******************************** Conceptual Questions ********************************

Q1: State THREE factors for ANY FOUR points of the following for the following:

A. Carnot Vapor Power cycle is not practical.
B. Condenser is used in Vapor Power cycles.
C. Diffuser is used in Jet Engines.
D. Methods to improve the efficiency of Brayton cycle.
E. Discuss the effect of cut-off ratio on the cycle's thermal efficiency, work net and MEP of the cycle.

******************************** Vapor Power Cycle ********************************

Q(2)

Consider a steam power plant operating on the simple Rankine cycle.
Steam enters the non-adiabatic turbine at 6 MPa and 450°C at rate of 12 kg/s. The Turbine efficiency is 85%.
It is condensed in the condenser at a pressure of 25 kPa.
Heat is supplied to the steam from a furnace maintained at 1000 K, and waste heat is rejected to the surroundings at 20 °C.
Determine

(a) Draw the T-s diagram showing all processes names.
(b) The turbine and pump powers (kW).
(c) The rate of heat added and rejected from the cycle (kW)
(d) The cycle first and second law efficiencies.
(e) The maximum net power that the cycle should have produced.
(f) The exergy at the steam turbine inlet (kW).

-------------------------------- Gas Power Cycle --------------------------------

ABET QUESTION

Q(3)

In an air standard Diesel cycle, the compression ratio is 15.
At the beginning of isentropic compression, the temperature is 20 °C and the pressure is 0.1 MPa.
Heat is added until the temperature at the end of the constant pressure process is 1480°C.
Assuming constant specific heat, take the source and sink temperatures as 2000 and 280 K,
Calculate :

$T_2 = 865.57$

$T_3 = 1753$

$T_4 = 788.21$

(a) The cut-off ratio,
(b) The heat supplied per kg of air,
(c) The cycle thermal and second law efficiencies,
(d) The mean effective poressure, (kPa)
(e) Exergy destroyed during the cycle.
(f) The exergy at the start of expansion process.
(g) The exergy expended and recovered of the cycle.

For air, take : Cv = 0.718 kJ/kg-K ; Cp = 1.005 kJ/kg-K ; R = 0.287 kJ/kg-K ; k = 1.4

Ans First Test, Thermodynamics II
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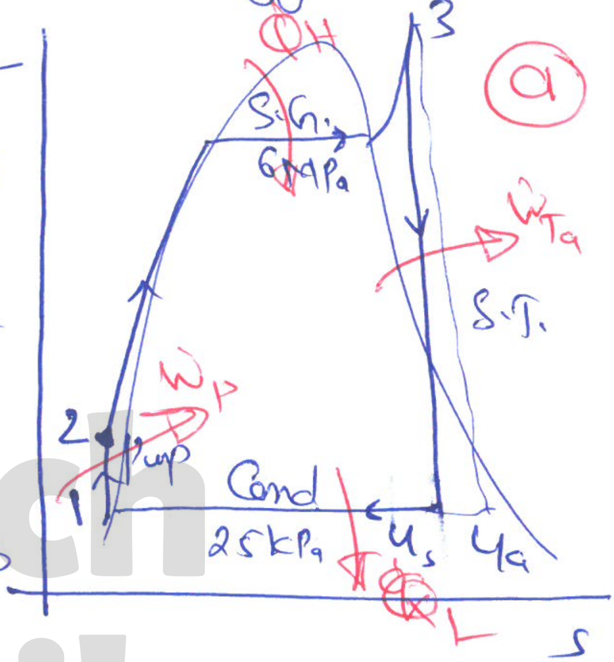
Q1) Check Textbook / Note.

Q2) Actual Rankine Cycle + Exergy



a) Dead state 20°C, 1atm

$h_0 = h_f @ 20°C = 83.915 \frac{kJ}{kg}$

$s_0 = s_f @ 20°C = 0.2965 \frac{kJ}{kg \cdot K}$

1) Sat. liq. at 25 kPa.

$h_1 = h_f = 271.96 \frac{kJ}{kg}$

$v_1 = v_f = 0.001020 \ m^3/kg$

$s_f = 0.8932 \frac{kJ}{kg \cdot K}$

$s_{fg} = 6.9370$, $s_g = 7.8302$

$h_{fg} = 2345.5$, $h_g = 2617.5$

2) Ideal pump, $(h_{2s} - h_1) = v_{f1}(P_2 - P_1)$

$\therefore h_{2s} = 271.96 + 0.00102(6000 - 25)$

$= 278.0545 \frac{kJ}{kg}$; $s_2 = s_1$

3) Ideal steam generator, 6MPa, 450°C

$\therefore h_3 = 3302.9 \frac{kJ}{kg}$; $s_3 = 6.7219 \frac{kJ}{kg \cdot K}$

4_s) Condenser, $s_{4s} = s_3 < s_g @ 25kPa \Rightarrow$ Wet mix.

