Carnot cycle

Draw a process scheme and $T - s$ diagram for a Carnot cycle using steam as the working fluid. Calculate the work and heat transfers, cycle efficiency η and work ratio W_R for the cycle operating at maximum and minimum pressures of 40 and 0.04 bar. Use the steam chart.

W_{12}=300 kJ/kg; Q_{23}=1650 kJ/kg; W_{34}=-1000 kJ/kg; Q_{41}=-950 kJ/kg; η_{ideal}=42.4%

Make the same calculation using the steam tables - find the respective dryness fractions x after expansion of the steam through the turbine, and after partial condensation of the vapour in the condenser.

W_{12}=248 kJ/kg; Q_{23}=1714 kJ/kg; W_{34}=-977 kJ/kg; Q_{41}=-985 kJ/kg; x_1=29.5%; x_4=70.1%; η_{ideal}=42.5%

Calculate the cycle efficiency assuming isentropic efficiencies of 85% for the expansion and compression processes.

η_{real}=31.3%

Rankine cycle

As above, but for the Rankine cycle operating between the same pressures. The boiler is fed by a water pump and generates saturated steam. Also calculate the cycle efficiency assuming an isentropic efficiency of 85% for the turbine expansion.

Q_{23}=2600 kJ/kg; W_{34}=-977 kJ/kg; Q_{41}=-1600 kJ/kg; η_{ideal}=38.5%; η_{real}=32.6%

Comparison of cycle efficiencies

cycle	ideal	real	W_R
Carnot	42.4%	31.3%	75%
Rankine	38.5%	32.6%	$\approx$ 100%

Table 1: ideal and real cycle efficiences for Carnot and Rankine cycles

Equations

$$Q + W = \Delta h \tag{1}$$

$$s = xs'' + (1-x)s'; \quad h = xh'' + (1-x)h' \tag{2}$$

$$\eta = \frac{|\sum W|}{Q_{in}} \tag{3}$$

$$W_R = \frac{|\sum W|}{W_{out}} \tag{4}$$

References

[1] Rogers & Mayhew. *Engineering Thermodynamics: Work & Heat Transfer*. Pearson, 4th edition, 1992.