CH EN 3453 – Heat Transfer

Heat Transfer from Extended Surfaces Part 1

Reminders…

- Homework #3 due Friday
- Help session this afternoon, 4:30 pm in MEB 2325
- Exam #1 in three weeks
  - Covers all assigned reading material in Chapters 1, 2, 3, 4, 5

Extended Surfaces (fins)

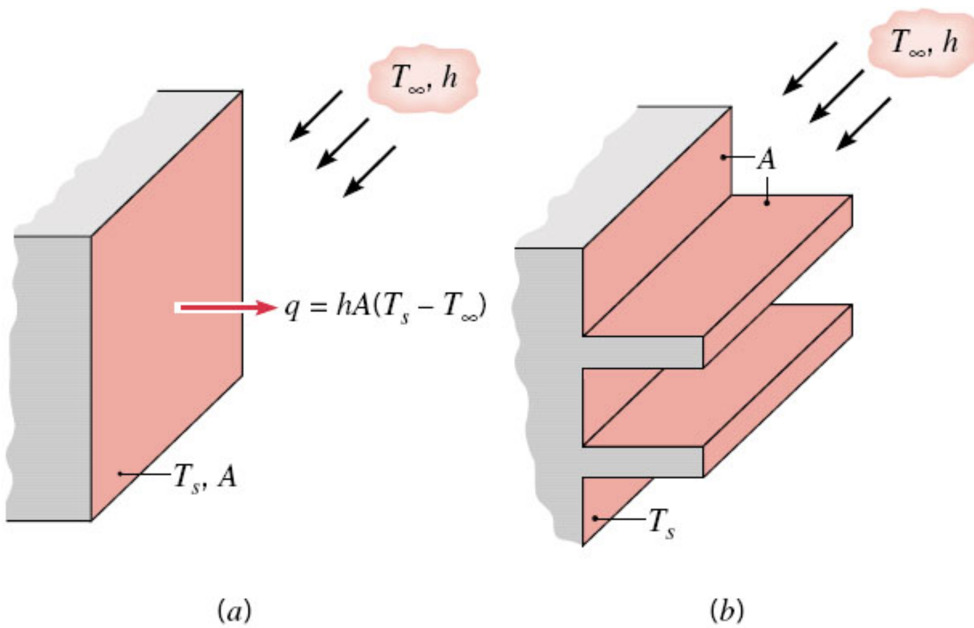

Figure 3.12 Use of fins to enhance heat transfer from a plane wall.
(a) Bare surface. (b) Finned surface.

Types of Fins

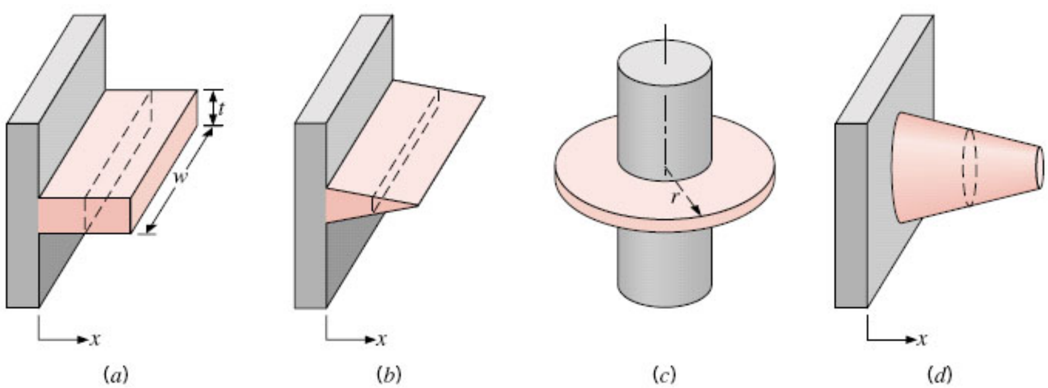

FIGURE 3.14 Fin configurations. (a) Straight fin of uniform cross section. (b) Straight fin of nonuniform cross section. (c) Annular fin. (d) Pin fin.

