Problem 4.60

KNOWN: Air is compressed at steady state from a given initial state to a given final pressure. The mass flow is known, and each unit of mass undergoes a specified process in going from inlet to exit.

FINN: Determine the compressor power.

SCHEMATICAL & GIVEN DATA: 

\[ T_i = 300 \, \text{K} \]
\[ P_i = 1 \, \text{bar} \]
\[ m = 4 \, \text{kg/s} \]
\[ W_{cv} = ? \]
\[ Q_{cv}/m = -469.5 \, \text{kJ/kg} \]

ENG\, MODEL: (1) The control volume is at steady state. (2) Each unit of mass undergoes a process described by \( p^n v^{1.27} \text{= constant} \). (3) The air can be modeled as an ideal gas. (4) Kinetic and potential energy effects are negligible.

ANALYSIS: To determine the power, begin with mass and energy rate balances at steady state.

\[ 0 = \dot{Q}_{cv} - W_{cv} + \dot{m} [ (h_1 - h_2) + g(h_i - h_2) ] \]

where \( \dot{m} = m_2 = m \) and the indicated terms are deleted by assumption 4. Rearranging and solving for \( W_{cv} \)

\[ W_{cv} = \dot{m} \left[ \left( \frac{\dot{Q}_{cv}}{\dot{m}} \right) + (h_1 - h_2) \right] \]  

Now, specific enthalpy \( h_1 \) is read from Table A-22 at 300 K; \( h_1 = 300.19 \, \text{kJ/kg} \).

To get \( T_2 \), we use Eq. 3.56 with \( n = 1.27 \)

\[ \frac{T_2}{T_i} = \left( \frac{P_2}{P_i} \right)^{\frac{n}{n-1}} \Rightarrow T_2 = \left( \frac{P_2}{P_i} \right)^{\frac{1.27-1}{1.27}} (300 \, \text{K}) = 439.1 \, \text{K} \]

Interpolating in Table A-22; \( h_2 = 440.7 \, \text{kJ/kg} \). Inserting values in (*)

\[ W_{cv} = (4 \, \text{kg/s}) \left[ (-469.5 \, \text{kJ/kg}) + (300.19 - 440.7) \, \text{kJ/kg} \right] \left[ \frac{1 \, \text{kW}}{1 \, \text{kJ/s}} \right] = -750 \, \text{kW} \]

1. The applicability of the ideal gas model can be checked by reference to the generalized compressibility chart.
2. The negative sign for power denotes energy transfer by work into the control volume, as expected.
2. (4 pts) For the problem above, use the compressibility chart to check the validity of the ideal gas assumption at the inlet state.

\[
\text{Air} \quad P_c = 37.7 \text{ bar} \quad T_c = 133 \text{ K} \quad \left( \right)
\]

\(\text{Pr} = \frac{P_i}{P_c} = \frac{1 \text{ bar}}{37.7 \text{ bar}} = 0.03 \quad \left( \right) \quad \Rightarrow \quad \zeta = 0.98 \)

\(\text{Tr} = \frac{T_i}{T_c} = \frac{300 \text{ K}}{133 \text{ K}} = 2.26 \quad \left( \right) \)
Problem 13

(a) Given: DC voltage, 200 V; AC voltage, 120 V; load resistance, 50 Ω;

Solution:

1. Calculate the DC current: I = V / R = 200 V / 50 Ω = 4 A

2. Calculate the AC current: I = V / (2πfR) = 120 V / (2π(50 Hz)(50 Ω)) = 0.24 A

3. The total current: I_total = I_DC + I_AC = 4 A + 0.24 A = 4.24 A

(b) Known: Data are provided for a power cycle, output power is required.

(c) From the data, the cycle cannot operate.

(d) From the data, the cycle cannot operate.

(e) From the data, the cycle cannot operate.

(f) From the data, the cycle cannot operate.

(g) From the data, the cycle cannot operate.