Air enters a turbine in steady flow at 0.5 kg/s with negligible velocity. Inlet conditions are 1300 °C and 2.0 MPa (abs). The air is expanded through the turbine to atmospheric pressure. If the actual temperature and velocity at the turbine exit are 500 °C and 200 m/s, determine the power produced by the turbine. Determine the change in specific entropy for the process. Label state points on a *Ts* diagram for this process.

SOLUTION:

Apply the 1st Law across the turbine to determine the power produced by the turbine.

$$m_2\left(h+\tfrac{1}{2}V^2\right)_2 - m_1\left(h+\tfrac{1}{2}V^2\right)_1 = Q_{\text{into}} + W_{\text{into}} \quad (1)$$

$$W_{\text{into}} = m\left[c_P\left(T_2-T_1\right)+\tfrac{1}{2}V_2^2\right] \quad (2)$$

where

$$m = m_2 = m_1 \quad \text{(from conservation of mass)} \quad (3)$$

$$h_2 - h_1 = c_P\left(T_2-T_1\right) \quad \text{(assuming the air behaves as a perfect gas)} \quad (4)$$

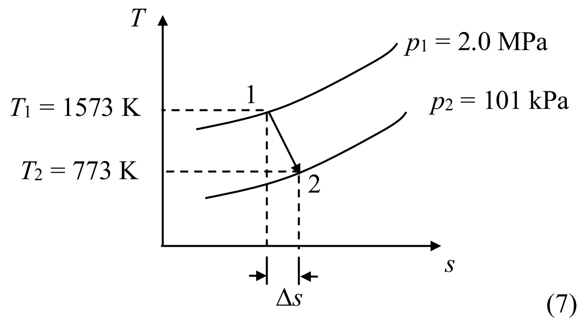
$$Q_{\text{into}} = 0 \quad \text{(flow through the turbine is assumed to occur adiabatically)} \quad (5)$$

$$V_1 \approx 0 \quad \text{(flow at the inlet has negligible velocity)} \quad (6)$$

Substitute the given parameters.

m = 0.5 kg/s
c_P = 1004 J/(kg·K)
T_2 = (500 + 273) = 773 K
T_1 = (1300 + 273) = 1573 K
V_2 = 200 m/s

$$\therefore W_{\text{into}} = -390 \text{ kW} \quad \text{or} \quad W_{\substack{\text{extracted}\\\text{from air}}} = 390 \text{ kW}$$



The change in the entropy during the process is:

$$\Delta s = s_2 - s_1 = c_P \ln\frac{T_2}{T_1} - R\ln\frac{p_2}{p_1} \quad (7)$$

$$\therefore \Delta s = 140 \ \text{J}/\left(\text{kg}\cdot\text{K}\right) > 0$$ ($\Delta s > 0$ for an adiabatic, irreversible process)