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A Review of Rectangular Fin Thermal Performance Using Various Perforated Fin Surface Geometry

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ABSTRACT

Fins have been used for a long time to facilitate heat transmission. Fin size optimization is crucial since there is a rising need for fins that are lightweight, thin, and inexpensive. In order to improve heat extraction while using the least amount of material, fins must be built while taking into account their simplicity of fabrication. The thermal boundary layer is reset after every disturbance, increasing the heat transfer coefficient.

On fin plates, a surface disturbance might produce various perforated geometry structures. The purpose of this study is to look at the temperature decrease across different parts of a rectangular fin. The ANSYS Fluent program is used for numerical simulation to investigate fins with different perforated shapes. When compared to other factors like heat flow and thermal gradient, the perforated structure of a rectangular fin is considered to be continuous. It was discovered that the temperature had significantly dropped and that heat transfer had improved. The findings might be used to improve the design of rectangular fin heat exchangers.

Keywords: *Rectangular fin, Steady State Thermal, ANSYS, Heat flux, Temperature, perforated geometry structure*

I. INTRODUCTION

The machine When fuel is burned, heat is produced. Additional heat is also produced by friction between the moving parts. Only around 30% of the energy released can be used for productive activity. The remaining portion (70%) of the engine must be removed in order to prevent the components from melting. For two-wheelers, air-cooled engines are the sole choice due to their benefits over water-cooled engines, such as their smaller weight and need for less space. Engine cooling systems are designed to remove heat from the engine for this purpose. Systems for cooling water are used in several big vehicles. The expansion of the high-temperature and high-pressure combustion gases has a direct impact on one or more engine components, such as pistons, turbine blades, or nozzles. This force propels the thing further, generating mechanical energy that might be useful. When an air-fuel mixture is burned, an engine cylinder may reach temperatures of up to 2500°C. A material with a very high melting point must be used to create an engine that can withstand such a high temperature.

Heat sinks and radiators employ fins as heat exchange fins to control temperature. Fins are surfaces that speed up convection to or from the ground while examining heat transfer. The heat exchange may be increased by increasing the temperature angle between the protest and the earth, the convective heat exchange coefficient, or the protest's surface area. Heat transfer problems could be resolved by adding a balance to a protest to increase its surface area.

II. LITERATURE REVIEW

According to several studies conducted over the last ten years, the amount of fins, the fin pitch, the fin shape, the wind speed, the material, and the environment all affect how much heat is transferred via the fin.

Abdul Razak Kaladgi, Faheem Akhtar et al. (2021) Fins are a kind of heat transfer enhancement device that has been used for a while. Fin size optimization is crucial since there is a rising need for fins that are lightweight, thin, and economical. In order to maximize heat extraction while using the least amount of material, fins must be developed while taking into account their simplicity of construction. As a result of each disturbance, the thermal boundary layer is reset, which results in an improvement in heat transfer coefficient. Examples of surface disturbances include fins' perforated plates. This study's objective is to examine how temperature decreases through various circular holes. The examination of fins with perforations uses numerical simulation (ANSYS Fluent code). Equations for turbulent air flow and heat transfer between fins are solved with the help of an FVM programmed. Other parameters like heat flow and thermal gradient are compared across a range of circular perforation counts. In addition to an improvement in heat transport, it was seen that the temperature dropped significantly. The design of rectangular fin heat exchangers may be improved using the findings.

Chandrakant R Sonawane, Pratyush Rath et al. (2021) The engine is the most crucial component of a car, thus it must be maintained in good operating order under all sorts of weather situations. In order to prevent thermal breakdown and damage to the engine, the heat produced within the combustion chamber must be expelled. This research presents a numerical simulation of the finned cylinder to increase the engine's heat dissipation rate. The model is created using Autodesk Fusion 360, and the steady-state thermal analysis is done using ANSYS. Aluminum alloy 204 and 6061 are the two fin materials for which numerical simulations are performed. A thorough comparison for temperature distribution and total heat flow is shown, along with an analysis of the impact of fin shape with different fin thickness, pitch, and orientation. Our numerical findings demonstrate that the aluminum alloy 6061 outperformed the current setup with significant gains in power to weight ratio and heat transport.

