۱- با مراجعه به جدول خواص ترمودینامیکی نقاط سیکل رانکین و هم چنین از روی روابط گاز ایده‌آل در حالت آیزنتروپیک مشخصات سیکل برایتون آمده را مشخص می نماییم.

در این سوال جواب آخر متفاوت از مقدار ارایه شده در صورت سوال بود. لطفا فقط راه حل را مد نظر قرار دهید.

نقطه 8 $\begin{cases} P = 15\ kPa \\ x = 0 \end{cases} \rightarrow \begin{cases} h = 225.9351213557\ kJ/kg \\ s = 0.7548386491\ kJ/kgK \\ v = 0.0010140296\ m^3/kg \end{cases}$

نقطه 9 $\begin{cases} P = 10\ MPa \\ s = 0.7549 \end{cases} \rightarrow \begin{cases} v = 0.001009014 \\ h = 236.0591570559 \end{cases}$

نقطه 6 $\begin{cases} P = 10\ MPa \\ T = 400\ ^\circ C \end{cases} \rightarrow \begin{cases} v = 0.026439087 \\ s = 6.213928894 \\ h = 3097.3752744945 \end{cases}$

نقطه 7 $\begin{cases} P = 15\ kPa \\ s = 6.2120 \end{cases} \rightarrow \begin{cases} v = 7.415987383 \\ h = 1981.642 \\ x = 74.0065\ \% \end{cases}$

* برای بدست نرخ جرمی بخار خواهیم داشت:

$$(\dot{Q}_L)_{BC} = (\dot{Q}_H)_{RC}$$

$$T_4 = ? \quad \left(\frac{T_4}{T_3}\right) = \left(\frac{v_3}{v_4}\right)^{k-1} \rightarrow T_4 = (1500\ K)\left(\frac{1}{15}\right)^{0.4} = 507.756\ K$$

$$\Rightarrow \dot{Q}_L = \dot{m} C_p \Delta T = \left(13\ \frac{kg}{s}\right)\left(1.0035\ \frac{kJ}{kg\,K}\right)(507.756 - 420) \Rightarrow$$

$$\dot{Q}_L = 1.144816191\ MW$$

$$\Rightarrow 1.144816191 = \dot{m} \times (h_6 - h_9) = \dot{m} \times (3097.3752744945 - 236.059157)$$

پاسخ قسمت الف ←

⇒ $\dot{m}_2 = 0.400 \ kg/s$

$$\dot{W}_{Tot} = \dot{W}_{BC} + \dot{W}_{RC} = (\dot{W}_{GT} - \dot{W}_{comp}) + (\dot{W}_{ST} - \dot{W}_{pump}) \rightarrow$$

$$\dot{W}_{Tot} = \dot{m}_1 (h_3 - h_4) - \dot{m}_1 (h_2 - h_1) + \dot{m}_2 (h_6 - h_7) - \dot{m}_2 (h_9 - h_8)$$

در این قسمت از حل نیاز به محاسبه‌ی T_2 خواهیم داشت :

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow T_2 = (300\,K) \times 15^{\frac{0.4}{1.4}} \rightarrow T_2 = 650.350 \ K$$

⇒ $$\dot{W}_{Tot} = (13)\left\{(1.0035)\left[(1500 - 507.756) - (650.350 - 300)\right]\right\}$$

$$+ (0.4)\left\{(3097.3752744945 - 1981.642) - (236.059157 - 225.935121)\right\}$$

$$\Rightarrow \dot{W}_{Tot} = 8.81607 \ MW$$

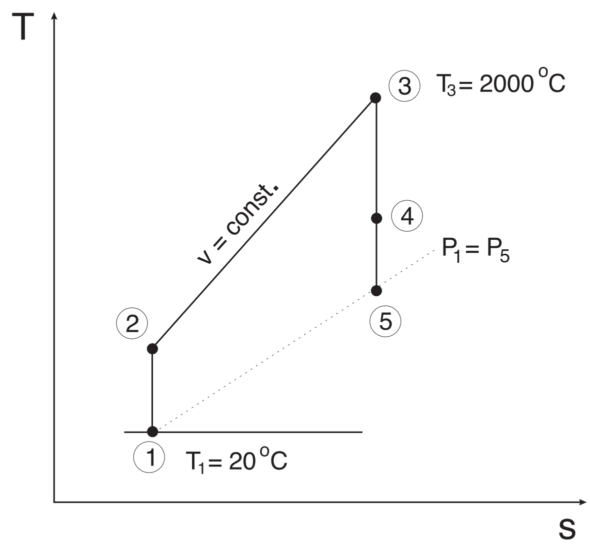
پاسخ قسمت ب ←

$$(\dot{Q}_H)_{BC} = (\dot{Q}_H)_{Tot} = (13)(1.0035)(1500 - 650.350) \rightarrow$$

