Colby Watts

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MET 350 Test 2

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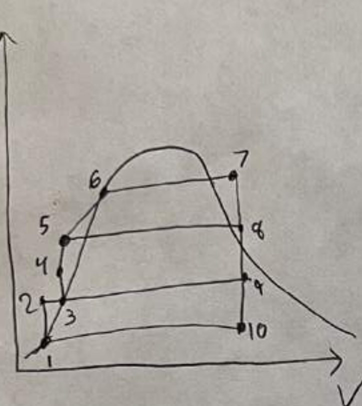
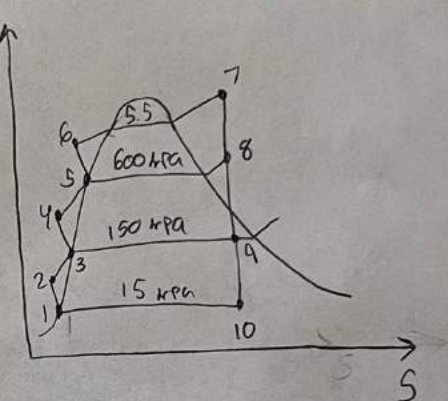
Purpose

Determine the utilization factor, make P-V and T-s diagrams, as well as the Turbine work per kilogram. We also have to figure out for a 50,000 kW load mass flow steam entering the turbine. The heat supplied to the working areas for the conditions in (d). Figure out all the states in the cycle as well as the mass fractions y_2 and y_1. Then solve for the rate of the heat exchanger.

Drawings & Diagrams





Sources

- Thermodynamics: An engineering approach.
- Interpolating Calculator
- Dr. Ayala Solutions and examples in Canvas

Design Considerations

One design consideration is that this should maximize the efficiency of the plant. Another one is that the throttling process should be designed to minimize energy losses.

Data & Variables

5.5 MPa 500°C $y_2 = y_1$ 50,000 kW

660 kPa 150 kPa 15 kPa Appendix one

Isentropic — P-const — Isent — P const

State 1

$P_1 = 15\,kPa$

$h_1 = 225.58\ \frac{kJ}{kg}$

$V_1 = 0.00104\ \frac{m^3}{kg}$

State 2

$P_2 = 150\,kPa$

$h_2 = 225.71\ \frac{kJ}{kg}$

$h_2 = h_1 + V_1(P_2 - P_1)$

$h_2 = 225.71\ \frac{kJ}{kg}$

State 3 (Sat liquid)

$P_3 = 150\,kPa$

$h_3 = 467.13\ \frac{kJ}{kg}$

$V_3 = 0.001053\ \frac{m^3}{kg}$

h_3 @ 150kPa

State 4

$P_4 = 660\,kPa$

$h_4 = 467.66\ \frac{kJ}{kg}$

$h_4 = w_{3\text{-}4} + h_3$

$w_{3\text{-}4} = V_3(P_4 - P_3)$

$0.001053(660 - 150)$

$w_{3\text{-}4} = 0.53703\ kJ/kg$

State 5

$P_5 = 660\,kPa$

$h_5 = 686.38\ \frac{kJ}{kg}$

$V_5 = .001105\ \frac{m^3}{kg}$

$w_{5\text{-}6} = V_5(P_6 - P_5)$

$w_{5\text{-}6} = 5.35\ \frac{kJ}{kg}$

$h_6 = w_{5\text{-}6} + h_5 \quad h_6 = 691.73\ \frac{kJ}{kg}$

State 6

$P_6 = 5.5\,MPa$

$h_6 = 691.73\ \frac{kJ}{kg}$

State 7 (Sheated steam)

$P_7 = 5.5\,MPa$

$h_7 = h_{g7}$ @ 5500kPa

$h_7 = 2789.73\ \frac{kJ}{kg}$

$S_7 = 5.93\ \frac{kJ}{kg \cdot k}$

State 8 (Sheated steam)

$P_8 = 660\,kPa$

$h_8 = h_{g8}$ @ 660kPa

$h_8 = 2760.17\ \frac{kJ}{kg}$

$S_8 = S_{g8}$ @ 660 kPa

$S_8 = 6.72\ \frac{kJ}{kg \cdot k}$

State 9 (Sheated steam)