S.K. Mohammad Shareef, M Sai Vikas et al. (2021) Thermal stress and temperature variations are experienced by engine cylinders. On engines, fins are used to increase the rate of heat transmission. The engine cylinder's surface is covered with fins to speed up heat transmission. By increasing its surface area, engine cylinder fins may dissipate heat more quickly. The primary goal of the current numerical inquiry is to evaluate the engine cylinder's thermal characteristics by modifying the shape, composition, and profile of the cylinder fins using Ansys workbench. SolidWorks is used to assist in the creation of the models

Faheem Akthar, Abdul Razak Kaladgi et al. (2021) Fins have been used for a very long time to enhance heat transmission. A variety of metals, including copper, silver, mild steel, and stainless steel, are used to make fins. As the technology for fins (extended surfaces) develops, new design ideas have emerged, including composite fins, porous materials, interrupted, and perforated plates. Due to the growing need for compact, tiny, and affordable fins, fin size optimization is essential. Because of this, fins need to be designed to extract the most heat from the least amount of material while yet being simple to manufacture. Many different things may have contributed to the rise in heat transfer coefficient. The improvement in heat transfer coefficient is connected to the resetting of the thermal boundary layer after each disturbance. Fins' perforated plates are an example of surface disruption. Estimating the temperature drop through many circular holes is the goal of this paper.

S. Padmanabhan, S. Thiagarajan et al. (2021) Many studies on the fin's shape and material have been conducted recently to improve its use. Rectangular, triangular, and trapezoidal fin configurations were favoured in many situations where fins are utilised to speed up the rate of heat transfer from the system. The enlarged surfaces that are purposefully placed in a location from which heat is to be removed are known as fins. The amount of conduction, convection, or radiation a component has affects how much heat it emits. Heat transmission rises when the soil's surface area, the convection of heat coefficient, and the ambient temperature differential between the substance and the atmosphere all rise. This research article examines a numerical analysis for various profiles using aluminium as the material

III. RESEARCH OBJECTIVES

To maximize its use, a lot of research has lately been done on the fin's structure and shape. In many applications, utilizing fins to increase the rate of heat transfer from the system, rectangular, triangular, and trapezoidal fin designs were used. Fins are intentionally made extended surfaces that are positioned where heat is to be collected. Heat is released from a component either by conduction, convection, or radiation, depending on how much of each occurs. Increases in ground surface area, the material-atmosphere temperature difference, or the thermal convection coefficient all result in increased heat transfer. This research mathematically analyzes a variety of aluminum rectangular fin designs. CFD analysis may be used to determine the heat flow rate and temperature distribution at the fin's tip. The best and most suitable modified fin is chosen for the climatic conditions after studying the numerous perforated geometry's forms on the two sides of the rectangular fin.

The analysis focuses on the rectangular fin's tip, which has the lowest temperature dispersion and the maximum heat flow. We use three distinct designs for perforated aluminum alloy fins, including rectangular, triangular, and hexagonal shapes. We changed the rectangular fin by drawing various geometric forms on each of its surfaces. We investigated the temperature distribution using various fin geometry in order to determine the ideal fin shapes for heat transmission. At the steady state thermal section, CFD analysis is used to address each of these scenarios.

IV. GEOMETRY SETUP AND MODELLING

A. Model Description

The rectangular fin's geometry was made using the CATIA V5 application. In a condensed CADD schematic, the research rig-based simulation system is shown in Fig. 5.1. The geometry developed by Abdul Razak Kaladgi et al. (2021) is utilized for simulation analysis. The 150 mm long, 15 mm thick rectangular fin has rectangular, hexagonal, and triangular holes. Its dimensions are the same as those of the base paper.

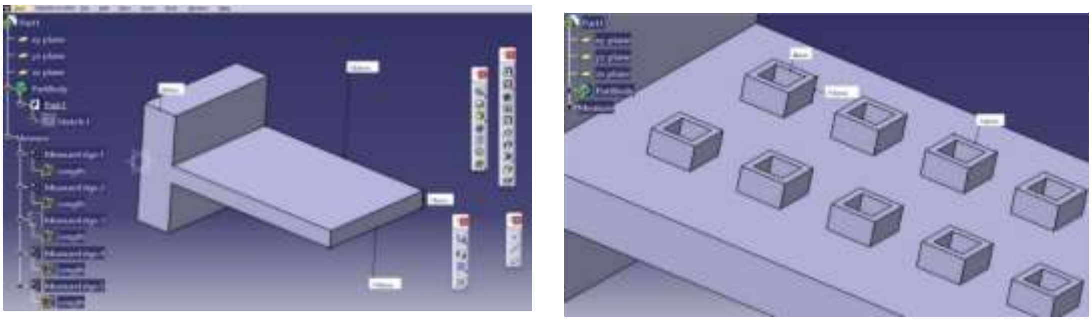

Figure 1. Geometric dimension of the rectangular fin and perforated rectangular shape having 15 mm thickness.

