A Parametric Study of Heat Transfer for the Optimization of Fin Sinks

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Abstract: Fin heat sinks are the most widely used type of heat sink for cooling purposes nowadays where space is a key factor, such as for the cooling of electronic equipment. Improved cooling capacity and the lowest possible thermal resistance in the design optimization process of these sink geometries means that we should consider a number of variable parameters, which can involve tedious design processes that are almost impossible to approximate to a sufficient degree of accuracy without computer simulation tools. The principal parameters are the heat dissipation base area, fin size, shape and material and the heat transfer coefficient. Computer numerical simulation tools greatly assist the design process, allowing in turn a greater range and more accurate analysis of the problem itself. In this study, we develop a design tool called "Opti-fin" for a Matlab ® environment that allows the user to configure a fin on the basis of the material and the thermal heat that will be released. Our study also includes a realistic estimation of fluid (air) flows that control the temperature dependency of the fin. This tool has been validated by computational fluid dynamic simulations using ANSYS-FLUENT®, in which the results of the simulation and the actual triangular shaped fin showed a remarkable similarity.

Keywords: Efficiency, fins, heat transfer, conduction and convection, parametric study, Matlab, CFD.

1. INTRODUCTION

Fin heat sinks [1, 2] are additional areas installed at certain locations to increase the interface between the heat exchange surface and the surrounding environment in a given piece of equipment [3]. They are nowadays the most frequently used cooling strategy where space is a key factor, as in the case of electronic equipment [4], or when the coefficients of convective heat transfer between the solid and the medium present low values, as occurs in some cases of natural convection [5, 6, 7]. Thus, low coefficients can in some way be compensated, by increasing the heat transfer area in contact with the fluid, as the heat power that is delivered is given by:

$$\dot{Q} = \alpha \cdot S \cdot \left(\theta_S - \theta_a\right) \quad (1)$$

The design of this type of heat sink implies the lowest thermal resistance for a given size, following a tedious design process that involves a series of parameters that are almost impossible to approximate to an acceptable degree without the use of computa-tional tools. These tools are of great assis-tance in this design process [8], because of the wider range and the accuracy of the calculations that are required to solve the problem.

Fin configurations currently on the market present a myriad of sophisticated geometries [9, 10]. These settings are designed for very specific applications that require high performance under maximum constraints in relation to space [11] and materials [12]. However, the bulk of the applications employing additional surfaces to enhance simple heat transfer geometries use longitudinal fins (among which, "rectangular" root straight surfaces with constant profiles and "triangular" fins with reduced sections along the generatrix) and cylindrical "ring" surfaces with a constant starting and generating profile [13]. There is also the special case of either conical or cylindrical fins called "needles". We have developed a thermal design tool from these configurations based on Matlab, which we refer to as "Opti-fin" [14].

In this paper, we compare the performance of the "Opti-fin" tool for a triangular fin with the results of CFD modelling, validated with the ANSYS-FLUENT software package. A remarkable similarity in the results of both models may be observed. The thermal behaviour of a triangular fin along its length and width are presented, as well as a comparison between a triangular fin and a rectangular fin of equal length.

2. AIMS AND METHODOLOGY

The aim of this study is to present a new tool in the Matlab environment that calculates the heat transference of fins, contributing to quick and reliable

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It may be observed that a wider fin width, leads to greater the efficiency [20, 21]. However from a certain width (15 mm in this case), the increase in efficiency is negligible. Therefore, W = 15mm may be considered the width limit.

5.2. Effect of Variations in Length "L"

In this case, three lengths were analyzed: 50, 70 and 100 mm for a fin width of W = 5mm and a depth of H = 450 mm. The results are shown in Figure **8**, where we can see the surface temperature for the above-mentioned lengths.

