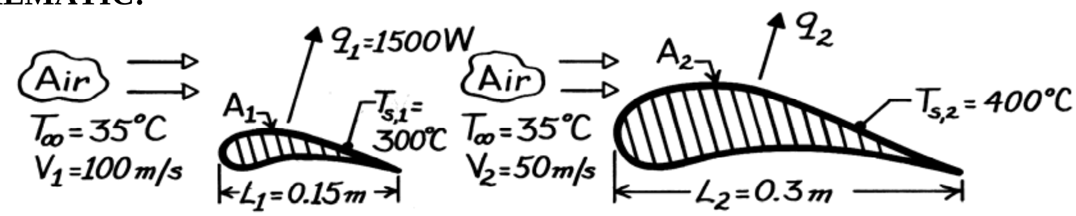
PROBLEM 6.28

KNOWN: Heat transfer rate from a turbine blade for prescribed operating conditions.

FIND: Heat transfer rate from a larger blade operating under different conditions.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Constant properties, (3) Surface area A is directly proportional to characteristic length L, (4) Negligible radiation, (5) Blade shapes are geometrically similar.

ANALYSIS: For a prescribed geometry,

$$\overline{Nu} = \frac{\overline{h}L}{k} = f\left(Re_L, Pr\right).$$

The Reynolds numbers for the blades are

$$Re_{L,1} = \left(V_1 L_1 / \nu\right) = 15/\nu \qquad Re_{L,2} = \left(V_2 L_2 / \nu\right) = 15/\nu.$$

Hence, with constant properties, $Re_{L,1} = Re_{L,2}$. Also, $Pr_1 = Pr_2$. Therefore,

$$\overline{Nu}_2 = \overline{Nu}_1$$
$$\left(\overline{h}_2 L_2 / k\right) = \left(\overline{h}_1 L_1 / k\right)$$
$$\overline{h}_2 = \frac{L_1}{L_2}\overline{h}_1 = \frac{L_1}{L_2}\frac{q_1}{A_1\left(T_{s,1} - T_\infty\right)}.$$

Hence, the heat rate for the *second blade* is

$$q_2 = \overline{h}_2 A_2\left(T_{s,2} - T_\infty\right) = \frac{L_1}{L_2}\ \frac{A_2}{A_1}\ \frac{\left(T_{s,2} - T_\infty\right)}{\left(T_{s,1} - T_\infty\right)} q_1$$
$$q_2 = \frac{T_{s,2} - T_\infty}{T_{s,1} - T_\infty} q_1 = \frac{(400 - 35)}{(300 - 35)}(1500\text{ W})$$

$$q_2 = 2066\text{ W}.$$ <

COMMENTS: The slight variation of ν from Case 1 to Case 2 would cause $Re_{L,2}$ to differ from $Re_{L,1}$. However, for the prescribed conditions, this non-constant property effect is small.