

Comparative Study of Fin Cross-Sections using ANSYS

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Abstract—The efficient design of finned cross-section is crucial in various engineering applications, such as electronic cooling, automotive radiators, and industrial heat exchangers. Fins are commonly used to enhance heat dissipation by increasing the surface area, and their cross-sectional geometry significantly influences heat transfer performance. This study presents a comparative analysis of different fin cross-sections analytically and ANSYS is used for simulations.

Keywords-- Cross-sections, Fin, Temperature, ANSYS; Heat

1. INTRODUCTION

An efficient heat transfer is crucial in engineering applications such as electronic cooling systems, automotive and aerospace systems. Fin is one of the widely used approaches to improve heat dissipation, which act as extended surfaces that increase the surface area (effective) for heat transfer between a solid surface and the surrounding medium. The effectiveness of a fin largely depends on factors such as its geometric configuration, material properties, and operating conditions. These parameters influence both the thermal performance of the fin and its mechanical stability during operation. In this paper, the performance of different fin cross-sections is evaluated using ANSYS, a widely used simulation platform capable of performing both thermal and structural analyses. Among various numerical tools, ANSYS (particularly Fluent and Workbench) has been widely adopted for simulating heat transfer and fluid flow behaviour because of its accuracy and ability to handle complex geometries and boundary conditions. Recent literature demonstrates that computational approaches provide results that closely match experimental findings, making ANSYS a reliable platform for comparative analysis of different fin configurations [1]. Further researchers concentrate on the optimization of rectangular fin configurations using ANSYS by systematically varying geometric parameters such as thickness, length, and material composition. The findings indicate that materials possessing higher thermal conductivity, particularly aluminium alloys, contribute significantly to enhanced heat transfer performance. Moreover, parametric analyses conducted within the ANSYS environment facilitate the determination of optimal design configurations through detailed evaluation of

temperature distribution and heat flux under varying operating conditions. Such optimization strategies have been demonstrated to improve fin efficiency while simultaneously minimizing material utilization [2]. This study focuses to examine the effect of fin geometry on heat transfer characteristics with the goal of improving design efficiency and addressing limitations found in earlier studies. A fin's heat dissipation capability is strongly influenced by its cross-sectional shape. In practical engineering applications, several cross-sectional geometries are commonly used, including rectangular, triangular, circular, and trapezoidal fins, each possessing specific advantages. Rectangular fins are frequently applied in electronic cooling devices because they are easy to manufacture and provide relatively uniform heat distribution over flat surfaces [3].

Triangular fins are often utilized in high-performance heat exchangers because their gradually reducing cross-section helps lower thermal resistance and enhances heat transfer efficiency [4]. Circular fins are generally used in cylindrical systems such as pipes and tubular heat exchangers, where they offer a more uniform temperature distribution and perform effectively in natural convection conditions [5]. Trapezoidal fins offer a balanced compromise between heat transfer efficiency and material usage, making them ideal for scenarios where both performance and cost are critical [6]. Although these fin geometries are widely used, comprehensive comparative evaluations under different operating conditions remain relatively limited in the existing literature [7].

The advent of advanced computational tools such as ANSYS has greatly enhanced the capability of engineers and researchers to analyse and optimize fin designs. ANSYS provides powerful features such as thermal-structural coupling, transient thermal analysis, and parametric optimization, thereby functioning as useful tool for thermal system design and analysis [8]. Transient thermal simulations enable researchers to study temperature changes over time, which is important for systems subjected to varying heat loads [9]. In addition, structural analysis can be performed to evaluate stresses that arise due to thermal expansion, the durability and reliability of fins in severe operating environments can be ensured. [10]. Parametric studies available within ANSYS also enable systematic investigation of important design parameters such as fin thickness, spacing, and

aspect ratio, allowing designers to identify configurations that enhance heat transfer performance while reducing material usage [11].

Material selection is another crucial aspect influencing fin performance. Traditionally, aluminium and copper have been the preferred materials for fin manufacturing due to their high thermal conductivity and ease of fabrication using conventional methods [12]. However, with ongoing progress in materials science, advanced materials such as composites and high-performance alloys have been introduced to provide enhanced thermal and mechanical properties [13].