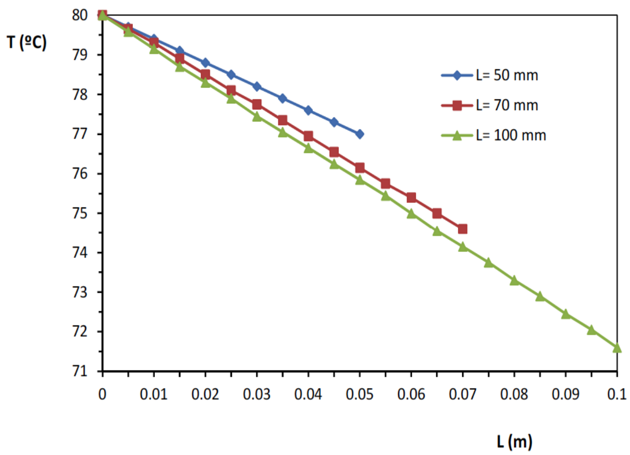

Figure 8: Surface temperature of the fin for L = 50, 70 and 100 mm. respectively.

As the fin length increases, the temperature at its tip is reduced, so that the dissipated power is also slightly reduced. Increased length is therefore related to decreased efficiency [22], as shown in Table **2.**

Table 2: Effect of Fin Length on Dissipated Power

L (mm)	$\dot{Q}$ (W)
50	95.13
70	95.05
100	95

5.3. Comparative Rectangular VS. Triangular Fin

A design decision between either a rectangular or a triangular fin often arises when designing a heat sink. In this section, the relative efficiencies of both configurations are compared for a length L = 50 mm with the same outer surface "S" of the heat exchange. Figure **9** shows how the temperature at the tip of the rectangular fin is lower than that of the triangular fin. These results point to the increased thermal resistance of the rectangular shape as opposed to the triangular shape with the same exchange surface.

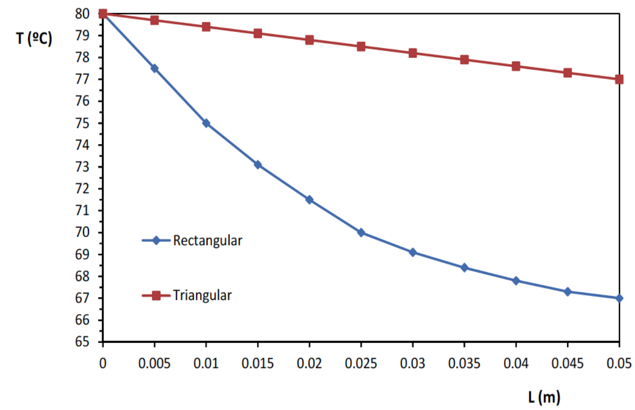

Figure 9: Surface temperature distribution for rectangular and triangular fin respectively.

The efficiency of the triangular fin is 1.04 times greater than that of the rectangular fin:

$$\frac{\eta_T}{\eta_R} = 1.04 \qquad (13)$$

CONCLUSIONS

The following conclusions can be outlined from this study:

The "Opti-Fin" tool under predicts temperature values by a maximum of 3% with regard to the results obtained by CFD with ANSYS FLUENT; a result that, in our opinion, validates its use as a design tool.

As has been shown, it is a simple and quick tool for the optimal design of fins with effective results.

Comparative studies have been conducted to evaluate the influence of the different parameters of the fin (such as width and length) on the performance of the fin in terms of cooling capacity.

Furthermore, the effect of fin shape (triangular versus rectangular) on efficiency was compared, with better results for the triangular rather than the rectangular shape with the same heat-exchange outer surface.

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NOMENCLATURE

CFD	=	Computational Fluid Dynamics
f	=	Geometrical factor of the fin
H	=	Depth of the fin (mm)
I_0	=	Modified Bessel function of the first kind of order zero
I_1	=	Modified Bessel function of the first kind of order one
L	=	Length of the fin (mm)
L_c	=	Characteristic length of the fin
$\dot{Q}$	=	Thermal power released by the fin (W)
S	=	Heat exchange surface of the fin (mm^2)
S_0	=	Root surface of the fin (mm^2)
W	=	Width of the fin (mm)

Greek Symbols

α	=	External convection coefficient (W/m^2 K)
β	=	Relative temperature
θ_a	=	Ambient temperature (ºC)
θ_0	=	Temperature at the root of the fin (ºC)
θ_s	=	Temperature at the surface of the fin (ºC)
λ	=	Thermal conductivity (W/m K)
η_T	=	Efficiency of the triangular fin
η_R	=	Efficiency of the rectangular fin

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