Thermodynamics 4
Tutorial 3 – Power Cycles 2 (Questions)

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1) Consider a 210-MW steam power plant that operates on a simple ideal Rankine cycle. Steam enters the turbine at 10 MPa and 500°C and is cooled in the condenser at a pressure of 10 kPa. Show the cycle on a T-s diagram with respect to saturation lines, and determine (a) the quality of the steam at the turbine exit, (b) the thermal efficiency of the cycle, and (c) the mass flow rate of the steam.

(a) 0.793, (b) 40.2 percent, (c) 165 kg/s

2) How do the following quantities change when a simple ideal Rankine cycle is modified with reheating? Assume the mass flow rate is maintained the same.

Pump work input: (a) increases, (b) decreases, (c) remains the same

Turbine work output: (a) increases, (b) decreases, (c) remains the same

Heat supplied: (a) increases, (b) decreases, (c) remains the same

Heat rejected: (a) increases, (b) decreases, (c) remains the same

Moisture content at turbine exit: (a) increases, (b) decreases, (c) remains the same

3) Steam enters a turbine at 8 bar and 400°C and exits at 0.05 bar. The isentropic efficiency of the turbine is 90%.

Using the steam tables, find:

a) The enthalpy and entropy at the inlet of the turbine.

$h_1 = 3267.6$ kJ/kg, $s_1 = 7.573$ kJ/kgK

b) The entropy of saturated liquid and saturated vapour at the outlet of the turbine.

$s_f = 0.4763$ kJ/kgK, $s_g = 8.394$ kJ/kgK

c) Calculate the dryness fraction for a reversible expansion.

$x_{2s} = 0.896$

d) The isentropic outlet enthalpy.

$h_{2s} = 2309$ kJ/kg

e) The actual turbine enthalpy and dryness fraction.

$h_2 = 2405$ kJ/kg, $x = 0.936$

4) Steam enters a turbine at 10 bar and 400°C and exits at 0.05 bar. The isentropic efficiency of the turbine is 90%.

Find the isentropic enthalpy at the outlet of the turbine, the actual enthalpy at the outlet of the turbine, and the outlet dryness fraction. You might find it helpful to use a Mollier diagram (h-s diagram for steam) included with the steam tables on Learn.

$h_{2s} = 2277$ kJ/kg, $h_2 = 2376$ kJ/kg, $x = 0.924$

5) Steam is generated at 100 bar and 600°C in a sub-critical boiler and is expanded in a turbine down to 0.1 bar.

a) For a turbine with isentropic efficiency of 90% calculate the turbine work output.

$W = 1295$ kJ/kg

b) Calculate the efficiency of the corresponding Rankine cycle, assuming a pressure drop in the boiler of 20 bar and pump efficiency of 80%.

$\eta_{cycle} = 0.374$

c) Compare the result to the corresponding Carnot cycle efficiency.

$\eta_{Rankine} = 0.374$, $\eta_{Carnot} = 0.635$

6) **Consider an ideal steam reheat cycle where steam enters the high-pressure turbine at 30 bar, 400°C, and then expands to 8 bar. It is then reheated to 400°C and expanded to 10 kPa in the low-pressure turbine.**

Calculate the cycle thermal efficiency and the moisture content (dryness fraction) of the steam leaving the low-pressure turbine.

$\eta_{Cycle} = 0.353,\ x = 0.923$

7) **A closed feedwater heater (FWH) in a regenerative steam power cycle heats 20 kg/s of water from 100°C, 20 MPa to 200°C, 20 MPa. The extraction steam from the turbine enters the heater at 275°C, 4 MPa, and leaves at 4 MPa as a saturated liquid.**

What is the required mass flow rate of extraction steam?

$\dot{m} = 4.74\ kg/s$