Thermal Analysis of Engine Cylinder Fins by Varying Fin Geometry and Material

Naveen Kumar P [1], Dr. Vinayak Talugeri [2]
[1]*Departemnt of Mechanical Engineering SKSVMACET, Laxmeshwar, visveswaraya technological university,* Karnataka-582116
[2]*Department of Automation and robotics, sharad institute engineering and technlology, Dr. Babasaheb Ambedkar Technological university.* lonere. maharstra 402103
naveenmtpbiet@gmail.com, vinataktalugeri@gmail.com

***Abstract*— Internal combustion engines generate a large amount of heat during combustion. Excessive temperature inside the engine cylinder can lead to lubrication failure, component deformation, and reduction in engine efficiency. To maintain an optimum operating temperature, cooling systems are employed in engine design. In air-cooled engines, extended surfaces known as fins are used to enhance the heat transfer rate from the cylinder surface to the surrounding atmosphere. The present study focuses on the thermal analysis of engine cylinder fins with different geometries, thicknesses, and materials using finite element analysis. Square and circular fin geometries with thicknesses of 2 mm and 3 mm are analyzed using Aluminum Alloy 6061 and Magnesium Alloy as fin materials. The models are designed using Fusion 360 and analyzed using ANSYS Workbench under transient thermal conditions. Parameters such as temperature distribution, total heat flux, and directional heat flux are evaluated. The results indicate that circular fins with Aluminum Alloy demonstrate better heat transfer performance compared to other configurations. The study concludes that fin geometry and material selection play a significant role in improving cooling efficiency and reducing thermal stresses in air-cooled internal combustion engines.**

Keywords*— *Internal combustion engine, Cylinder fins, Thermal analysis, ANSYS Workbench, Heat flux, Temperature distribution, Aluminum alloy, Magnesium alloy.

I. Introduction

Internal combustion engines (IC engines) are widely used in automobiles, power generation systems, and industrial applications. During the combustion of air–fuel mixtures inside the engine cylinder, high temperatures are generated which may range between 500°C and 800°C. Such elevated temperatures can adversely affect the performance and durability of engine components.

The high temperature inside the combustion chamber may cause several problems such as:

- Burning of lubricating oil film between moving components
- Seizure of piston rings
- Thermal stresses in the cylinder walls
- Material deformation and wear

Therefore, it is necessary to maintain the engine temperature within a desirable operating range, typically between 150°C and 200°C, to ensure safe and efficient operation.

Cooling systems play an important role in maintaining the optimum temperature of the engine. Cooling methods can be classified into two major categories:

1. Air Cooling System
2. Liquid Cooling System

Air-cooled engines are widely used in two-wheelers, motorcycles, and small engines because they are lightweight, compact, and require less maintenance compared to liquid-cooled systems.

To improve heat dissipation in air-cooled engines, extended surfaces called fins are attached to the cylinder surface. These fins increase the effective surface area exposed to atmospheric air, thereby enhancing convective heat transfer.

The performance of cooling fins depends on several factors such as:

- Fin geometry
- Fin material
- Fin thickness
- Air velocity
- Ambient temperature

In this work, the thermal behavior of engine cylinder fins with different geometries and materials is analyzed using Finite Element Analysis (FEA) through ANSYS software.

Engine

II. LITERATURE REVIEW

Engine cylinder fins have been extensively studied to improve heat dissipation and enhance engine performance.

Several researchers have investigated the effect of **fin geometry, thickness, and material properties** on heat transfer performance.

Nagarani investigated the thermal behavior of **circular and elliptical annular fins** and concluded that elliptical fins provide higher heat transfer efficiency under certain space constraints.

Ajay Paul conducted a parametric study on extended fins used in motorcycle engines and observed that **fin thickness and material conductivity significantly affect cooling performance**.

Babu and Lavakumar studied different fin geometries such as **rectangular, circular, and curved fins** using

ANSYS analysis. Their study revealed that curved fins reduce weight and improve cooling efficiency.

Phani Raja Rao analyzed cylinder fins using **Aluminum Alloy 6061 and Magnesium Alloy** and found that aluminum alloys provide better heat transfer characteristics due to higher thermal conductivity.