$P_9 = 150\,kPa$

$S_8 = S_9$

$h_{f9} = 467.13\ \frac{kJ}{kg}$

$h_{fg9} = 2226\ \frac{kJ}{kg}$

$h_9 = 2499.91\ \frac{kJ}{kg}$

S_{f9} @ 150kPa $= 1.4337\ \frac{kJ}{kg \cdot k}$

S_{fg9} @ 150kPa $= 5.789\ \frac{kJ}{kg \cdot k}$

$$x_9 = \frac{S_9 - S_{f9}}{S_{fg9}} = \frac{6.72 - 1.4337}{5.789\ \frac{kJ}{kg \cdot k}}$$

$x_9 = 0.9132$

$h_9 = h_{f9} + x_9 h_{fg9}$

$h_9 = 2499.91\ \frac{kJ}{kg}$

State 10 (Sheated steam)

$P_{10} = 15\,kPa$

$S_{10} = 6.72$

$h_{f10} = 225.94\ \frac{kJ}{kg}$

$h_{fg10} = 2372.3\ \frac{kJ}{kg}$

$h_{10} = 2167.2\ \frac{kJ}{kg}$

State 10

$S_{f10} = .7849\ \frac{kJ}{kg \cdot k}$

$S_{fg10} = 7.2522\ \frac{kJ}{kg \cdot k}$

$$x_{10} = \frac{S_{10} - S_{f10}}{S_{fg10}} = \frac{6.72 - .7849}{7.2522}$$

$x_{10} = .8183$

$h_{10} = h_{f10} + x_{10} h_{fg10}$

$h_{10} = 2167.2\ \frac{kJ}{kg}$

$$y = \frac{h_3 - h_2}{h_6 - h_2} = \frac{467.13 - 225.71}{691.73 - 225.71}$$

$y_1 = .51804 = y_2$

Table A-5

Procedure & Calculations

After finding all the information needed for each state using interpolation, I can finally go on and calculate each step. To Determine the utilization factor with this equation,

$$\epsilon_v = 1 - \frac{W_{T,out}}{\dot{Q}_{in}}$$

I need to calculate for the Turbine work as well as the total heat for the system. To calculate for total heat in the system I used this equation.

$$\dot{Q}_{in} = h_7 - h_6$$

$$\dot{Q}_{in} = 2789.73 \frac{kJ}{kg} - 691.73 \frac{kJ}{kg}$$

$$\dot{Q}_{in} = 2098 \frac{kJ}{kg}$$

Then I calculate for the extracted steam w/ FWH

$$\dot{m} h_8 + (1-y) h_4 = 1(h_5) = \dot{m}(2760.17) + (1-467.66) = 1(686.38)$$

$$\dot{m} = .299 \, kg$$

Now I can plug that into my Turbine equation to find the work produced by the turbine.

$$W_{T,out} = 1(h_7 - h_8) + (1-\dot{m}) \cdot (h_8 - h_9) + (1-2\dot{m})(h_9 - h_{10})$$

$$W_{T,out} = 1(2789.73 - 2760.17) + (1-.299) \cdot (2760.17 - 2499.91) + (1-2(.299))(2499.91 - 2167.2)$$

$$W_{T,out} = 345.75 \frac{kJ}{kg}$$

Now, that I have the work output of the Turbine and my heat in I can now solve for the utilization

$$\epsilon_v = 1 - \frac{345.75 \frac{kJ}{kg}}{2098 \frac{kJ}{kg}} = .8352$$

Now I can also solve for the mass flow rate of steam entering the turbine with a 50,000 kW load. I use this equation.

$$\dot{m} = \frac{load}{w_{T,out}} = \frac{50{,}000\,kW}{345.75\,\frac{kJ}{kg}} = 144\,kg/s$$

Summary

Part of me thinks I have too many states because in the examples provided on canvas specifically 10-60 looks a little and sounds a little like this problem for this test. Some of my equations are derived from other equations in the book and posted solutions. I think I got all the information needed for the questions. Also, what else is mixing me up is the states processes. I understand most of it but I am having a hard time where to put the lines going to what state.

Materials

- Steam
- liquid saturated

Analysis

If I did my states correctly I should have no trouble in getting the right answers. What I do not know is if my equations were used correctly, specifically for the extracted steam.
Adding more stages of fwh could increase the efficiency by extracting more heat from the steam before it enters the condenser. That would not be cost effective though.