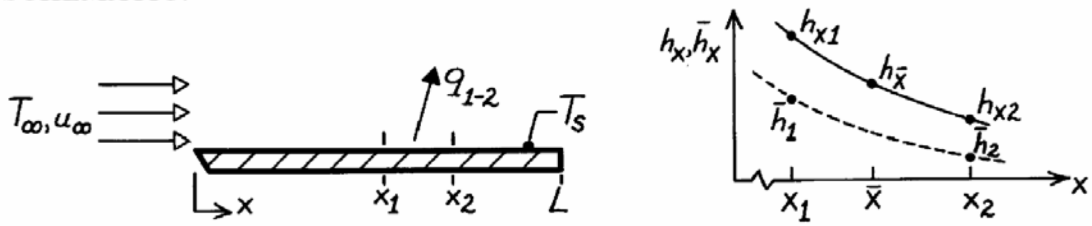
PROBLEM 7.7

KNOWN: Parallel flow over a flat plate and two locations representing a short span x_1 to x_2 where $(x_2 - x_1) << L$.

FIND: Three different expressions for the average heat transfer coefficient over the short span x_1 to x_2, $\bar{h}_{1-2}$.

SCHEMATIC:



ASSUMPTIONS: (1) Parallel flow over a flat plate.

ANALYSIS: The heat rate per unit width for the span can be written as

$$q'_{1-2} = \bar{h}_{1-2}(x_2 - x_1)(T_s - T_\infty) \quad (1)$$

where $\bar{h}_{1-2}$ is the average heat transfer coefficient over the span and can be evaluated in either of the following three ways:

(a) *Local coefficient at* $\bar{x} = (x_1 + x_2)/2$. If the span is very short, it is reasonable to assume that

$$\bar{h}_{1-2} \approx h_{\bar{x}} \quad (2)$$

where $h_{\bar{x}}$ is the local convection coefficient at the mid-point of the span.

(b) *Local coefficients at x_1 and x_2*. If the span is very short it is reasonable to assume that $\bar{h}_{1-2}$ is the average of the local values at the ends of the span,

$$\bar{h}_{1-2} \approx [h_{x1} + h_{x2}]/2. \quad (3)$$

(c) *Average coefficients for x_1 and x_2*. The heat rate for the span can also be written as

$$q'_{1-2} = q'_{0-2} - q'_{0-1} \quad (4)$$

where the rate q_{0-x} denotes the heat rate for the plate over the distance from 0 to x. In terms of heat transfer coefficients, find

$$\bar{h}_{1-2} \cdot (x_2 - x_1) = \bar{h}_2 \cdot x_2 - \bar{h}_1 \cdot x_1$$

$$\bar{h}_{1-2} = \bar{h}_2 \frac{x_2}{x_2 - x_1} - \bar{h}_1 \frac{x_1}{x_2 - x_1} \quad (5)$$

where $\bar{h}_1$ and $\bar{h}_2$ are the average coefficients from 0 to x_1 and x_2, respectively.

COMMENTS: Eqs. (2) and (3) are approximate and work better when the span is small and the flow is turbulent rather than laminar ($h_x \sim x^{-0.2}$ vs $h_x \sim x^{-0.5}$). Of course, we require that $x_c < x_1, x_2$ or $x_c > x_1, x_2$; that is, the approximations are inappropriate around the transition region. Eq. (5) is an exact relationship, which applies under any conditions.