Figure 2. Geometric dimension of perforated triangular and hexagonal shape on rectangular fin surface

The purpose of this study is to examine the temperature drop and heat flow via various holes. Other elements like heat flow and thermal gradient are compared throughout a continuum of perforation counts. This study made use of the ANSYS Fluent code.

B. Geometric Parameters

By first identifying the variables that have the most impact on heat transfer and then presenting the best combination of those variables using an optimization technique, our study examines what a feasible solution would be for the maximum heat dissipation from rectangular fin. Based on the results of a review of the literature, the factors that affect the heat transmission of engine fins are selected from a broad list.

Table 1. Geometrical Parameter of the rectangular fin

S.N.	Parameter of rectangular fin	Value (mm)	Internal Dimension (mm) of perforated geometry	External Dimension (mm) of perforated geometry	Hight (mm) of perforated geometry (one side)
1	Length of the rectangular fin	150	-	-	-
2	Width of the rectangular fin	30	-	-	-
3	Thickness of rectangular fin	15	-	-	-
4	Perforated rectangular geometry	-	8	12	7.5
5	Perforated Triangular geometry	-	8	12.625	7.5
6	Perforated Hexagonal geometry	-	7	11	7.5

Table 2. Properties of the Aluminum Alloy

S.N.	Materials properties	symbol	values
1.	Thermal conductivity	k	236 Wm^{-1}K^{-1}
2.	Thermal expansion	α	2.32 e^{-5} /K^{-1}
3.	Density	ρ	2.7 e^{-3} g/mm^{3}

C. Boundary Conditions

In order to determine the temperature dispersion and heat flux of modified rectangular fins with holes of the same surface and fins with embossed spherical surfaces, steady state thermal analysis was utilized. The experiment included an alloy of aluminum. To ascertain which had the best perforated surface, many designs of rectangular fins of varied sizes were examined:

- Rectangular Fins with rectangular perforation geometry shape.
- Rectangular Fins with triangular perforation geometry shape.
- Rectangular Fins with hexagonal perforation geometry shape.

Table 3. Details of boundary conditions.

Detail	**Value**
Rectangular fin	Aluminum Alloy
Thermal model	steady state thermal modal
Film co-efficient	5.489 Wm^{-2} C^{-1}
Inter connected wall of rectangular fin	200^0C

The following are the four main assumptions made for the thermal analysis of the engine cylinder fins.

- The inter connect wall of the fin is uniformly kept at constant temperature, i.e., at 473 K or 200^0C.
- The thermal model considered here is the steady state thermal model for validation & transient for research work.
- Heat transfer due to radiation has not been considered in this study.
- The ambient temperature is taken as 293 K (20 ^0C).
- The film coefficient for convection is taken as 5.489 W/m^2.

V. RESULTS AND DISCUSSIONS

The evaluation of the rectangular fin with an embossed spherical form and changed geometry is the focus of this section. In order to investigate the rate of heat transfer, the differences in temperature distribution and heat flux are studied at several modified rectangular fin geometries.

A. Validation of numerical computations

Comparison with the work described in Base paper [1] was done in order to verify the correctness of the created numerical technique. The rectangular fin geometry that was utilised to verify numerical calculations was taken into consideration to be the same as the geometry in the following picture.

We will use the rectangular aluminum alloy fin with the material attribute listed in Table 5.2 and the boundary condition listed in Table 5.2 to verify the modal. For our investigation, we are employing the same study state thermal model as Base Paper [1], and others (2021) used.