For instance, carbon-fibre-reinforced composites offer effective heat transfer with a significant reduction in system weight. Owing to this advantage, such materials are extensively employed in aerospace and automotive applications [14]. Additionally, the anisotropic behaviour of such advanced materials can be effectively modelled and analysed using ANSYS, which enables researchers with an accurate assessment of their performance under real service conditions [15]. In recent years, advancements in innovative cooling technologies has further broadened the scope for improving fin performance. Nano fluids are produced by dispersing extremely small solid particles, known as nanoparticles, into conventional base fluids. The addition of these nanoparticles improves the fluid's thermal conductivity and enhances its heat transfer capability. Because of this advantage, Nano fluids have gained significant attention in recent years for their potential use in advanced cooling and thermal management systems [16].

In a similar way, phase-change materials (PCMs) have garnered substantial interest for their role in thermal control applications. Such materials are able to accumulate thermal energy while undergoing a phase change and release it again during the reverse process. Due to this property, PCMs can store and regulate thermal energy effectively, making them useful in many temperature management applications [17]. ANSYS-based simulations have demonstrated that integrating these materials with fin structures significantly enhances heat dissipation efficiency [18]. Although simulations yield useful information on thermal behaviour, experimental validation remains an essential component of fin design research. Prototype fins are often manufactured and tested under controlled thermal and structural conditions to confirm agreement between simulations and experiments [19]. This iterative process of modelling, validation, and refinement improves the reliability of computational predictions and provides a better understanding of complex phenomena such as turbulent heat transfer and thermal resistance effects [20]. Multi-objective optimization techniques, including genetic algorithms and other approaches, are progressively utilized to balance thermal, structural, and manufacturing design requirements [21].

In this study, a comparative analysis of different fin cross-sections is conducted using analytical methods and numerical simulations performed in ANSYS. The objective is to examine the thermal behaviour of various

fin geometries and identify configurations that provide improved heat dissipation performance. The subsequent sections of this paper describe the analytical formulation, modelling approach, simulation procedure, and discussion of the obtained results in detail.

2. ANALYSIS OF FIN

This section illustrates the temperature profile and The volume element for fin analysis is depicted in Figure 1. The Fourier's law of heat conduction for fin analysis can be expressed as:

$$Q = -kA_c \left. \frac{dT}{dx} \right|_{x=0} \quad (1)$$

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

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0 \quad (3)$$

Where $m^2 = \frac{hp}{kA_c}$ and $\theta = T - T_\infty$ and p is perimeter and (A_c) is cross-section area.

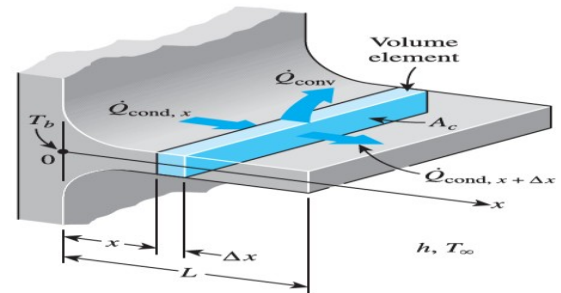


Figure 1: Volume element of a fin

Thus, general solution of equation (3) is given as:

$$\theta(x) = C_1 e^{mx} + C_2 e^{-mx} \quad (4)$$

Where C_1 and C_2 are constants determined using boundary conditions.

In this paper, the fin is analysed assuming an insulated tip condition.

Temperature distribution and heat transfer rate for the insulated-tip fin are given by:

$$T(x) = T_\infty + (T_b - T_\infty) \frac{\cosh m(L-x)}{\cosh mL} \quad (5)$$

$$\dot{Q} = \sqrt{phkA_c} (T_b - T_\infty) \tanh mL \quad (6)$$

Where T_b is the base temperature of the fin and T_∞ is the ambient temperature.

3. RESULTS AND DISCUSSIONS

In this section, circular, triangular and rectangular fins with identical cross-sectional areas and lengths are considered for the analysis. The dimensions and boundary conditions of these fins are presented in Table 1 and Table 2, respectively.