$x_{4s} = \frac{s_{4s} - s_f}{s_{fg}} = 0.84$ (not acceptable)

$\therefore h_{4s} = h_f + x_{4s} h_{fg} = 2242.727 \frac{kJ}{kg}$

4a) from turbine η_{Ts}, we get

$$\eta_{Ts} = \frac{h_3 - h_{4a}}{h_3 - h_{4s}} \Rightarrow h_{4a} = 2401.75 \frac{kJ}{kg}$$

$$h_{4a} = h_{f1} + x_{4a} h_{fg} \Rightarrow x_{4a} = 0.908$$

$$\therefore s_{4a} = s_{f1} + x_{4a} s_{fg} = 7.1922$$

B $\quad \dot{W}_{Ta} = \dot{m}_s (h_3 - h_{4a}) = 10813.8 \text{ kW}$

$$\dot{W}_{Ps} = \dot{m}_s (h_2 - h_1) = 73.134 \text{ kW}$$

$$\dot{W}_{neta} = \dot{W}_{Ta} - \dot{W}_p = 10740.666 \text{ kW}$$

C $\quad \dot{Q}_H = \dot{m}_s (h_3 - h_2) = 36298.146 \text{ kW}$

$$\dot{Q}_L = \dot{m}_s (h_{4a} - h_1) = 25557.48 \text{ kW}$$

D $\quad \eta_{th} = 1 - \frac{\dot{Q}_L}{\dot{Q}_H} = 0.296$

$$\eta_{Carnot} = 1 - \frac{T_L}{T_H} = 0.707$$

$$\eta_{II} = \eta_{th} / \eta_{Carnot} = 0.4126$$

E $\quad \dot{W}_{net\,rev} = \eta_{Carnot} * \dot{Q}_H = 25662.789 \text{ kW}$

F $\quad \dot{\psi}_3 = \dot{m}_s [(h_3 - h_0) - T_0 (s_3 - s_0)]$

$$= 16036.114 \text{ kW}$$

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$$\dot{I} = \dot{W}_{net_{max}} - \dot{W}_{net_{u}}$$

$$\dot{I} = \cancelto{0}{\dot{X}_{dest_{1-2}}} + \dot{X}_{dest_{2-3}} + \dot{X}_{dest_{3-4a}} + \dot{X}_{dest_{4a-1}}$$

$$\dot{X}_{dest_{2-3}} = \dot{m}_s T_0 \left[s_3 - s_2 - \frac{q_H}{T_H} \right]$$

$$= 9858.352 \text{ kW}$$

$$\dot{X}_{dest_{3-4a}} = \dot{m}_s T_0 \left[s_{4a} - s_3 \right] = 1653.5748 \text{ kW}$$

$$\dot{X}_{dest_{4a-1}} = \dot{m}_s T_0 \left[s_1 - s_{4a} + \frac{q_L}{T_L} \right]$$

$$= 8410.196$$

$$\therefore \dot{I} = 14922.1228 \text{ kW}$$

$$\therefore \dot{W}_{net_{max}} = 25662.7888 \text{ kW}$$

Q3) Diesel cycle, CR = 15,

1) 100 kPa, 293 K, $v_1 = \frac{RT_1}{P_1} = 0.84091 \frac{m^3}{kg}$

2) $T_2 = T_1 CR^{k-1} = 865.573$ K

$P_2 = P_1 CR^k = 4431.265$

$v_2 = \frac{v_1}{CR} = 0.05606 \frac{m^3}{kg}$

3) $T_3 = 1480 + 273 = 1753$ K

(a) $r_c = \frac{T_3}{T_2} = \frac{v_3}{v_2} = \underline{2.025}$

$\therefore v_3 = r_c v_2 = 0.1135$ m3/kg

$P_3 = P_2$

4) $\frac{T_4}{T_3} = \left(\frac{r_c}{CR}\right)^{k-1} \Rightarrow T_4 = 786.93$ K

$\frac{P_4}{P_3} = \left(\frac{r_c}{CR}\right)^{k} \Rightarrow P_4 = 268.53$ kPa

$v_4 = v_1$

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b) $q_{in} = c_p(T_3 - T_2) = 891.86$ kJ/kg

c) $\eta_{th} = 1 - \frac{1}{CR^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right] = \underline{0.6024}$

$\eta_{Carnot} = 1 - \frac{T_L}{T_H} = \underline{0.86}$

$\eta_{II} = \underline{0.7}$

d) $W_{net} = \eta_{th} * q_{in} = 537.256$

$mep = \frac{W_{net}}{v_1 - v_2} = 684.534 \text{ kPa}$

e) $W_{net_{max}} = \eta_{Carnot} * q_{in} = 766.9996 \frac{kJ}{kg}$

$X_{dest_{cycle}} = W_{net_{max}} - W_{net_{a}} = 229.75 \frac{kJ}{kg}$

X_{dest} 1-2, 3-4 $= 0$ $\quad S = C.$

$X_{dest_{2-3}} = T_0 \left[s_3 - s_2 - \frac{q_H}{T_H} \right] = 73.687 \frac{kJ}{kg}$

$s_3 - s_2 = C_{v} \ln\left(\frac{T_3}{T_2}\right) - R \cancel{\ln}\left(\frac{P_3}{P_2}\right) = 0.7099$

$X_{dest_{4-1}} = T_0 \left[s_1 - s_4 + \frac{q_L}{T_L} \right] = 156.0965 \frac{kJ}{kg}$

$q_L = C_v (T_4 - T_1) = 354.64 \frac{kJ}{kg}$

$s_4 - s_1 = -(s_3 - s_2)$

f) $\phi_3 = (U_3 - U_0) + P_0 (v_3 - v_0) - T_0 (s_3 - s_0) = 772.1 \frac{kJ}{kg}$

$v_0 = \frac{RT_0}{P_0} = 0.8036$, $s_3 - s_0 = -0.7553 \frac{kJ}{kg}$

g) $X_{recovered} = W_{net} = 537.25 \frac{kJ}{kg}$

$X_{expended} = \left(1 - \frac{T_0}{T_H}\right) q_{in} = 766.99 \frac{kJ}{kg}$

s3 - s0 = $C_v \ln\left(\frac{T_0}{T_3}\right) + R \ln\left(\frac{v_0}{v_3}\right) = -0.755 \frac{kJ}{kg}$