We have an adiabatic turbine with 100 bar and 400 C inlet, 1 bar, x = 0.9 at the outlet. Find: work output of turbine per kg of flow and turbine efficiency.

From the first law, turbine work output is just \( h_{in} - h_{out} \). From the steam tables, the inlet is superheated vapor with \( h_{in} = 3096.5 \text{ kJ/kg} \) and \( s_{in} = 6.2120 \text{ kJ/kg-K} \). At the outlet, we know we’re mixed, and we get \( h_{out} \) from \( h_f + x h_{fg} = 417.46 + 0.9(2258.0) = 2449.66 \text{ kJ/kg} \). This gives us 647 kJ/kg.

For efficiency, we need to define the ideal outlet state, which is the state with the actual outlet pressure (1 bar) and \( s = s_{in} = 6.2120 \text{ kJ/kg-K} \). At 1 bar, \( s_f = 1.3026 \) and \( s_g = 7.3594 \), which means that we’re mixed, and using the quality relation gives us \( x_s = 0.8106 \). Plugging this into our equation for \( h \) in the mixed region, we get \( h_s = 2247.7 \).

Then, \( \eta_t = \frac{w_{actual}}{w_{ideal}} = \frac{(h_{in} - h_{out})}{(h_{in} - h_s)} = 0.76 \), or 76%.

Grading guide:

Give 10 points each for the two bulleted items below. Be fairly lenient.

- Writing the open system first law in any recognizable form.
- In some recognizable way, recognizing that the ideal outlet state is the one for which \( P = 1 \text{ bar} \) and \( s = s_{in} \).

For each of the following 4 items, give 5 points, assigned in the same fashion as the homework - being tolerant of minor mistakes and focusing on whether the student demonstrates knowledge of the key principles.

1) Looking up \( h_{in} \) and \( s_{in} \) correctly.
2) Using the quality relation to try to get \( h_{out} \) and \( h_s \).
3) Using the quality relation to get \( x_s \).
4) Using some form of efficiency equation like \( \eta_t = \frac{w_{actual}}{w_{ideal}} = \frac{(h_{in} - h_{out})}{(h_{in} - h_s)} \) to calculate efficiency.

Total points possible = 40.