Engineering Thermodynamics homework(2)

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1 第三章: 熵与热力学第二定律

3-3: 已知卡诺机 A,B 串联, $T_A = 627^oC = 900K, T_B = 27^oC = 300K$,

(1) 二热机输出功相同, 设高温热源 A 排出热量 Q_1, 中间热源吸收排出热量 Q_2, 低温热源 B 吸收热量 Q_3, 可得

$$W_A = Q_1 - Q_2$$

$$W_B = Q_2 - Q_3$$

$$\text{由题干可知}: W_A = W_B$$

$$\text{即}: Q_1 + Q_3 = 2Q_2$$

由于 A、B 均为卡诺热机, 有:$\frac{T_1}{T} = \frac{Q_1}{Q_2}, \frac{T}{T_2} = \frac{Q_2}{Q_3}$, 代入上式可得

$$T = \frac{T_1 + T_2}{2} = \frac{900 + 300}{2}K = 600K = 327^oC$$

(2) 二热机效率相等, 即 $\eta_1 = \eta_2 \Rightarrow 1 - \frac{T}{T_A} = 1 - \frac{T_B}{T}$, 可得:

$$T = \sqrt{T_1 T_2} = \sqrt{300 \times 900} = 519.6K = 246.6^oC$$

3-4: 由题可得,$T_{out} = -8^oC = 265K, T_{build} = 27^oC = 300K, Q = 2 \times 10^5 kJ/h$,

(1) 因为是卡诺热泵, 有 $\frac{Q_{input}}{Q} = \frac{T_{out}}{T_{build}}$, 可得 $Q_{input} = 1.767 \times 10^5 kJ/h$

(2)$P_W = Q_{input} \times \frac{T_{out}-T_{build}}{T_{out}}/3600 = 6.48kW$

3-7: 用可逆热机驱动可逆制冷机, 可知:

$$\text{可逆热机热效率:}\eta_1 = 1 - \frac{T_0}{T_H}$$

$$\text{热机输出功量/制冷机输入功量:}W = \eta_1 Q_H = (1 - \frac{T_0}{T_H})Q_H$$

$$= \frac{Q_L}{\epsilon} = \frac{T_0 - T_L}{T_L} Q_L$$

$$\text{联立可得:}\frac{Q_L}{Q_H} = \frac{T_H - T_0}{T_H}\frac{T_L}{T_0 - T_L}$$

$$\text{当}T_H >> T_L, \frac{T_H - T_0}{T_H} \to 1, \frac{Q_L}{Q_H} \to \frac{T_0 - T_L}{T_L}, \text{成立}$$

3-9: 设混合后水温为 T, 冰的融解热 $c_0 = 333kJ/kg$, $T_1 = 0^oC, T_2 = 50^oC$ 则:

$$m_1 c_0 + c m_1 (T - T_1) = c m_2 (T_2 - T)$$

可得 $T = 301.4K$

混合后系统的熵增:

$$\Delta S = \Delta S \ + \Delta S \ = \frac{m_1 c_0}{T_1} + \int_{T_1}^{T} c m_1 \frac{dT}{T} + \int_{T}^{T_2} c m_2 \frac{dT}{T} = 0.930kJ/K$$

3-10: 已知 $t_1 = 600^oC, t_2 = 300^oC$, 循环吸热 $Q_1 = 3000kJ$:

(1) 循环功量 $W=(1-\frac{T_2}{T_1})Q_1=1030.9kJ$

(2) $Q_2=Q_1-W=3000-1030.9=1969.1kJ$

$\Delta S\ =\frac{Q_2}{T_2}=3.436kJ/K$

(3) 不可逆使系统熵增 $\Delta S_g=0.2kJ/K$, 有 $\Delta W=\Delta Q_2=T_0\Delta S_g=114.63kJ$

3-13:(1) 设 A 物体初温为 T_A, 放热降温至 T,B 物体初温为 T_B, 吸热升温至 T_m, 可逆热机在两者间工作, 则:

$$\begin{aligned}\Delta S\ &=0=\Delta S_A+\Delta S_B\\ &=\int_{T_A}^{T_m}cm\frac{dT}{T}+\int_{T_m}^{T_B}cm\frac{dT}{T}=cm\ln\frac{T_m^2}{T_AT_B}\end{aligned}$$

可知 $\ln\frac{T_m^2}{T_AT_B}=0\Rightarrow\frac{T_m^2}{T_AT_B}=1\Rightarrow T_m=\sqrt{T_AT_B}$

(2) 总功量 $W=Q_1-Q_2=cm(T_A-T_m)+cm(T_m-T_B)=cm(T_A+T_B-2T_m)$

(3)A、B 直接接触, 有 $cm(T_A-T)=cm(T-T_B)\Rightarrow T=\frac{T_A+T_B}{2}$

$\Delta S\ =\int_{T_A}^{T}cm\frac{dT}{T}+\int_{T}^{T_B}cm\frac{dT}{T}=cm\ln\frac{T^2}{T_AT_B}=cm\ln\frac{(T_A+T_B)^2}{4T_AT_B}$

3-14: 要使得制冷机所需功量最小, 则必须为可逆制冷机,$\Delta S=0$

$$\Delta S=\Delta S\ +\Delta S\ =cm\ln\frac{T_0}{T}+cm\ln\frac{T_t}{T}=0$$

可得 $T_t=\frac{T^2}{T_0}$, 则最小功量 $W=Q_1-Q_2=cm(T_t-T)-cm(T-T_0)=cm(\frac{T^2}{T_0}+T_0-2T)$

3-22: 由题得,$T_{in} = 20^oC = 293K, T_{out} = -2^oC = 271K$, 对外放热 $Q = 80000kJ/h$, 热泵 COP 即 ϵ 为 2.5:

(1) 热泵所耗功率 $W = Q/\epsilon = 32000kJ/h$

(2)$Q \ = Q - W = 48000kJ/h$

(3) 耗功增加 2.5 倍