Module 2 :

“Diffusive” heat and mass transfer

Lecture 8:

Performance of Fins

Fin Performance

It is essential to evaluate the performance of fins to achieve high heat transfer rate or minimum weight etc. Fin effectiveness, fin efficiency and total efficiency are some methods used for performance evaluation of fins.

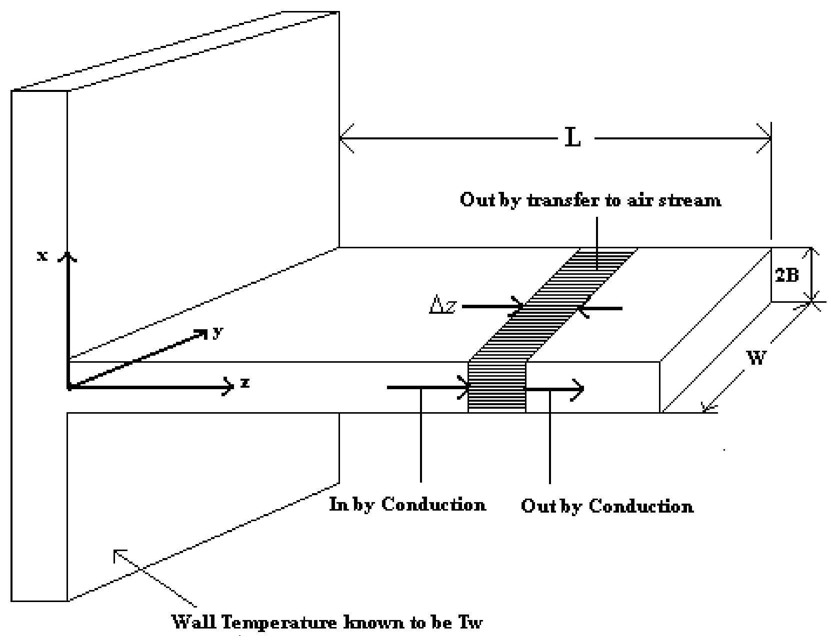

Fig. 8.1 A Rectangular Fin of length L, width W and thickness 2B

Fin efficiency, η

This quantity is more often used to determine the heat flow when variable area fins are used. Fin efficiency is defined as the ratio of heat dissipation by the fin to the heat dissipation takes place if the whole surface area of the fin is at the base temperature T_W.

$$\eta = \frac{\text{Actual heat dissipation}}{\text{Heat that would be dissipate if the fin surface was at } T_w \text{ everywhere}}$$

Then we can write

$$\eta = \frac{W\int_0^1 h\,(T-T_a)\,dz}{W\int_0^L h\left(T_w-T_a\right)dz} = \int_0^1 \theta\, dJ \tag{8.1}$$

Put eqn. (7.12) (from previous chapter) in eqn. (8.1) and after solving, we get

$$\boxed{\eta = \int_0^1 \theta\, dJ = \int_0^1 \frac{\text{Cosh}N(1-J)}{\text{Cosh}N} dJ = \frac{\tanh N}{N}} \tag{8.2}$$

Equation (8.2) can be used in general without significant error by increasing the fin length with surface area equal to the area at the tip. In the case of plate fins new length can be expressed as

$L_c = L + \frac{t}{2}$, where t is the fin thickness.

In the case of circular fins $L_c = L + D/4,$ where D is the diameter of the fin. Fig (8.3) shows fin efficiency plot for rectangular and triangular fins.