A Fin

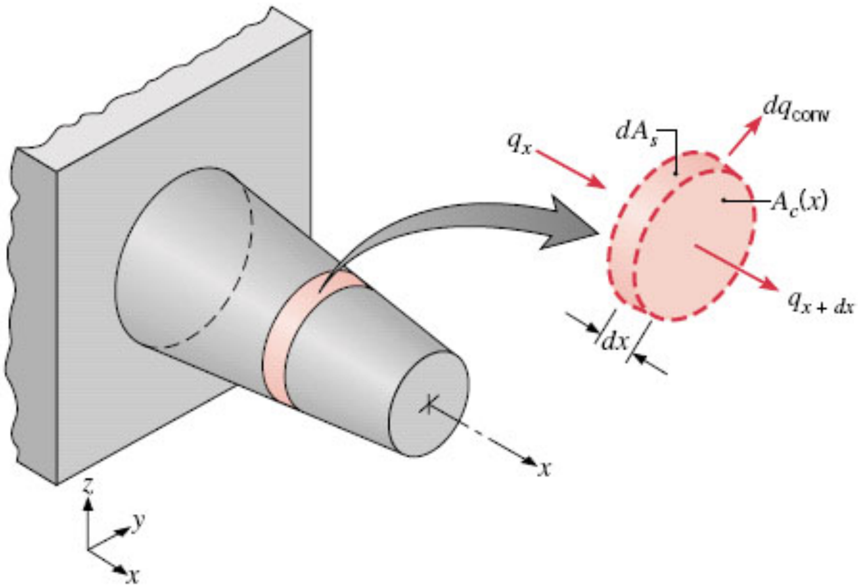

FIGURE 3.15 Energy balance for an extended surface.

Energy Equation for Extended Surface

General Form:

$$\frac{d^2T}{dx^2} + \left(\frac{1}{A_c}\frac{dA_c}{dx}\right)\frac{dT}{dx} - \left(\frac{1}{A_c}\frac{h}{k}\frac{dA_s}{dx}\right)(T - T_\infty) = 0$$

Eq. 3.66
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…where A_c is the cross-sectional area of the pin
A_s is the external surface area on the sides of the pin

For a straight fin of constant cross-sectional area:

$$\frac{d^2T}{dx^2} - \frac{hP}{kA_c}(T - T_\infty) = 0$$

Eq. 3.67
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…where P is the perimeter (meters) of the pin

Four Scenarios for Treating Pin Tips

Table 3.4 Temperature distribution and heat loss for fins of uniform cross section

Case	Tip Condition ($x = L$)	Temperature Distribution θ/θ_b	Fin Heat Transfer Rate q_f
A	Convection heat transfer: $h\theta(L) = -kd\theta/dx\|_{x=L}$	$\dfrac{\cosh m(L-x) + (h/mk)\sinh m(L-x)}{\cosh mL + (h/mk)\sinh mL}$ (3.70)	$M\dfrac{\sinh mL + (h/mk)\cosh mL}{\cosh mL + (h/mk)\sinh mL}$ (3.72)
B	Adiabatic $d\theta/dx\|_{x=L} = 0$	$\dfrac{\cosh m(L-x)}{\cosh mL}$ (3.75)	$M \tanh mL$ (3.76)
C	Prescribed temperature: $\theta(L) = \theta_L$	$\dfrac{(\theta_L/\theta_b)\sinh mx + \sinh m(L-x)}{\sinh mL}$ (3.77)	$M\dfrac{(\cosh mL - \theta_L/\theta_b)}{\sinh mL}$ (3.78)
D	Infinite fin ($L \rightarrow \infty$): $\theta(L) = 0$	e^{-mx} (3.79)	M (3.80)

$\theta \equiv T - T_\infty$ $\quad m^2 \equiv hP/kA_c$

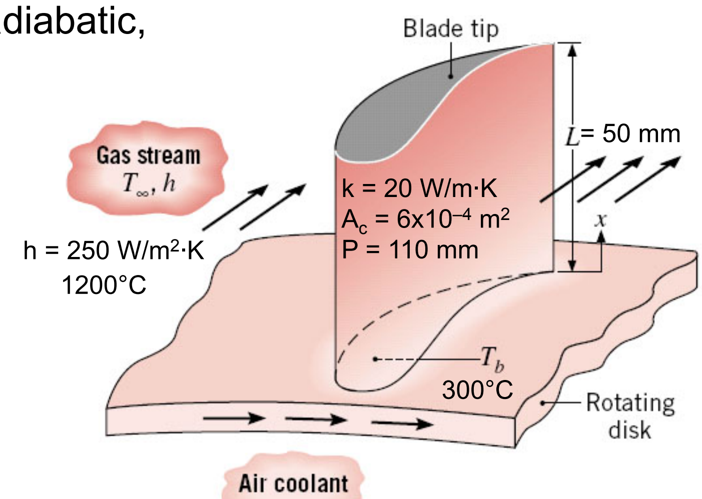
$\theta_b = \theta(0) = T_b - T_\infty$ $\quad M \equiv \sqrt{hPkA_c}\,\theta_b$