Karthikeyan investigated rectangular fin arrays and concluded that **rectangular extensions increase heat transfer by nearly 13–21% compared to conventional fins**.

Hardik Rathod examined the influence of fin thickness and air velocity on heat transfer and concluded that **larger numbers of thin fins improve cooling efficiency in high-speed vehicles**.

Vignesh proposed a sinusoidal fin structure to improve turbulence and heat transfer rate, resulting in improved cooling performance.

From the review of previous studies, it is evident that **fin geometry and material selection are crucial parameters influencing heat dissipation in air-cooled engines**

III. PROBLEM STATEMENT

During combustion inside the cylinder, the temperature rises significantly due to the chemical reaction of fuel and air. If this heat is not effectively dissipated, it may lead to overheating and component failure.

Air-cooled engines rely mainly on fins to dissipate heat to the surrounding atmosphere. However, the efficiency of fins depends on several factors such as:

- Geometry of the fin
- Thickness of the fin
- Thermal conductivity of the material
- Air flow conditions

Therefore, it is necessary to analyze different fin configurations to identify the most efficient design for maximum heat dissipation.

IV. OBJECTIVES OF THE STUDY

The main objectives of this study are:

1. To design engine cylinder fins using CAD modeling software.
2. To analyze thermal behavior using ANSYS Workbench.
3. To compare temperature distribution and heat flux for different materials.
4. To study the effect of fin thickness on heat dissipation.
5. To identify the most efficient fin configuration for air-cooled engines.

V. METHODOLOGY

A. Material Selection

The fin material should possess the following properties:

- High thermal conductivity
- Low density
- Good machinability
- Low cost

Two materials were selected for the study:

Aluminum Alloy 6061

Properties include:

- Density: 2.7 g/cm³
- Thermal conductivity: 167 W/mK
- Good corrosion resistance
- High strength-to-weight ratio

Magnesium Alloy

Magnesium alloys are lightweight structural materials with moderate thermal conductivity and good casting properties.

B. Fin Geometry

Two types of fin geometries were considered:

1. Square Fin
2. Circular Fin

Two different thicknesses were analyzed:

- 2 mm
- 3 mm

Model Design

The fin models were created using Fusion 360 CAD software.

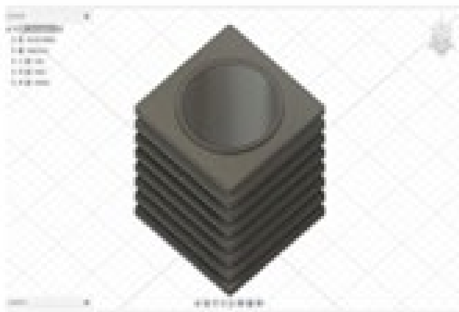

Fig. 1. Design of square fin (2mm)

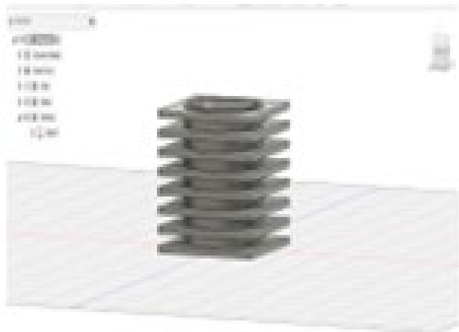

Fig. 2. Side view of square fin (3mm)

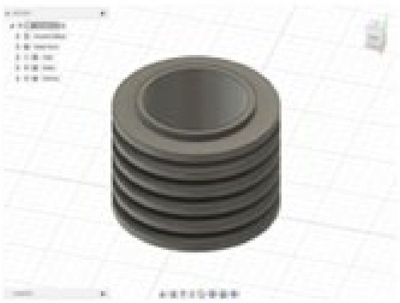

Fig. 3. Side view of square fin (2mm)

Fig. 4. Side view of square fin (3mm)

VI. THERMAL ANALYSIS USING ANSYS

Thermal analysis was performed using **ANSYS Workbench** under transient thermal conditions.

