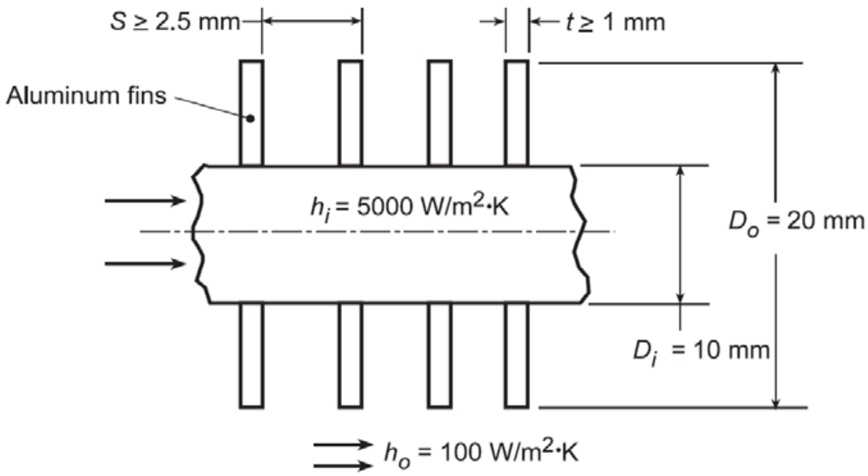
PROBLEM 08

KNOWN: Diameter and inner and outer convection coefficients of a condenser tube. Thickness, outer diameter, and pitch of aluminum fins.

FIND: (a) Overall heat transfer coefficient without fins, (b) Effect of fin thickness and pitch on overall heat transfer coefficient with fins.

SCHEMATIC:



ASSUMPTIONS: (1) Negligible tube wall conduction resistance, (2) Negligible fouling and fin contact resistance, (3) One-dimensional conduction in fin.

PROPERTIES: *Table A.1*, Aluminum (T = 300 K): k = 237 W/m·K.

ANALYSIS: (a) With no fins, Eq. 11.1 yields

$$U = \left(h_i^{-1} + h_o^{-1}\right)^{-1} = \left(2\times10^{-4} + 0.01\right)^{-1} \mathrm{W/m^2\cdot K} = 98.0\,\mathrm{W/m^2\cdot K} \qquad <$$

(b) With fins and a unit tube length, Eqs. 11.1 and 11.3 yield

$$\frac{1}{U_i \pi D_i} = \frac{1}{h_i \pi D_i} + \frac{1}{\eta_o h_o A'_o}$$

and $\eta_o = 1 - \left(A'_f/A'_o\right)\left(1-\eta_f\right)$. The total fin surface area per unit length is $A'_f = N' 2\pi\left(r_{oc}^2 - r_i^2\right)$, where the number of fins per unit length is $N' = 1\mathrm{m}/S(\mathrm{m})$. The total outside surface area per unit length is $A'_o = A'_f + (1 - N't)\pi D_i$.

For t = 0.0015 m and S = 0.0035 m, $r_{oc} = (D_o/2) + (t/2) = 0.01075$ m, $N' \approx 286$, $A'_f = 0.163\ \mathrm{m^2/m}$, and $A'_o = (0.163 + 0.018)\ \mathrm{m^2/m} = 0.181\ \mathrm{m^2/m}$. With $r_{oc}/r_i = 2.15$, $L_c = 0.00575$ m, $A_p = 8.625 \times 10^{-6}\ \mathrm{m^2}$, and $L_c^{3/2}\left(h_o/kA_p\right)^{1/2} = 0.0964$, Fig. 3.20 yields $\eta_f \approx 0.99$. Hence, $\eta_o \approx 1 - (0.163/0.181)(0.01) = 0.99$ and

$$U_i = \left[\left(1/h_i\right) + \left(\pi D_i/\eta_o h_o A'_o\right)\right]^{-1}$$

$$U_i = \left[2\times10^{-4}\,\mathrm{m^2\cdot K/W} + \pi\times0.01\,\mathrm{m}\big/0.99\times100\,\mathrm{W/m^2\cdot K}\times0.181\,\mathrm{m^2/m}\right]^{-1} = 512\,\mathrm{W/m^2\cdot K} \qquad <$$

We may use the IHT *Extended Surface* Model (*Performance Calculations* for a *Circular Rectangular Fin Array*) to consider the effect of varying t and S. To maximize N', the minimum allowable value of

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PROBLEM 11.6 (Cont.)

S - t = 1.5 mm should be selected. It is then a matter of choosing between a large number of thin fins or a smaller number of thicker fins. Calculations were performed for the following options.

t (mm)	S (mm)	N'	U_i ($W/m^2 \cdot K$)
1	2.5	400	640
2	3.5	286	512
3	4.5	222	460
4	5.5	182	420

Since heat transfer increases with U_i, the best configuration corresponds to t = 1 mm and S = 2.5 mm, which provides the largest airside surface area.

COMMENTS: The best performance is always associated with a large number of closely spaced fins, so long as the flow between adjoining fins is sufficient to maintain the convection coefficient.