Question #83234

An ideal Otto cycle has a compression ratio of 8 and takes in air at 95 kPa and 15°C, and the maximum cycle temperature is 1200°C. Determine the heat transferred to and rejected from this cycle, as well as the cycle's thermal efficiency.

Answer:

Figure 1 shows an ideal Otto cycle on pV-diagram.

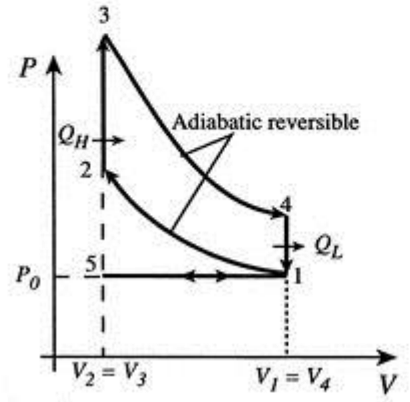

FIGURE 1. An ideal Otto cycle

The thermal efficiency η of an ideal Otto cycle is given by:

$$\eta = 1 - r^{1-k}, \quad (1)$$

where r = 8 – the compression ratio,

k = 1.4 – the adiabatic index for the ideal air.

Substitute into (1):

$$\eta = 1 - 8^{1-1.4} = 0.565.$$

The heat Q_H is transferred to the cycle in process 2-3:

$$Q_H = c_v(T_3 - T_2), \quad (2)$$

where the heat capacity at constant volume for the ideal (diatomic) air is given by:

$$c_v = \frac{5}{2}R, \quad (3)$$

R = 287 J.kg^{-1}K^{-1} – the gas constant of air.

Now, let us determine the temperatures T_2 and T_3.

The maximum cycle temperature is achieved at state 3. So, T_3 = 1200°C = 1473K.

In the isentropic (adiabatic) process 1-2, we have:

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{k-1} = T_1 r^{k-1}, \quad (4)$$

where T_1 = 15°C = 288K – the initial absolute temperature of the air.

Substitute into (4), (3) and (2) to obtain the heat Q_H transferred to the cycle:

$$T_2 = 288 \cdot 8^{0.4} = 661.7\ \mathrm{K},$$

$$c_v = \frac{5}{2} \cdot 287 = 717.5\ \mathrm{J/kg.K} = 0.7175\ \mathrm{kJ/kg.K},$$

$$Q_H = 0.7175(1473 - 661.7) = 582.1\ \mathrm{kJ/kg}.$$

The thermal efficiency of a cycle is given by:

$$\eta = 1 - \frac{Q_L}{Q_H}, \quad (5)$$

we can find the heat Q_L rejected from the cycle as follow:

$$Q_L = Q_H(1 - \eta), \quad (6)$$

$$Q_L = 582.1(1 - 0.565) = 253.4\ \mathrm{kJ/kg}.$$