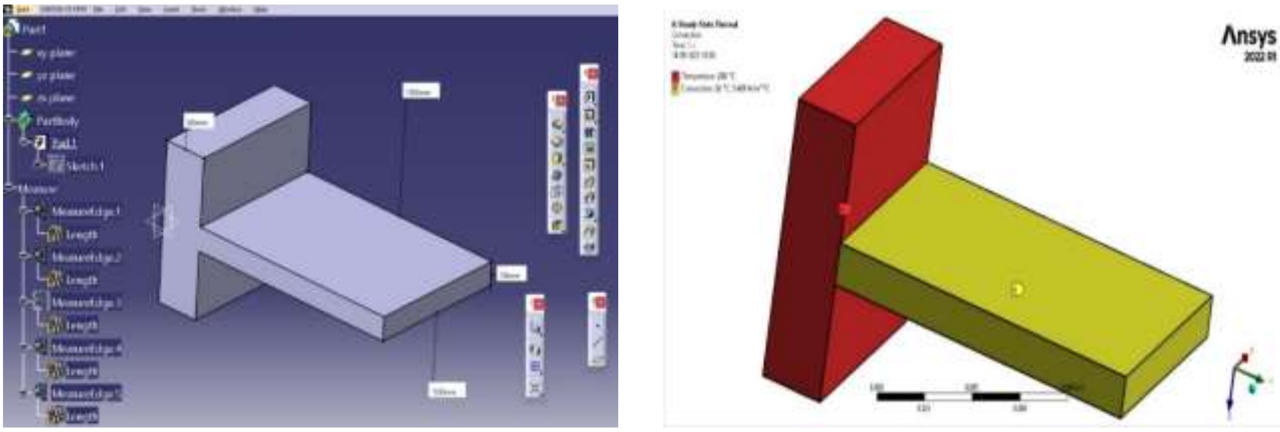

Figure 3. Rectangular fin modal & applied boundary condition

Here we are using the rectangular fin made of aluminum without any modification of geometry and find out the temperature at the tip of the fin (minimum temperature) with the help of CFD.

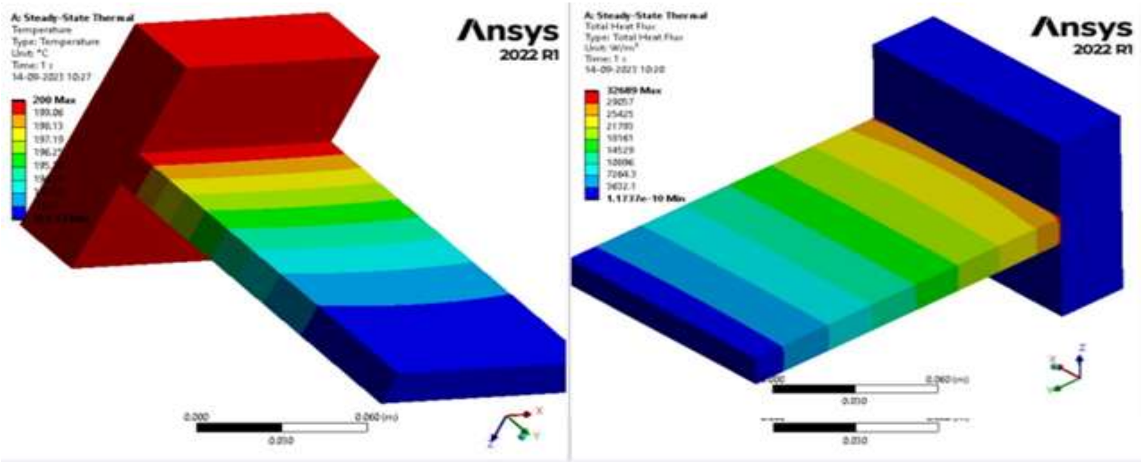

Figure 4. Temperature & Heat flux contour of rectangular fin.

In Above analysis, validate the result of the base paper, taking the same configuration for the rectangular fin geometry. Following graph shown the temperature distribution and the heat flux in rectangular fin geometry. We can compare the minimum temperature value at the tip of the fin & maximum heat flux value on the fin. In the contour the red mark shows the maximum value & blue mark show the minimum value.

Table 4 Shows the values of min. temperature distribution & maximum heat flux calculated from the CFD modeling compared with the values obtained from the analysis performed by Base paper [1].