Finite Element Analysis (FEA) involves dividing the geometry into small elements known as **mesh elements**. These elements are connected through nodes, allowing numerical solution of temperature and heat transfer equations.

Boundary Conditions

Initial Temperature: 28°C

Combustion Temperature: 800°C

Ambient Temperature: 25°C

Heat Transfer Mode: Convection

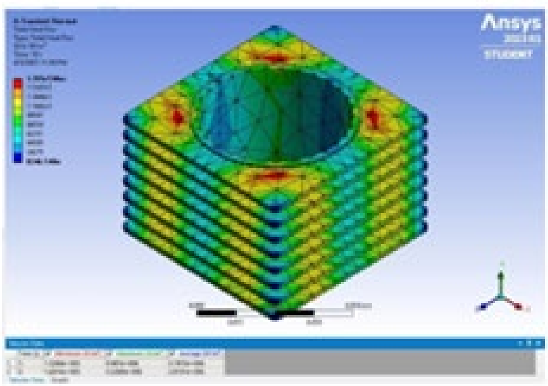

Fig. 5. Total heat flux for Aluminum alloy 6061 at 2mm thickness

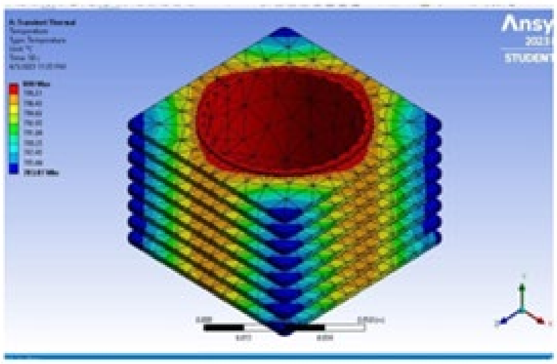

Fig. 6. Temperature distribution for Aluminum alloy 6061 at 2mm thickness.

VII. RESULTS AND DISCUSSION

The thermal analysis results were obtained for different combinations of geometry, material, and fin thickness.

Parameters evaluated include:

- Temperature distribution
- Total heat flux
- Directional heat flux

A. Temperature Distribution

The results indicate that circular fins with **Aluminum Alloy 6061** provide better temperature distribution compared to magnesium alloy fins.

The maximum temperature observed is approximately **800°C**, while the minimum temperature varies depending on fin geometry and material.

VIII. RESULT AND DISCUSSION

A. Temperature Distribution:

The third type, which is composed of aluminum alloy with 2 mm thick circular circumferential fins, can reach a maximum temperature of 797.84°C, as can be seen from the preceding findings. It takes 10 seconds to reach this steady state, and it is the highest temperature value among all the other models. However, fig3.3.4 faces fierce competition from fig, 1 which is constructed of magnesium alloy and has the similar characteristics of being round in shape and 2 mm thick. The maximum temperature obtained is lower than that of fig. (797.58 °C), but it required much less time—9.74 seconds—than any of the other models to reach that temperature.

For Fig 2 which is composed of magnesium alloy with circular circumferential fins that are 3 mm thick, the rate of temperature change is high. Therefore, in Fins of Circular Geometry, both the Attained Value of Maximum Temperature and Temperature Change with respect to Time are high

B. Total Heat flux:

The following variation is seen when it comes to the cylinder's overall heat flux: When compared to all the other models, the model-1, which is composed of aluminum alloy and has 2 mm rectangular circumferential fins, transmits higher total heat flux. Aluminum alloy conducts higher total heat flux when material is the subject of interest because model-2, which is composed of magnesium alloy and has the same characteristics as model-1 but conducts less total heat flux due to material difference. Another finding is that a material's total heat flow increases as its mass increases. Because of this, its value is higher in rectangular geometry than in circular geometry, and it likewise falls as fin thickness increases.

C. Directional Heat flux:

All of the outcomes for directional heat flux are comparable to those for total heat flux. When compared to circular geometry, the directional heat flux conducted by the material is higher in rectangular geometry and rises with increasing material content but falls with increasing fin thickness.

