Heat Oct 2018

APPLIED HEAT

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. A perfect gas is heated at constant pressure and then expands reversibly according to the law $pV^{1.4}$=constant.

   The initial pressure and temperature are 15 bar 600°C respectively.

   The final pressure is 1.0 bar and the final volume is 12 times the initial volume.

   (a) Sketch the process on a Temperature-specific entropy diagram. (2)

   (b) Calculate EACH of the following:

   (i) the final temperature; (2)

   (ii) the temperature after the heating process; (2)

   (iii) the specific work transfer; (4)

   (iv) the net change in specific entropy for the polytropic process. (6)

Note: for the gas c_p = 5.179 kJ/k and R = 2.078 kJ/kgK

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2. In the open cycle gas turbine plant shown in Fig Q2, the HP turbine drives the compressor and the LP turbine drives the load.

Air enters the compressor at a pressure and temperature of 1.05 bar and 15°C respectively.

The combustion products enter the HP turbine at a pressure of 9.45 bar and temperature of 1027°C.

The gas entering the LP turbine is at a pressure of 3.23 bar and leaves at a pressure of 1.05 bar.

The isentropic efficiency of the compressor is 0.84.

The isentropic efficiency of the LP turbine is 0.86.

The mass flow of fuel and all system losses may be ignored.

(a) Sketch the cycle on a Temperature-specific entropy diagram. (3)

(b) Calculate EACH of the following:

(i) the compressor specific work input; (4)

(ii) the specific net work output; (6)

(iii) the cycle thermal efficiency. (3)

Note: for air $\gamma = 1.4$ *and* $c_p = 1.005$ *kJ/kgK*

for the combustion products $\gamma = 1.33$ *and* $c_p = 1.15$ *kJ/kgK*

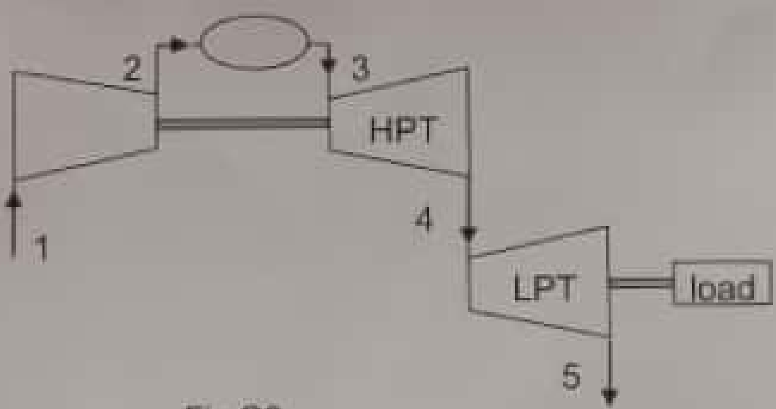

Fig Q2

3. Heptane (C_7H_{16}) is burned with an air fuel ratio of 13:1 by mass.

The combustion products are then cooled to a temperature of 127°C at a constant pressure of 1.105 bar.

Calculate EACH of the following for 1 kg of fuel:

(a) the mass of carbon burned to CO_2; (6)

(b) the volumetric analysis of the total combustion products; (6)

(c) the volume of the combustion products after cooling. (4)

Note: *atomic mass relationships H = 1, C = 12, O = 16, N = 14.*
universal gas constant R_o = 8.3145 kJ/kmolK
air contains 23.3% oxygen by mass.

4. The volume of a steam condenser shell is 8 m^3. It contains 0.47 kg of wet steam and an additional mass of air at a temperature of 36.2°C.

The vacuum gauge reading at this condition is 93%.

After a period of time 0.037 kg of steam has condensed and 0.09 kg of air has leaked in.

The atmospheric pressure remains constant at 1 bar.

Calculate EACH of the following:

(a) the initial mass of air;

(b) the initial mass of dry saturated vapour and saturated liquid;

(c) the final temperature;

(d) the vacuum gauge reading at the final condition.

Note: for air R = 0.287 kJ/kgK

5. In a 50% reaction turbine stage, dry saturated steam at pressure of 3 bar leaves the fixed blades with a velocity of 120 m/s.

The moving blade exit angle is 25° and the mean blade height is 40 mm.

The axial velocity of the steam is 75% of the blade velocity at the mean blade radius.

The mass flow of steam through the stage is 7200 kg/hr.

(a) Sketch the stage velocity diagram indicating the velocities and relationships. (4)

(b) Calculate EACH of the following:

(i) the rotor speed in rev/min; (6)

(ii) the diagram power; (3)

(iii) the stage enthalpy drop. (3)

6. A vapour compression refrigeration plant uses R134a.

The refrigerant enters the compressor at a pressure and temperature of 1.6393 bar and -5°C respectively and undergoes isentropic compression to 13.174 bar.

The liquid refrigerant leaves the condenser at a temperature of 35°C.

The cooling load is 250 kW.

(a) Sketch the cycle on a pressure-specific enthalpy diagram indicating areas of heat and work transfer. (2)

(b) Sketch the cycle on a Temperature-specific entropy diagram indicating areas of superheat and sub cooling. (2)

(c) Calculate EACH of the following:

(i) the mass of dry saturated vapour entering the evaporator; (4)

(ii) the compressor power; (4)

(iii) the coefficient of performance; (2)

(iv) the Carnot coefficient of performance between the same temperature limits. (2)

7. A steel pipe has an internal diameter of 100 mm and a wall thickness of 8 mm.

It carries wet steam a pressure of 7 bar and is covered with two layers of insulation, each 10 mm thick.

The outer layer of insulation becomes contaminated and is removed.

The surrounding air temperature remains constant at 20°C.

Calculate EACH of the following:

(a) the heat loss per metre length of pipe when covered in two layers of insulation; (6)

(b) the percentage increase in heat loss when the outer layer is removed; (5)

(c) the percentage increase in outer surface temperature. (5)

Note: *the heat transfer coefficient of the inner surface may be ignored.*
the thermal conductivity of steel = 52 W/mK
the thermal conductivity of the inner insulation = 0.045 W/mK
the thermal conductivity of the outer insulation = 0.13 W/mK
the heat transfer coefficient of the outer surface = 15 W/m²K

8. A single acting, two stage reciprocating compressor is designed for minimum work with perfect intercooling.

The low pressure cylinder contains a mass of 0.02 kg of air when the piston is at bottom dead centre.

The air is compressed from a pressure and temperature of 0.95 bar and 25°C respectively through an overall pressure ratio of 16:1.

The index of expansion and compression in both stages is 1.28.

The clearance volume in each stage is 5% of the respective swept volume and the compressor runs at a speed of 500 rev/min.

(a) Sketch the cycle on a pressure-Volume diagram. (2)

(b) Calculate EACH of the following:

(i) the compressor indicated power; (6)

(ii) the heat rejected during the compression process; (4)

(iii) the rate of heat rejection in the intercooler. (4)

Note: *for air* $\gamma = 1.4$, $c_p = 1.005$ kJ/kgK and R= 0.287 kJ/kgK

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9 A straight section of horizontal pipe tapers in diameter from 300 mm at inlet to 150 mm at outlet.

The mass flow of fresh water through the pipe is 500 tonne per hour and the pressure at inlet is 3 bar.

(a) Calculate EACH of the following:

(i) the fluid velocity at the outlet end; (2)

(ii) the pressure at the outlet end; (5)

(iii) the longitudinal thrust on the pipe. (5)

(b) Sketch a diagram of forces acting on the pipe. (4)