Example – Book Problem 3.116

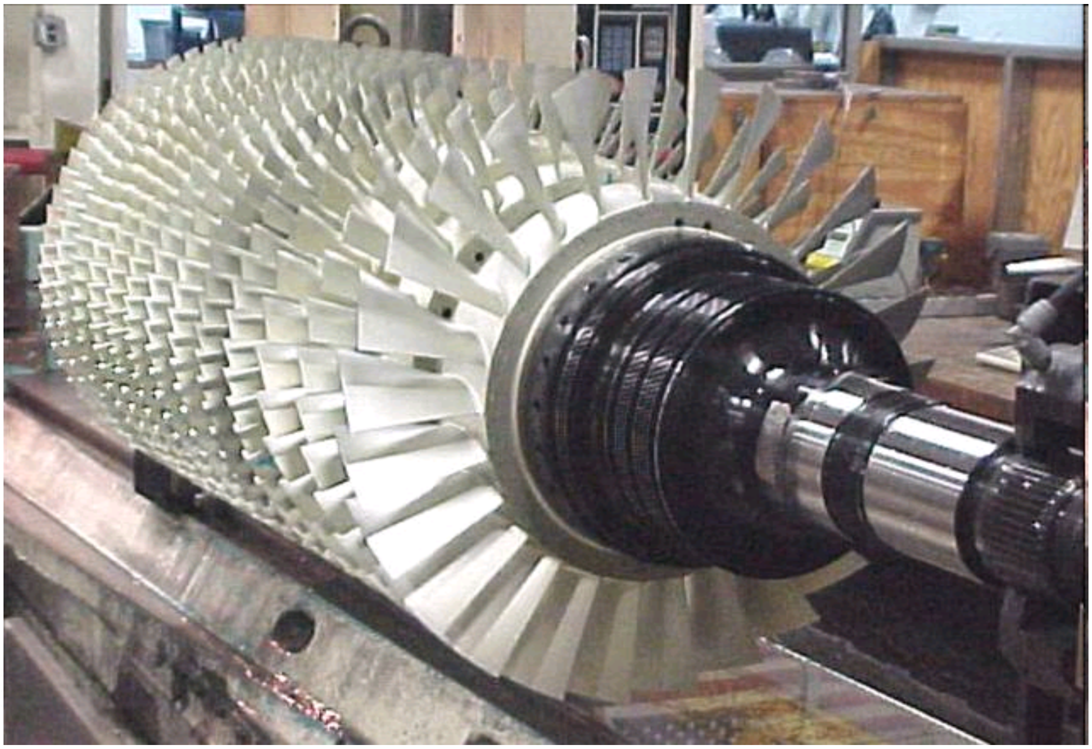
Turbine blade mounted on proposed air-cooled rotating disc (T_b = 300°C) in a gas turbine with gas stream at T_∞ = 1200°C.

(a) If max allowable blade temperature is 1050°C and blade tip is assumed to be adiabatic, will the air cooling approach work?

(b) What is the rate of heat transfer from blade to coolant?



Gas Turbine Blade



8. (20 pts) The case covering the back of my cell phone is soft vulcanized rubber 1/8 inch thick. On the front I have a screen protector of 1/16-inch thick soda lime glass. The phone itself is 2.3 inches wide, 4.5 inches tall and 0.4 inches thick. Each Friday night I watch Star Wars on my phone, which results in heat production of 10 Watts. I notice that the front of the phone (between the phone and glass) is 3°C cooler than the back of the phone (between the phone and rubber). If the air temperature on my windy back porch is 28°C and the convective heat transfer coefficient is 150 W/m^2·K, what are the temperatures at (a) the phone-rubber interface and (b) the phone-glass interface? Ignore any heat loss through the edges of the phone (i.e., consider only heat loss through the front and back).