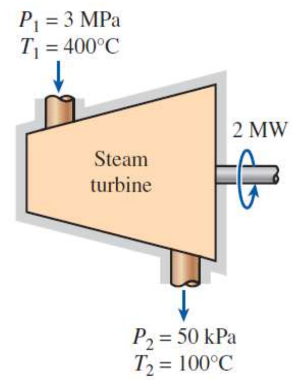
Given: $kJ := 1000J$

Steam enters an adiabatic turbine steadily at 3 MPa and 400°C and leaves at 50 kPa and 100°C.

$P_1 := 3MPa \qquad T_1 := 400\,°C \qquad P_2 := 50kPa \qquad T_2 := 100\,°C$



Required:

If the power output of the turbine is 2 MW, determine the isentropic efficiency and the mass flow rate of the steam.

Solution:

The power output of the turbine is defined as

$$W'_{out} := 2MW$$

The isentropic efficiency is given by

$$\eta_T = \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$$

Going to Table A-5 @ $P_1 = 3000\,kPa$ shows

$$T_{sat} := 233.85\,°C$$

Since $T_1 > T_{sat}$ the state is superheated. Going to Table A-6 @ $P_1 = 3 \cdot MPa$ & $T_1 = 400 \cdot °C$ shows

$$h_1 := 3231.7\frac{kJ}{kg} \qquad s_1 := 6.9235\frac{kJ}{kg \cdot K}$$

Going to Table A-4 @ $T_2 = 100 \cdot °C$ shows

$$P_{sat} := 101.42kPa$$

Since $P_2 < P_{sat}$ the stae is superheated. Going to Table A-6 @ $T_2 = 100 \cdot °C$ & $P_2 = 0.05 \cdot MPa$ shows

$$h_{2a} := 2682.4\frac{kJ}{kg}$$

The enthalpy h_{2s} is the final state of an isentropic process. Thus

$$s_{2s} := s_1 = 6.923 \cdot \frac{kJ}{kg \cdot K}$$

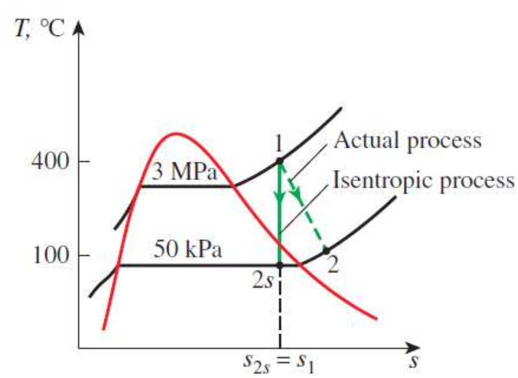
Going to Table A-5 @ $P_2 = 50 \cdot kPa$ & $s_{2s} = 6.923 \frac{kJ}{kg \cdot K}$ shows

$$s_f := 1.0912\frac{kJ}{kg \cdot K} \qquad s_g := 7.5931\frac{kJ}{kg \cdot K}$$

$$h_f := 340.54\frac{kJ}{kg} \qquad h_g := 2645.2\frac{kJ}{kg}$$

$$x_{2s} := \frac{s_{2s} - s_f}{s_g - s_f} = 0.897$$

$$h_{2s} := h_f + x_{2s} \cdot \left(h_g - h_f\right) = 2407.9 \cdot \frac{kJ}{kg}$$



Solution (contd.):

Thus the isentropic efficiency is

$$\boxed{\eta_T := \frac{h_1 - h_{2a}}{h_1 - h_{2s}} = 66.68\cdot\%}$$

<u>1st Law</u> for a steady state adiabatic turbine with negligible changes in KE and PE shows

$$\frac{d}{dt}E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$

$$0 = m'_{in}\cdot\left(h_{in} + \frac{V_{in}^{\ 2}}{2} + g\cdot z_{in}\right) - m'_{out}\cdot\left(h_{out} + \frac{V_{out}^{\ 2}}{2} + g\cdot z_{out}\right) - W'_{out}$$

$$0 = m'_{in}\cdot h_{in} - m'_{out}\cdot h_{out} - W'_{out}$$

Since the turbine has a single inlet and outlet mass stream, the mass flow rates are the same. Thus

$$0 = m'\cdot\left(h_{in} - h_{out}\right) - W'_{out}$$

$$\boxed{m' := \frac{W'_{out}}{h_1 - h_{2a}} = 3.641\,\frac{kg}{s}}$$