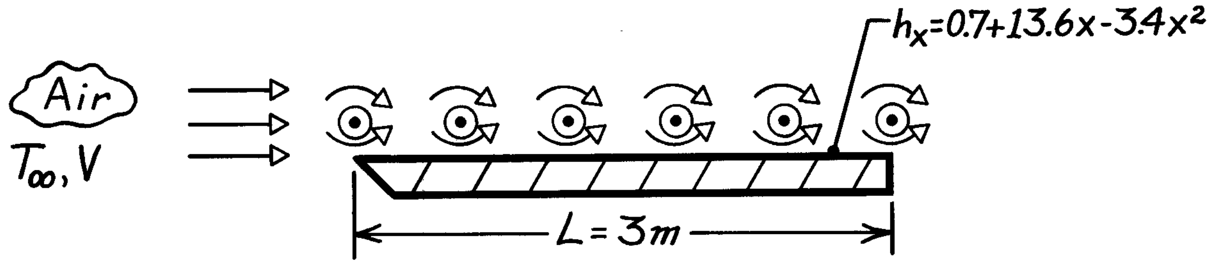
PROBLEM 6.4

KNOWN: Distribution of local convection coefficient for obstructed parallel flow over a flat plate.

FIND: Average heat transfer coefficient and ratio of average to local at the trailing edge.

SCHEMATIC:



ANALYSIS: The average convection coefficient is

$$\bar{h}_L = \frac{1}{L}\int_0^L h_x dx = \frac{1}{L}\int_0^L \left(0.7 + 13.6x - 3.4x^2\right)dx$$

$$\bar{h}_L = \frac{1}{L}\left(0.7L + 6.8L^2 - 1.13L^3\right) = 0.7 + 6.8L - 1.13L^2$$

$$\bar{h}_L = 0.7 + 6.8(3) - 1.13(9) = 10.9 \text{ W/m}^2 \cdot \text{K}.$$ <

The local coefficient at x = 3m is

$$h_L = 0.7 + 13.6(3) - 3.4(9) = 10.9 \text{ W/m}^2 \cdot \text{K}.$$

Hence,

$$\bar{h}_L / h_L = 1.0.$$ <

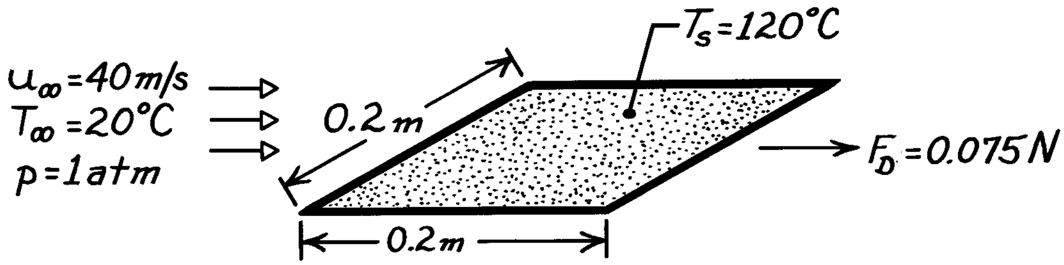
COMMENTS: The result $\bar{h}_L / h_L = 1.0$ is unique to x = 3m and is a consequence of the existence of a maximum for $h_x(x)$. The maximum occurs at x = 2m, where $(dh_x / dx) = 0$ and $\left(d^2h_x / dx^2 < 0.\right)$

PROBLEM 6.40

KNOWN: Drag force and air flow conditions associated with a flat plate.

FIND: Rate of heat transfer from the plate.

SCHEMATIC:



ASSUMPTIONS: (1) Chilton-Colburn analogy is applicable.

PROPERTIES: *Table A-4*, Air (70°C,1 atm): ρ = 1.018 kg/m^3, c_p = 1009 J/kg·K, Pr = 0.70, $\nu = 20.22 \times 10^{-6} m^2/s$.

ANALYSIS: The rate of heat transfer from the plate is

$$q = 2\bar{h}\left(L^2\right)\left(T_s - T_\infty\right)$$

where $\bar{h}$ may be obtained from the Chilton-Colburn analogy,

$$\bar{j}_H = \frac{\bar{C}_f}{2} = \bar{S}t\,Pr^{2/3} = \frac{\bar{h}}{\rho\, u_\infty\, c_p} Pr^{2/3}$$

$$\frac{\bar{C}_f}{2} = \frac{1}{2}\frac{\bar{\tau}_s}{\rho\, u_\infty^2/2} = \frac{1}{2}\frac{(0.075\text{ N}/2)/(0.2\text{m})^2}{1.018\text{ kg/m}^3(40\text{ m/s})^2/2} = 5.76\times10^{-4}.$$

Hence,

$$\bar{h} = \frac{\bar{C}_f}{2}\rho\, u_\infty\, c_p\, Pr^{-2/3}$$

$$\bar{h} = 5.76\times10^{-4}\left(1.018\text{kg/m}^3\right)40\text{m/s}\,\left(1009\text{J/kg}\cdot\text{K}\right)\,(0.70)^{-2/3}$$

$$\bar{h} = 30\text{ W/m}^2\cdot\text{K}.$$

The heat rate is

$$q = 2\left(30\text{ W/m}^2\cdot\text{K}\right)(0.2\text{m})^2\,(120-20)^\circ\text{C}$$

$$q = 240\text{ W}.$$ <

COMMENTS: Although the flow is laminar over the entire surface ($Re_L = u_\infty L/\nu$ = 40 m/s $\times$ 0.2m/20.22 $\times 10^{-6}$m^2/s = 4.0 $\times 10^5$), the pressure gradient is zero and the Chilton-Colburn analogy is applicable to *average*, as well as *local*, surface conditions. Note that the only contribution to the drag force is made by the surface shear stress.