國 立 清 華 大 學 命 題 紙

94學年度 工程與系統科學 系（所） 乙 組碩士班入學考試

科目 熱力學 科目代碼 2902 共 3 頁 第 1 頁 *請在試卷【答案卷】內作答

1. In the design of a conventional heater, electricity is used to heat the fluid in the heater to a temperature of 77 ℃ and the heat is then dissipated to the room via convection or radiation. During the steady state operation of the heater, 95% of the electric energy can be transferred to the room. The electricity consumption rate of the heater is 500 Watts. Assume the outdoor environment temperature is -3 ℃ and room temperature is 22 ℃. (a) What is the first law efficiency of the heater (3%)? (b) What is second law efficiency of the heater (7%)? Assume the temperature of dead state is 20 ℃ (c) What is the irreversibility generation rate of the heater (5%)? (d) Please propose a way to use the electricity more effectively. You need to describe the method in detail (3%). (e) With the identical electricity consumption rate, theoretically, what is the maximum amount of power can be delivered to the room with the method you proposed (7%)?

2. (a) Please plot the schematic diagram and T-s diagram of Brayton cycle with intercooler, reheater, and regenerator (8%). (b) Please describe the purpose of the incorporation of intercooler and reheater in the cycle and explain thermodynamically why these devices can achieve these functions (7%). Please label all the components in your plots. The name of the components has to be correct in order to get points. Hints: The processes involved in a simple Brayton cycle are: isentropic compression, constant pressure heat addition, isentropic expansion, constant pressure heat rejection.

3. A Supercritical Rankine cycle operates between 24 MPa and 3.169 kPa. The isentropic efficiencies of turbine and pump are 95% and 90%, respectively. The steam temperature at turbine inlet is 560 ℃. (a) Please draw the T-s diagram of the cycle (3%). You need draw the saturation liquid line and saturated vapor line in your plot. (b) Please calculate the thermal efficiency of the cycle (7%). (c) If the heat is added to the cycle from a high temperature reservoir of 572 ℃, please calculate the second law efficiency of the cycle (10%). The dead state is 100 and 25 ℃. (d) For this particular supercritical Rankine cycle, please name a few ways to improve its thermal efficiency. You need to incorporate the proposed devices into the schematic plot (5%). The processes involved in a simple Rankine cycle are isentropic compression, constant pressure heat addition, isentropic expansion, and constant pressure heat rejection.

   Thermodynamic properties of water:

   At $P = 24$ MPa, $T = 560$ ℃, $h = 3370.9$ kJ/kg, $s = 6.2488$ kJ/kg K

   $P = 3.169$ kPa, $T_{sat} = 25$ ℃, $h_f = 104.89$ kT/kg, $h_g = 2547.2$ kJ/kg

   $v_f = 1.0029\times10^{-3}$, $s_f = 0.3674$ kJ/kg K, $s_g = 8.5580$ kJ/kg K

4. An engineer designs a new refrigerator, which uses 20 kW of power to extracts 300 kW from a environment at -3 ℃ and delivers to a room with temperature of 27 ℃.
   (1) Please use *the Clausius Inequality* to determine whether the proposed heat pump is realistic or not (5%).
   (2) Please use *Principle of Entropy Increase* to verify your answer (5%).
   (3) Please use *Principle of Exergy Destruction* to verify your answer (5%)

5. Argon gas enters an adiabatic turbine steadily at 900 kPa and 450 ℃ with a velocity of 80 m/sec and leaves at 150 kPa with a velocity of 150 m/sec. The inlet area of the turbine is 60 cm^2. If the power output of the turbine is 250 kW, determine: (a) the mass flow rate of argon (7%), (b) the exit temperature of argon (8%). (c) The entropy change of the argon gas (5%). (For argon gas: R = 0.2081 kPa m^3/kg K, Cp = 0.5023 kJ/kg, Cv = 0.2942 kJ/kg)

Please note: Equations are provided in the next page for your reference.

Some Useful Equations

Tds Relations:

$$Tds = du + Pdv, \quad Tds = dh - vdp$$

The entropy change of ideal gas:

$$s_2 - s_1 = \int_1^2 C_v(T)\frac{dT}{T} + R\ln\frac{v_2}{v_1}$$

$$s_2 - s_1 = \int_1^2 C_p(T)\frac{dT}{T} - R\ln\frac{P_2}{P_1}$$

$$s_2 - s_1 = s_2^o - s_1^o - R\ln\frac{P_2}{P_1}$$

Polytropic process relations:

$$Tv^{n-1} = \text{constant}$$

$$TP^{(1-n)/n} = \text{constant}$$

$$Pv^n = \text{constant}$$

Work for the Reversible Steady-State Process:

$$w = -\int_i^e v\,dp + \frac{V_i^2 - V_e^2}{2} + g(Z_i - Z_e)$$

Rate equation for entropy:

$$\dot{S}_{C.V.} = \sum \dot{m}_i s_i - \sum \dot{m}_e s_e + \sum \frac{\dot{Q}_{C.V.}}{T} + \dot{S}_{gen}$$

Reversible work:

$$W_{C.V.}^{rev} = T_\circ(m_2 s_2 - m_1 s_1) - (m_2 e_2 - m_1 e_1) + T_\circ(m_e s_e - m_i s_i) - (m_e h_{Tot,e} - m_i h_{Tot,i}) + Q_{C.V.}\left(1 - \frac{T_\circ}{T_H}\right)$$

$$e = u + V^2/2 + gZ, \qquad h_{Tot} = h + V^2/2 + gZ$$

Availability (or exergy) :

$$\varphi = \left(h - T_\circ s + \frac{1}{2}V^2 + gZ\right) - (h_\circ - T_\circ s_\circ + gZ_\circ)$$

$$\phi = (e + P_\circ v - T_\circ s) - (e_\circ + P_\circ v_\circ - T_\circ s_\circ)$$