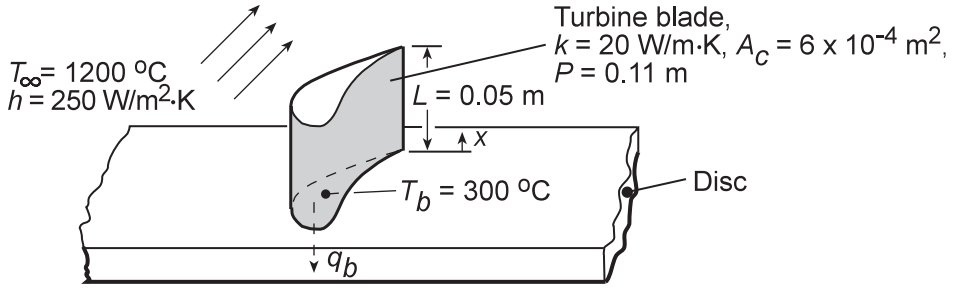
PROBLEM 3.126

KNOWN: Dimensions and thermal conductivity of a gas turbine blade. Temperature and convection coefficient of gas stream. Temperature of blade base and maximum allowable blade temperature.

FIND: (a) Whether blade operating conditions are acceptable, (b) Heat transfer to blade coolant.

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional, steady-state conduction in blade, (2) Constant k, (3) Adiabatic blade tip, (4) Negligible radiation.

ANALYSIS: Conditions in the blade are determined by Case B of Table 3.4.

(a) With the maximum temperature existing at x = L, Eq. 3.80 yields

$$\frac{T(L)-T_\infty}{T_b-T_\infty}=\frac{1}{\cosh mL}$$

$$m=\left(hP/kA_c\right)^{1/2}=\left(250\text{W/m}^2\cdot\text{K}\times 0.11\text{m}/20\text{W/m}\cdot\text{K}\times 6\times 10^{-4}\text{m}^2\right)^{1/2}$$

$m = 47.87\ m^{-1}$ and $mL = 47.87\ m^{-1} \times 0.05\ m = 2.39$

From Table B.1, cosh mL = 5.51. Hence,

$$T(L)=1200^\circ\text{C}+(300-1200)^\circ\text{C}/5.51=1037^\circ\text{C}$$ <

and the operating conditions are acceptable.

(b) With $M=\left(hPkA_c\right)^{1/2}\Theta_b=\left(250\text{W/m}^2\cdot\text{K}\times 0.11\text{m}\times 20\text{W/m}\cdot\text{K}\times 6\times 10^{-4}\text{m}^2\right)^{1/2}\left(-900^\circ\text{C}\right)=-517\text{W}$, Eq. 3.81 and Table B.1 yield

$$q_f=M\tanh mL=-517\text{W}(0.983)=-508\text{W}$$

Hence, $q_b=-q_f=508\text{W}$ <

COMMENTS: Radiation losses from the blade surface and convection from the tip will contribute to reducing the blade temperatures.