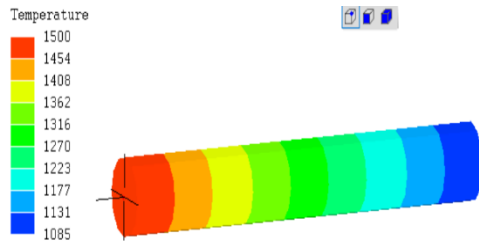
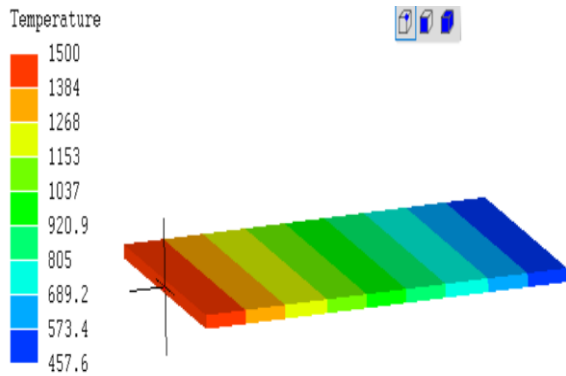
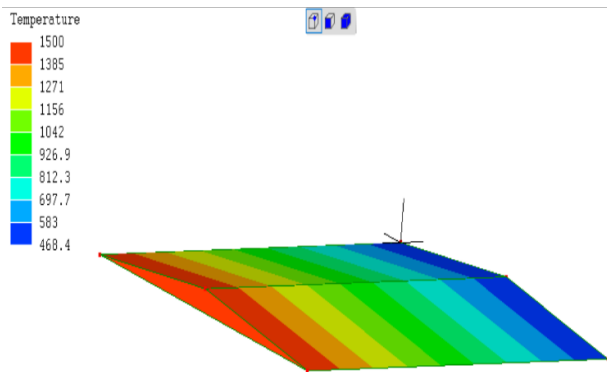
Table 1: Dimensions of fin cross-sections

Cross-section	Length (mm)	Width (mm)	Thickness/diameter (mm)	Area (mm ²)
Circular	100	-	15.14	180
Rectangle	100	90	4	180
Triangle	100	90	2	180

Table 2: Boundary conditions for fins

Material	Aluminium Alloy
Thermal conductivity (W/m-K)	152
Heat transfer coefficient (W/m ² -K)	40
Ambient temperature (°C)	30
Base temperature (°C)	1500

Cross-sections of fins are simulated using ANSYS as shown in figures 2, 3 and 4.

**Figure 2:** Temperature distribution for circular cross-section fin**Figure 3:** Temperature distribution for rectangular cross-section fin**Figure 4:** Temperature distribution for triangular cross-section fin

Distribution of heat transfer for different cross-sections along length of fin are shown in figure 5.

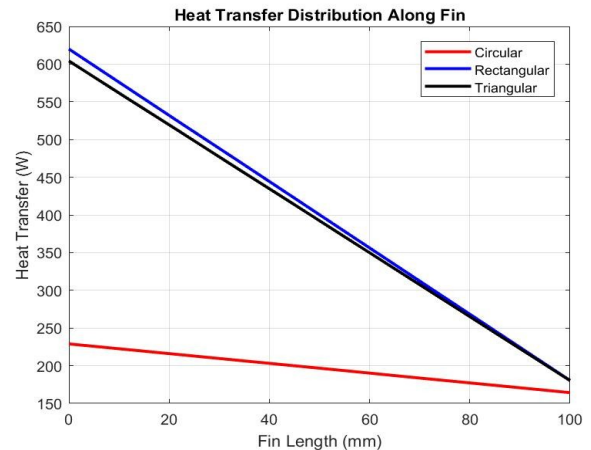
4. CONCLUSIONS

In this paper, the thermal performance of fins with different cross-sectional shapes, namely circular, rectangular, and triangular are investigated and ANSYS is used for simulation. The simulation results show that the temperature decreases steadily from the base toward the tip for all fin cross-sections. This trend occurs because heat is continuously lost from the fin surface to the

surrounding air through convection. Although the overall pattern of temperature reduction is similar in all cases, the rate of temperature drop differs depending on the fin geometry. This behaviour is largely influenced by differences in perimeter and exposed surface area, which govern the amount of heat transferred to the surrounding environment.

Among the analysed cross-sections, the rectangular fin gives the highest heat transfer rate and better thermal performance for comparable operating conditions.

Thus, the results show the importance of fin cross-section in calculating heat dissipation performance.

**Figure 5:** Heat transfer distribution along length of fin

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