$$(\dot{Q}_H)_{Tot} = 11.08411 \ MW$$

⇒ $$\eta_{th} = \frac{\dot{W}}{\dot{Q}} = \frac{8.81607}{11.08411} = 0.79538$$

سوال 2



Part i)

For an isentropic process

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{(k-1)} \quad \text{and} \quad \frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{(k-1)} = \left(\frac{P_4}{P_3}\right)^{(k-1)/k}$$

Therefore

$$T_2 = T_1 \left(\frac{v_1}{v_2}\right)^{(k-1)} = 293\ K\ (10)^{1.4-1} = 735.98\ K$$

and

$$T_4 = T_3 \left(\frac{v_3}{v_4}\right)^{(k-1)} = T_3 \left(\frac{v_4}{v_3}\right)^{-(k-1)}$$

But we know for an IC engine,

$$\frac{v_4}{v_3} = \frac{v_1}{v_2}$$

Therefore

$$T_4 = T_3 \left(\frac{v_4}{v_3}\right)^{-(k-1)} = T_3 \left(\frac{v_1}{v_2}\right)^{-(k-1)}$$

and

$$T_4 = (2000 + 273)\ K \quad \times (10)^{-(1.4-1)} = 904.9\ K$$

The net work output from the Otto cycle is

$$\begin{aligned} w_{net,otto} &= c_p(T_3 - T_4) - c_p(T_2 - T_1) \\ &= 1.005\ kJ/(kg \cdot K)(2273 - 904.9 - 735.98 + 293)\ K \\ &= 929.75\ kJ/kg \end{aligned}$$

We have and isentropic process between 3 and 5, and we can write

$$\frac{T_5}{T_3} = \left(\frac{P_5}{P_3}\right)^{(k-1)/k}$$

Since the air behaves as and ideal gas, and we know that $P_1 = P_5 = P_{atm}$, we can write

$$\begin{aligned} P_3 &= R \cdot T_3/v_3 \\ P_1 = P_5 &= R \cdot T_1/v_1 \end{aligned}$$

Therefore

$$\frac{T_5}{T_3} = \left(\frac{P_5}{P_3}\right)^{(k-1)/k} = \left(\frac{R \cdot T_1}{v_1} \cdot \frac{v_3}{R \cdot T_3}\right)^{(k-1)/k}$$

But for an Otto cycle we have constant volume heat addition between 2 and 3 and $v_2 = v_3$

$$\frac{T_5}{T_3} = \left(\frac{R \cdot T_1}{v_1} \cdot \frac{v_2}{R \cdot T_3}\right)^{(k-1)/k} = \left(\frac{T_1}{T_3} \cdot \frac{v_2}{v_1}\right)^{(k-1)/k}$$

Therefore

$$T_5 = (2000 + 273)\ K \quad \left(\frac{(20 + 273)\ K}{(2000 + 273)\ K} \cdot \frac{1}{10}\right)^{0.4/1.4} = 655.7\ K$$

The work output of the turbine is

$$\begin{aligned} w_{turbine} &= (h4 - h5) = c_p(T_4 - T_5) \\ &= 1.005\ kJ/(kg \cdot K)(904.9 - 655.7)\ K \\ &= 250.4\ kJ/kg \Leftarrow \end{aligned}$$

Part ii)

The thermal efficiency of the compound engine is given by

$$\eta_{th} = \frac{w_{net,otto} + w_{turbine}}{q_h}$$

where

$$q_h = (w_{net,otto})/\eta_{otto} = 929.75\ (kJ/kg)/0.6 = 1549.58\ kJ/kg$$

Therefore

$$\eta_{th} = (929.75\ kJ/kg + 250.4\ kJ/kg)/1549.58\ kJ/kg = 0.762 \Leftarrow$$