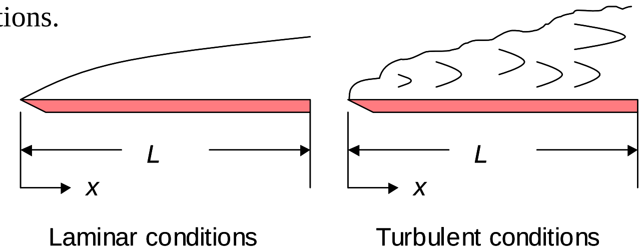
PROBLEM 6.20

KNOWN: Flat plate in parallel flow, free stream velocity, expressions for the local heat transfer coefficient under laminar and fully turbulent conditions. Water temperature of 300K.

FIND: Plate length for which the average heat transfer coefficient is the same for laminar and turbulent flow conditions.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Negligible viscous dissipation.

ANALYSIS: For laminar conditions and turbulent conditions,

$$\bar{h}_{\text{lam}} = \frac{1}{L}\int_0^L h_{\text{lam}} dx = 2C_{\text{lam}} L^{-0.5} \quad ; \quad \bar{h}_{\text{turb}} = \frac{1}{L}\int_0^L h_{\text{turb}} dx = 1.25 C_{\text{turb}} L^{-0.2}$$

or

$$\frac{\bar{h}_{\text{lam}}}{\bar{h}_{\text{turb}}} = 1 = \frac{2 \times 395 \text{ W/m}^{1.5} \cdot \text{K}}{1.25 \times 2330 \text{ W/m}^{1.8} \cdot \text{K}} L^{-0.30} = \left(0.271 \text{m}^{0.30}\right) L^{-0.30}$$

or

$$L = \left(0.271 \text{m}^{0.30}\right)^{3.3333} = 0.0128 \text{ m} = 12.8 \text{ mm}$$ <

COMMENTS: (1) A plot of the local laminar and turbulent convection coefficient distributions is shown. The areas under the two curves are identical, reflecting the fact that $\frac{\bar{h}_{\text{lam}}}{\bar{h}_{\text{turb}}} = 1$. (2) A plate shorter than L = 12.8 mm is predicted to provide higher average coefficients under laminar flow conditions, as opposed to when turbulent conditions exist. However, this result may not be reliable because experimental measurement of local heat transfer coefficients is difficult, and the expressions of Example 6.2 may not be of sufficient accuracy to apply to such a short plate. (3) The plate is much shorter than the transition length, x_c = 0.43 m, that was calculated in Example 6.2. Hence, the laminar case is not subjected to a transition to turbulent flow.