TABLE I. TEMPERATURE DISTRIBUTION

Sl. No	Minimum value	Maximum value	Average
Model 1 Al alloy	783.87 ºC	800 ºC	793.76 °C
Model 1 Mg alloy	789.15 ºC	800 ºC	795.66 °C
Model 2 Al alloy	783.06 ºC	800 ºC	793.66 °C
Model 2 Mg alloy	789.28 ºC	800 ºC	795.88 °C
Model 3 Al alloy	789.78 ºC	800 ºC	799.35 °C
Model 3 Mg alloy	798.63 ºC	800 ºC	799.28 °C
Model 4 Al alloy	799.02 ºC	800 ºC	799.49 °C
Model 4 Mg alloy	798.93 ºC	800 ºC	799.44 °C

TABLE II. TOTAL HEAT FLUX

Sl no	Minimum value	Maximum value	Average
Model 1 Al alloy	8246.5 W/m^2	$1705*10^2$ W/m^2	85029 W/m^2
Model 1 Mg alloy	6306 W/m^2	$1030.9*10^2$ W/m^2	53275 W/m^2
Model 2 Al alloy	9707.4 W/m^2	$1721.5*10^2$ W/m^2	86569 W/m^2
Model 2 Mg alloy	6705.9 W/m^2	97664 W/m^2	50674 W/m^2
Model 3 Al alloy	15266W/m^2	22059W/m^2	19057W/m^2
Model 3 Mg alloy	15119W/m^2	21711W/m^2	18870W/m^2
Model 4 Al alloy	13249W/m^2	17559W/m^2	15054W/m^2
Model 4 Mg alloy	13026W/m^2	17353W/m^2	14798W/m^2

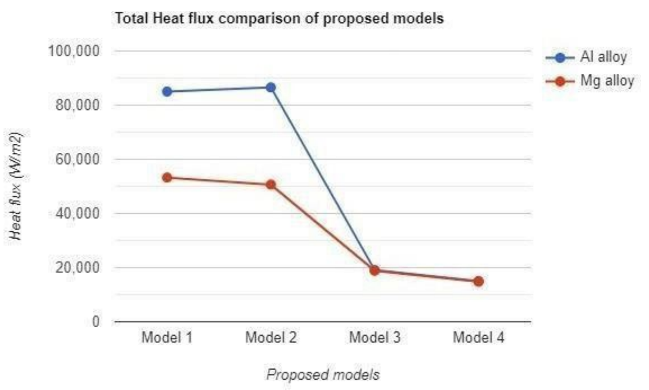

Fig. 7. Graph Heat Flux

IX. CONCLUSION

In this study, the thermal performance of engine cylinder fins was analyzed using ANSYS Workbench. Different fin geometries and materials were evaluated to determine their influence on heat transfer.

From the analysis, the following conclusions were drawn:

1. Fin geometry significantly affects heat dissipation performance.
2. Aluminum alloy fins show better heat transfer characteristics compared to magnesium alloy fins.
3. Circular fins provide improved efficiency with reduced weight.
4. Increasing fin thickness slightly improves heat transfer but increases material usage.
5. Proper selection of fin geometry and material can significantly improve the cooling performance of air-cooled engines.

REFERENCES

[1] N. Nagarani, “Finite Element Analysis of Convective Heat Transfer from Rectangular Fins,” International Conference on Mechanical Engineering, 2009.

[2] J. Ajay Paul, “Heat Transfer Simulation from Fins of an Air-Cooled Motorcycle Engine,” World Congress on Engineering, 2011.

[3] G. Babu and M. Lavakumar, “Air Cooling Effects of Fins on Motorcycle Engines,” Journal of Mechanical Engineering, 2005.

[4] P. Sai Chaitanya, “Thermal Analysis of Engine Cylinder Fin by Varying Geometry,” Journal of Mechanical Engineering, 2014.

[5] KM Sajesh, “Design Modification and Heat Transfer Analysis of Air-Cooled Rectangular Fins,” International Journal of Engineering Research, 2016.

[6] Vinay Kumar Attar, “Transient Thermal Analysis of IC Engine Piston using ANSYS,” International Journal of Engineering Science, 2016.