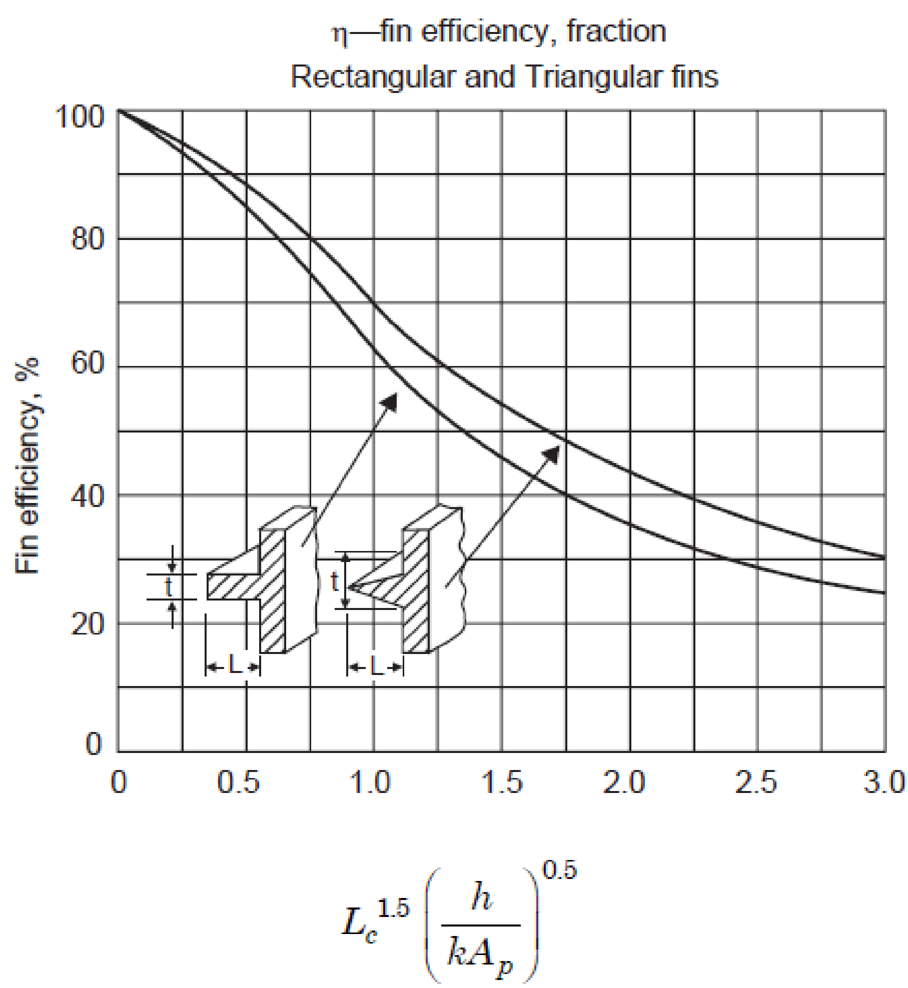

Fig 8.3: Fin efficiency for rectangular and triangular fins.

Fin Effectiveness, ε_f

Fins are employed to increase the rate of heat transfer from a surface by increasing the effective surface area. In the absence of fins, the heat convected by the base area is given by $Ah\left(T_w\text{-}T_a\right)$, where A is the base area. When the fins are present the heat transferred by the fin, Q_f can be calculated from eqn.(7.12). Taking the ratios of these two quantities, we can express $\boldsymbol{\varepsilon_f}$ as

$$\begin{aligned}\varepsilon_f &= \frac{Q_f}{hA\left(T_w\text{-}T_a\right)} = \frac{\sqrt{hPkA}\left(T_w\text{-}T_a\right)}{hA\left(T_w\text{-}T_a\right)} \\ &= \left(\frac{kP}{hA}\right)^{1/2}\end{aligned} \tag{8.3}$$

where P is the perimeter of a fin

The effectiveness of the fin should be as large as possible for effective use of material used.

Physical Significance of the Effectiveness of Fins

The physical significance of the effectiveness of the fin are

1. For effectiveness ε_f =1 indicates that the addition of the fin to the surface does not affect heat transfer at all. In other word, the heat transfer to the fin through the base area A_w is equal to the heat transferred from the same area A_w to the surrounding medium.
2. An effectiveness of ε_f <1 indicates that the fin actually acts as insulation, slowing down the heat transfer rate from the surface to the surrounding. This situation can occur when fins made of low thermal conductivity materials.
3. An effectiveness of ε_f >1 indicates that the fins are enhancing heat transfer rate from the surface to the surrounding. However, the role of a fin cannot be justified unless η is sufficiently larger than 1.Finned surfaces are designed on the basis of maximizing effectiveness of a specified cost or minimizing cost for a desired effectiveness.

Conclusions on Fin Performance

Conclusions drawn from equation (8.3) are

1. Thermal conductivity of the fin material should be high to give large fin effectiveness. This leads to the choice of aluminum and its alloys.

2. The ratio $\frac{P}{A}$ should be as large as possible. This requirement can be achieved by the use of thinner fins. Use more thin fins of closer pitch than fewer thicker fins at longer pitch.

3. Effectiveness will be higher if heat transfer coefficient, h is lower. Generally convection in gas flow, and heat flow under free convection lead to lower values of heat transfer coefficient, h. **Hence fins are used on the gas side of heat exchangers.**