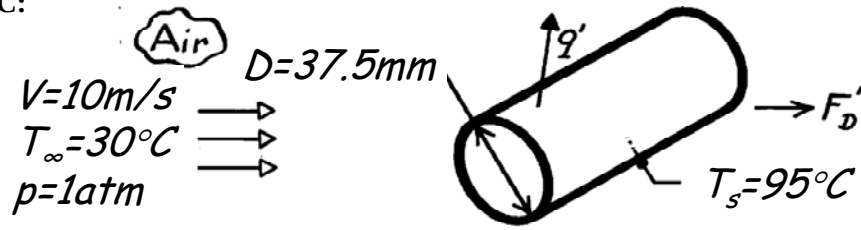


PROBLEM 7.47

KNOWN: Conditions associated with air in cross flow over a pipe.

FIND: (a) Drag force per unit length of pipe, (b) Heat transfer per unit length of pipe.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Uniform cylinder surface temperature, (3) Negligible radiation effects.

PROPERTIES: Table A-4, Air ($T_f = 335$ K, 1 atm): $\nu = 19.31 \times 10^{-6} \text{ m}^2/\text{s}$, $\rho = 1.048 \text{ kg/m}^3$, $k = 0.0288 \text{ W/m}\cdot\text{K}$, $\text{Pr} = 0.702$.

ANALYSIS: (a) From the definition of the drag coefficient with $A_f = DL$, find

$$F_D = C_D A_f \frac{\rho V^2}{2}$$

$$F_D' = C_D D \frac{\rho V^2}{2}$$

With

$$\text{Re}_D = \frac{VD}{\nu} = \frac{10 \text{ m/s} \times (0.0375 \text{ m})}{19.31 \times 10^{-6} \text{ m}^2/\text{s}} = 1.942 \times 10^4$$

from Fig. 7.9, $C_D \approx 1.1$. Hence

$$F_D = 1.1(0.0375 \text{ m}) 1.048 \text{ kg/m}^3 (10 \text{ m/s})^2 / 2 = 2.16 \text{ N/m.} \quad <$$

(b) Using Hilpert's relation, with $C = 0.193$ and $m = 0.618$ from Table 7.2,

$$\bar{h} = \frac{k}{D} C \text{Re}_D^m \text{Pr}^{1/3} = \frac{0.0288 \text{ W/m}\cdot\text{K}}{0.0375 \text{ m}} \times 0.193 (1.942 \times 10^4)^{0.618} (0.702)^{1/3}$$

$$\bar{h} = 59 \text{ W/m}^2 \cdot \text{K}.$$

Hence, the heat rate per unit length is

$$q' = \bar{h}(\pi D) (T_s - T_\infty) = 59 \text{ W/m}^2 \cdot \text{K} (\pi \times 0.0375 \text{ m}) (95 - 30)^\circ \text{C} = 450 \text{ W/m.} \quad <$$

COMMENTS: Using the Zukauskas correlation and evaluating properties at T_∞ ($\nu = 15.71 \times 10^{-6} \text{ m}^2/\text{s}$, $k = 0.0261 \text{ W/m}\cdot\text{K}$, $\text{Pr} = 0.707$), but with $\text{Pr}_s = 0.695$ at T_s ,

$$\bar{h} = \frac{0.0261}{0.0375} 0.26 \left(\frac{10 \times 0.0375}{15.71 \times 10^{-6}} \right)^{0.6} (0.707)^{0.37} (0.707/0.695)^{1/4} = 67 \text{ W/m}^2 \cdot \text{K}.$$

This result agrees with that obtained from Hilpert's relation to within the uncertainty normally associated with convection correlations.