S.N.	Analysis	Temperature		Heat flux	
		Max.	Min.	Max.	Min.
1.	Base Paper	200	192.08	32731	0
2.	Present study	200	191.57	32689	0

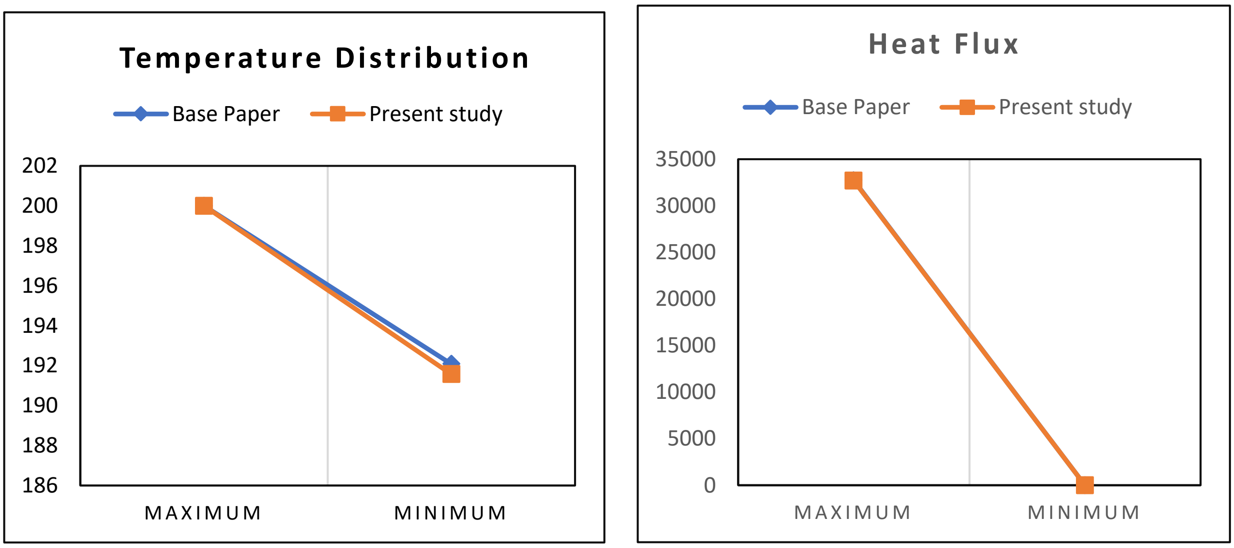

Figure 5. Graphical compression of temperature distribution & heat flux.

The above graph shows that the numerical model of the rectangular fin is accurate since the value of the minimum temperature distribution obtained via numerical analysis is close to the value of the minimum temperature distribution obtained from the base paper. We may also contrast the heat flow value, which is closer to the value of the base paper. The differences between experimental and numerical results are much smaller.

B. Analyze the modified fin geometry

At this point, the geometry of the rectangular fins has been modified. We provide different perforated geometries (rectangular, triangular, and hexagonal) for the front and rear surfaces of the rectangular fin. Applying the identical parameters as those given in the base article, calculate the minimum temperature distribution and heat flow using CFD.

We will analyze the following three cases for enhancement of the heat distribution & getting maximum flux. Perforated geometry on the surface of rectangular fin is shown in figure 1 and figure 2.

- In the first instance, we will utilize aluminum alloy as the fin's material and use a rectangular perforated geometry on both of the fin's side surfaces. As with the basis paper, the boundary condition is applied.
- In second scenario, with triangular perforation on both of its side surfaces, the fin in the final instance is built of an aluminum alloy with geometric perforations. As in the base article, the boundary condition is enforced.
- The fin in the final instance is built of an aluminum alloy and has hexagonal holes on each of its side surfaces geometric perforations. Just as it was in the base article, the boundary condition is now enforced.

VI. Conclusions

Fins and other heat transfer enhancement tools have been used for a while. Fin size optimization is crucial due to the rising need for inexpensive, lightweight, and thin fins. After doing the CFD analysis through the comparison chart shown above, we will see that the results will be quite encouraging. From the CFD analysis by using properties and boundary conditions the following conclusions are made:

- If the rectangular fin is replaced with other geometry with perforated form, we will see by what percentage the minimum temperature will be reduced.
- Through this analysis, we will also know how the heat flow changes when different types of geometries change the perforated form and what effect it will have on the fin.
- For various geometries with perforated forms (rectangular, triangular, and hexagonal), what will be the percentage heat flow and minimal temperature change at the fin tip, and can these geometries be simply manufactured and economically practical for any industry? will be accurate

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