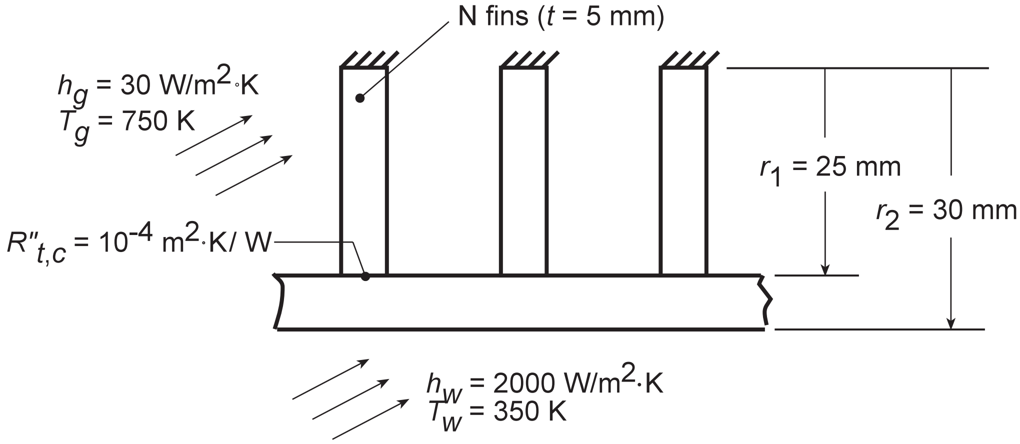
PROBLEM 3.163

KNOWN: Internal and external convection conditions for an internally finned tube. Fin/tube dimensions and contact resistance.

FIND: Heat rate per unit tube length and corresponding effects of the contact resistance, number of fins, and fin/tube material.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) One-dimensional heat transfer, (3) Constant properties, (4) Negligible radiation, (5) Uniform convection coefficient on finned surfaces, (6) Tube wall may be unfolded and approximated as a plane surface with N straight rectangular fins.

PROPERTIES: Copper: k = 400 W/m·K; St.St.: k = 20 W/m·K.

ANALYSIS: The heat rate per unit length may be expressed as

$$q' = \frac{T_g - T_w}{R'_{t,o(c)} + R'_{cond} + R'_{conv,o}}$$

where

$$R_{t,o(c)} = \left(\eta_{o(c)} h_g A'_t\right), \quad \eta_{o(c)} = 1 - \frac{NA'_f}{A'_t}\left(1 - \frac{\eta_f}{C_1}\right), \quad C_1 = 1 + \eta_f h_g A'_f \left(R''_{t,c} / A'_{c,b}\right),$$

$$A'_t = NA'_f + \left(2\pi r_1 - Nt\right), \quad A'_f = 2r_1, \quad \eta_f = \tanh mr_1 / mr_1, \quad m = \left(2h_g / kt\right)^{1/2} \quad A'_{c,b} = t,$$

$$R'_{cond} = \frac{\ln\left(r_2 / r_1\right)}{2\pi k}, \text{ and } R'_{conv,o} = \left(2\pi r_2 h_w\right)^{-1}.$$

Using the IHT *Performance Calculation, Extended Surface Model* for the *Straight Fin Array*, the following results were obtained. For the *base case*, q' = 3857 W/m, where $R'_{t,o(c)}$ = 0.101 m·K/W, R'_{cond} = 7.25 × 10^{-5} m·K/W and $R'_{conv,o}$ = 0.00265 m·K/W. If the contact resistance is eliminated ($R''_{t,c}$ = 0), q' = 3922 W/m, where $R'_{t,o}$ = 0.0993 m·K/W. If the number of fins is increased to N = 8, q' = 5799 W/m, with $R'_{t,o(c)}$ = 0.063 m·K/W. If the material is changed to stainless steel, q' = 3591 W/m, with $R'_{t,o(c)}$ = 0.107 m·K/W and R'_{cond} = 0.00145 m·K/W.

COMMENTS: The small reduction in q' associated with use of stainless steel is perhaps surprising, in view of the large reduction in k. However, because h_g is small, the reduction in k does not significantly reduce the fin efficiency (η_f changes from 0.994 to 0.891). Hence, the heat rate remains large. The influence of k would become more pronounced with increasing h_g.