THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
BACHELOR OF TECHNOLOGY – LEVEL 05
FINAL EXAMINATION – 2006/2007
APPLIED THERMODYNAMICS– MEX 5231

017

DATE : 26TH MARCH 2007
TIME : 1330 HRS – 1630 HRS
DURATION : THREE HOURS

ANSWER FIVE QUESTIONS ONLY.
ALL QUESTIONS CARRY EQUAL MARKS.
YOU MAY OBTAIN TABLES OF THERMODYNAMIC AND TRANSPORT PROPERTIES OF FLUIDS ON REQUEST.

(01) It is proposed to construct a steam power plant. There are two designs available for this purpose.

Design I

The boiler pressure is chosen to be 40bar and the condenser pressure is 0.035bar. The steam is to be superheated to 600°C and expanded through a turbine of isentropic efficiency 0.92. The feed pump has an isentropic efficiency of 0.95.

Design II

The boiler pressure is chosen to be 30bar and the condenser pressure is 0.04bar. The steam is to be superheated to 450°C and then expands in the first turbine till steam is dry saturated. Then the steam is reheated to the original superheat temperature and allowed to expand through a second turbine. You may assume that the turbine is 100 percent efficient and you may neglect the feed pump term.

Deduce the expected working characteristics of the two systems and compare and contrast them.

Which design would you choose if,

(a) High thermal efficiency
(b) Lower steam consumption, were the particular requirements.

(02) A closed cycle gas turbine plant takes in air at a temperature T_a and compresses it through a pressure ratio of ρ. After compression, the heat is added at constant pressure and the air enters the turbine at a temperature T_b. Air is expanded in the turbine and finally heat rejection takes place at a constant pressure. (04

The isentropic efficiencies of compression and expansion are η_C and η_T respectively. If an ideal regenerator is employed in this cycle, show that the thermal efficiency of the cycle (η) is given by.

$$\eta = 1 - \frac{\rho^{\alpha}}{\theta}$$

Where $\alpha = \left[\frac{\gamma - 1}{\gamma}\right]$ γ being the ratio of specific heats for air.

$\theta = \eta_C \eta_T (T_b/T_a)$ and

If T_a= 27°C, T_b = 1000°C, ρ = 4, γ = 1.4 and $\eta_C = \eta_T$ = 1, show that the thermal efficiency of the cycle is approximately two times the thermal efficiency of an ideal Brayton cycle working with the same pressure ratio but without regeneration. (0

(03) i. Describe the functions of the following devices of a simple vapour compression system.

(a) Compressor
(b) Condenser
(c) Expansion valve
(d) Evaporator

ii. A Freon-12 refrigerator producing a total refregerating effect of 20kJ/s operates on a simple vapour compression cycle. The enthalpy values at inlet to compressor, at exit from the compressor, and at exit from the condenser are 183.19, 209.41 and 74.59 kJ/kg respectively. Estimate,

(a) Refrigerant flow rate
(b) Coefficient of Performance (COP)
(c) Power required to drive the compressor and
(d) Rate of heat rejection from the condenser

(04) i. Define the following, in relation to steam turbines.

(a) Blade speed ratio
(b) Diagram efficiency
(c) Blade friction coefficient

ii. Steam with a velocity of 600m/s enters an impulse stage of a turbine and hits the blades at an angle of 25° to the plane of rotation of the blades. The mean blade speed is 255m/s. The exit angle from the blades is 30°. There is a 10% loss in relative velocity due to friction in the blades.

Determine,

(a) Entry angle of the blades
(b) Work done on the blades
(c) Diagram efficiency

(05) i. Define the term "nozzle". Briefly explain three types of nozzles.

ii. Air enters a nozzle at a pressure of 3.5MN/m^2 and at a temperature of 500°C and leaves at a pressure of 0.7MN/m^2. The air flow rate through the nozzle is 1.3kg/s and expansion may be considered adiabatic and to follow the law PV^{γ} = constant. Determine,

(a) Throat area
(b) Exit area
(c) Mach number at exit.

Take $\gamma = 1.4$ and R = 0.287kJ/kgK

You can use following equations with usual notations.

Velocity at throat

$$C_1 = \left[2\frac{\gamma}{\gamma-1} p_1 v_1 \left(1 - \left\{ \frac{p_2}{p_1} \right\}^{\gamma-1/\gamma} \right) \right]^{1/2}$$

$$\text{Critical pressure} = P_t = \left(\frac{2}{\gamma+1} \right)^{\gamma/\gamma-1} p_1$$

(06) i Describe primary fuels and secondary fuels with examples.

ii Coal to be used in a coal-fired power plant has the following ultimate analysis on a dry basis, percent by mass. This coal is to be burned with 30% excess air. Calculate the air to fuel ratio on a mass basis.

Component	Percent by mass
Sulfur	0.6
Hydrogen	5.7
Carbon	79.2
Oxygen	10.0
Nitrogen	1.5
Ash	3.0

(07) A furnace wall consists of 130mm wide refractory brick and 130mm wide insulating fire brick which are separated by an air gap. The outside wall is covered with a 20mm thickness of plaster. The inner surface of the wall is at 1100°C while the room temperature is 28°C. The heat transfer coefficient from the outside wall surface to the surrounding air in the room is 17W/m^{2}K and the resistance to heat flow of the air gap is 0.16K/W. The thermal conductivities of refractory brick, insulating fire brick and plaster are 1.6, 0.3 and 0.14W/mK, respectively. Calculate

(a) Rate of heat loss per unit area of wall surface.
(b) Temperature at each interface throughout the wall.
(c) Temperature at the outside surface of the wall.

(08) i. Enumerate the three modes by which heat can be transferred from one place to another. Which is the slowest of all?

ii. A long steel rod, 22mm diameter is to be heated from 420°C to 540°C. As shown in the figure Q 08, it is placed concentrically in a long cylindrical furnace which has an inner diameter of 180mm. The inner surface of the furnace is at a temperature of 1100°C, and has an emissivity of 0.82. If the surface of the rod has an emissivity of 0.62, find the time required for the heating operation.
Assume for steel C = 0.67kg/kJK, ρ = 7845 kg/m^3.

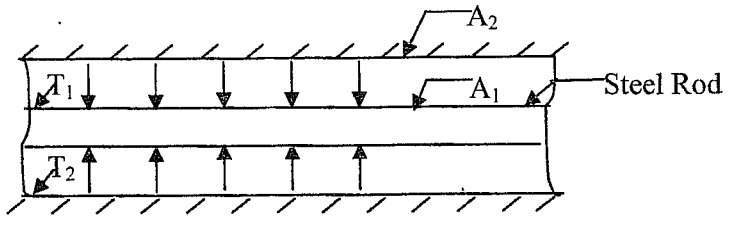


Figure Q. 08

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