (20marks)

4-a) Derive a relation for calculating the degree of reaction and the blade loading coefficient as a function on inlet and outlet blade angles (β_2 and β_3) for axial flow gas turbine? For a degree of reaction $\Lambda = 0.5$ prove that: $\psi = 4\phi \tan\beta_3 - 2$ and $\psi = 4\phi \tan\beta_2 + 2$ **(5marks)**

4-b) Draw and describes the velocity triangles and (T-S) diagram for the axial flow turbine indicating the values of pressure and velocity at all points. **(5 marks)**

4-c) In a single-stage axial flow gas turbine gas enters at stagnation temperature of 1100K and stagnation pressure of 5 bars. Axial velocity is constant through the stage and equal to 250 m/s. Mean blade speed is 350 m/s. Mass flow rate of gas is 15 kg/s and assume equal inlet and outlet velocities. Nozzle efflux angle is 63°, stage exit swirl angle equal to 9°. Determine the rotor-blade gas angles, degree of reaction, and power output. **(10 Marks)**

With Best Wishes Dr. Mohamed Amro and commit