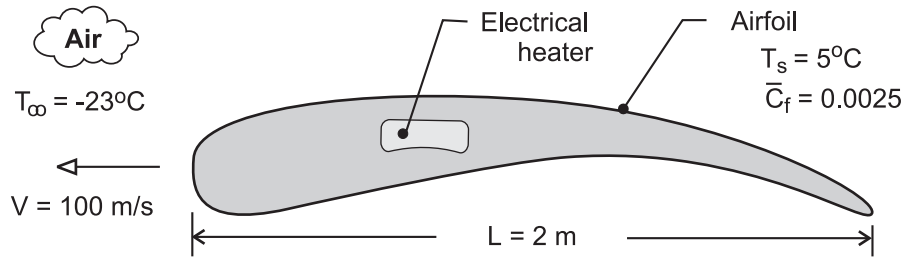
PROBLEM 6.50

KNOWN: Nominal operating conditions of aircraft and characteristic length and average friction coefficient of wing.

FIND: Average heat flux needed to maintain prescribed surface temperature of wing.

SCHEMATIC:



ASSUMPTIONS: (1) Applicability of modified Reynolds analogy, (2) Constant properties.

PROPERTIES: Prescribed, Air: $\nu = 16.3 \times 10^{-6}$ m^2/s, k = 0.022 W/m·K, Pr = 0.72.

ANALYSIS: The average heat flux that must be maintained over the surface of the air foil is $\bar{q}'' = \bar{h}\left(T_s - T_\infty\right)$, where the average convection coefficient may be obtained from the modified Reynolds analogy.

$$\frac{\bar{C}_f}{2} = St\,Pr^{2/3} = \frac{\overline{Nu}_L}{Re_L\,Pr}Pr^{2/3} = \frac{\overline{Nu}_L}{Re_L\,Pr^{1/3}}$$

Hence, with $Re_L = VL/\nu = 100\,m/s\left(2m\right)/16.3\times10^{-6}m^2/s = 1.23\times10^7$,

$$\overline{Nu}_L = \frac{0.0025}{2}\left(1.23\times10^7\right)\left(0.72\right)^{1/3} = 13,780$$

$$\bar{h} = \frac{k}{L}\overline{Nu}_L = \frac{0.022\,W/m\cdot K}{2m}\left(13,780\right) = 152\,W/m^2\cdot K$$

$$\bar{q}'' = 152\,W/m^2\cdot K\left[5-\left(-23\right)\right]°C = 4260\,W/m^2$$ <

COMMENTS: If the flow is turbulent over the entire airfoil, the modified Reynolds analogy provides a good measure of the relationship between surface friction and heat transfer. The relation becomes more approximate with increasing laminar boundary layer development on the surface and increasing values of the magnitude of the pressure gradient.