Mansoura University
Faculty of Engineering
Mech. Power Eng. Dept.
Fourth Year

Final term Exam
Steam and Gas Turbines-MPE4421
May 26, 2013- Time: 3 hours
Full Mark: 100

Answer the following questions. Use of steam tables and charts are allowed. Assume any necessary assumptions.

Mark

1- a) Classify briefly types of turbomachines. 5

b) Describe briefly the chemically recuperated gas turbine cycle and illustrate it on the block diagram. 5

c) Draw and explain briefly curves of thermal efficiency and specific work as functions of pressure ratio for CBE and CBEX for two different values of temperature ratio, T′. 6

2- a) Draw carefully the variation of pressure and velocity through an impulse turbine (Curtis and Rateau) and what are the main differences between them. 6

b) Deduce each of σ_{opt} and ε_{max} for a single stage impulse turbine. Carefully, plot the relations between (ε and η_{st}) versus σ at different nozzle angles 9

c) For an axial turbine stage, draw the simple velocity diagrams and derive the following relation; 5

$$R = 1 + \frac{\phi}{2}\left(\tan(\alpha_3) - \tan(\alpha_2)\right)$$

where α_2 is the nozzle angle, α_3 is the flow exit angle, R is the degree of reaction, and Φ is the flow coefficient.

d) For the following statements, explain briefly why? 6

i) the thermal efficiency of gas turbine engine is lower than steam turbine engine.

ii) more than two velocity stages are not employed in velocity compounded impulse turbine.

iii) in velocity compounded impulse turbine, the blade height is the same in all the rows.

3- A simple gas turbine engine is operating under the following conditions: 12

Compressor inlet temperature = 310K,
Turbine inlet temperature = 1400K,
Compressor polytropic efficiency = 90%,
Turbine polytropic efficiency = 92%,
$\sum(\Delta p_o/p_o) = 5\%$, $(R/\overline{Cp}_c) = 0.26$, $(R/\overline{Cp}_e) = 0.24$ and $[\dot{m}_e\overline{Cp}_e/\dot{m}_c\overline{Cp}_c] = 1.15$.
calculate the following:

1) the optimum pressure ratio for maximum specific work,

2) for the obtained pressure ratio calculate each of specific work and thermal

efficiency of the cycle, and

3) what is the effect of adding a heat exchanger to this cycle on the cycle thermal efficiency and specific power.

4- A turbojet engine is operating under the following conditions: 18

Ambient conditions (P_{st}=1 bar ,T_{st}=298 K). Flight speed at sea level =0. Compressor pressure ratio 12 . Air to fuel ratio A/F =55. The diffuser efficiency= 100% and the isentropic efficiencies of the compressor, the turbine and the nozzle are; 87%, 90% and 100 %, respectively. The jet fuel has low heating value = 43 MJ/kg, combustion efficiency 98% and the stagnation-pressure losses = 5 %. Assume an air standard cycle but take into account the mass of fuel added. Draw carefully the temperature-entropy chart and calculate each of: the specific thrust developed by this engine, the thermal efficiency and the thrust specific fuel consumption.

(assume that the expansion in the nozzle is back to ambient conditions)

5- A 150 MW steam turbine power plant, employing regenerative feed heating cycle, has the following data: Steam conditions at inlet are 80 bar and 550°C for pressure and temperature, respectively. Condenser pressure is 0.1 bar, bleed points are at pressures of 30, 15 and 5 bar. The overall turbine efficiency of 87 %. Draw T-S diagram of the cycle, and determine: 15

a) mass of steam raised in the boiler per kg of steam condensed in the condenser,

b) capacity of boiler in tons of steam per hour,

c) improvement in the thermal efficiency and heat rates due to feed heating , and

d) increase of steam supplied from the boiler per kW.hr due to feed heating.

(Assuming condition curve to be a straight line on the h-s diagram).

6- Steam enters a 50% degree of reaction turbine at 15 bar and 400 °C and is expanded to a pressure of 0.1 bar . The turbine has a stage efficiency of 80% for each stage and the reheat factor is 1.04. The turbine has 20 successive stages and the total power output is 12 MW. Assuming that all stages develop equal work. Calculate the steam flow rate. At a certain place in a turbine , the steam has a pressure of 1.5 bar and dry saturated. The blade exit angle is 70° and the blade to steam speed ratio is 0.75. Estimate the blade speed u , mean diameter D_m of annulus at this point in the turbine, and rotational speed of rotor N if the blade height is 1/12 of the blade mean diameter. 13

Good luck, Dr. Ahmed Abd Elsalam