

# Design Modifications of Cylinder Head Fins for Two-Wheeler Engine through Geometrical and Material Analysis

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**Abstract** — The primary objective of this study is to analyze and simulate the effects of fin geometry and material selection on the temperature distribution and heat flux of the Honda SP 125 engine cylinder fins. Various fin geometries were considered, including rectangular, slotted rectangular, circular, slotted circular, angular, and longitudinal fins, all with a uniform thickness of 2.5 mm. Among these, the circular fins with perforations demonstrated superior heat transfer efficiency and an advantageous power-to-weight ratio. Based on this optimal geometry, different materials—Aluminum 6082, AL204, Cast Iron, Magnesium Alloy AZ31, and Beryllium Oxide—were evaluated. 3D models were developed using SolidWorks and subsequently analyzed using ANSYS 16.2 under steady-state conditions. Finite Element Analysis (FEA) was performed to examine heat distribution and heat flux across all models. The findings indicate that Beryllium Oxide exhibits the highest thermal performance. The results were compared to determine the geometry and material combination that yields the maximum heat flux.

**Keywords-** Fins, Heat transfer, Aluminium 6082, Beryllium oxide, Ansys.

Managing heat effectively in internal combustion engines is especially important in two-wheelers to maintain efficiency, dependability, and long-term performance. Air-cooling is the most commonly used method in these vehicles because of its simple construction, low cost, and high durability. In such systems, heat produced during combustion is mainly dispersed through fins attached to the cylinder head.

Engine cooling performance is heavily influenced by fin design, including their geometry, quantity, size, and the material selected. Optimizing these elements involves a trade-off—while adding more fins or enlarging their surface area can enhance heat dissipation, it can also increase the engine's overall weight, which negatively affects the crucial power-to-weight ratio in two-wheelers. Furthermore, aspects like fin thickness, spacing, and alignment need to be carefully designed to ensure unobstructed airflow and efficient convective heat transfer. Recent research highlights that adding perforations to fins can enhance cooling by inducing turbulence and breaking up thermal boundary layers. Circular perforations, in particular, have demonstrated better heat transfer performance and weight reduction

compared to other shapes like rectangular or triangular ones. Additionally, selecting materials with high thermal conductivity—such as aluminum alloy 6063-T6—has been found to significantly improve cooling effectiveness while preserving the structural strength of the fins.

Considering these factors, the objective of this study is to conduct a comprehensive analysis of cylinder head fin designs in two-wheeler engines by examining different geometries and materials. Using computational modeling and simulation tools, the research evaluates multiple fin shapes, material options, and perforation layouts to identify configurations that enhance heat dissipation while keeping weight and production complexity low. The outcomes of this work aim to support advancements in engine cooling technologies and contribute to wider goals such as improved fuel economy, lower emissions, and environmentally sustainable transportation solutions.

**1.1 Fins:** A fin is an extended surface added to a component to enhance heat transfer between the object and its surroundings, primarily by boosting convective heat exchange. The rate at which heat is transferred depends on conduction, convection, and radiation. Heat transfer can be improved by increasing the temperature difference between the surface and its environment, enhancing the convective heat transfer coefficient, or expanding the surface area. Since adjusting the temperature difference or convection coefficient may not always be practical or cost-effective, incorporating fins offers a more feasible and economical alternative by enlarging the surface area. Common applications include circumferential fins on motorcycle engine cylinders and fins on condenser tubes in refrigerators. Maintaining an appropriate temperature distribution within a spark ignition (SI) engine is crucial for ensuring efficient operation and maximizing thermal efficiency. Engines must operate within specific thermal limits to perform optimally. Fins play a key role in this process by facilitating heat dissipation and preventing the engine from overheating. They act as a heat sink, protecting the engine from thermal damage. The number and size of fins on an engine cylinder generally correlate with the engine's capacity—higher-capacity engines typically require more fins to manage the increased heat. This cooling mechanism is essential for preventing thermal failure of both the engine and the lubricating oil, ensuring long-term reliability and performance.

## 2. LITERATURE REVIEW

Chandrakant R et al. conducted a numerical study to enhance the heat dissipation efficiency of an engine cylinder equipped with fins. The 3D model was created using Autodesk Fusion 360, and steady-state thermal analysis was performed using ANSYS software. Simulations were carried out using two different materials for the fins: Aluminum alloys 204 and 6061. The study also examined how variations in fin geometry—such as changes in thickness, spacing (pitch), and orientation—affect thermal performance. A comprehensive comparison of temperature distribution and total heat flux was made. The results indicated that Aluminum alloy 6061 outperformed the other configuration, offering noticeable improvements in both heat transfer efficiency and power-to-weight ratio.

Sroka ZJ et al. conducted heat transfer modeling and simulations on a single-cylinder, four-stroke, air-cooled engine to assess the heat transfer characteristics of the engine block. Using the SolidWorks platform, they modeled cylinders featuring varying numbers of fins and different fin geometries. The components tested were made from 6063-T6 aluminum alloy castings. The study examined the effects of fin count and geometry, including circular and rectangular perforations. The findings indicated that increasing the number of fins improves heat transfer but can reduce overall engine efficiency due to added weight. Among perforation shapes, circular designs proved superior to rectangular ones of the same cross-sectional area, offering a reduction in cylinder mass and over a 4% improvement in heat transfer rate. Perforation sizes tested included diameters of 7.14 mm, 8.5 mm, and 10 mm. The 7.14 mm perforations slightly enhanced heat transfer compared to larger sizes, while the 10 mm perforations achieved the greatest weight reduction.

S.K. Mohammad Shareef et al. conducted a numerical study focused on evaluating the thermal characteristics of engine cylinders by altering the geometry, material, and profile of the cylinder fins using ANSYS Workbench. The models were developed using SolidWorks software. This research involved the numerical optimization of engine cylinder fins made from cast iron, copper alloy, and Aluminum 6082, considering different fin shapes such as rectangular, circular, and angular profiles.

Nihal Chavan et al. conducted a study focused on identifying the most efficient fin materials and geometries to optimize heat transfer. Through thermal analysis of the chosen materials and shapes, average heat flux values were determined and compared. The results indicated that Aluminum 7075 exhibited the highest average heat flux among the various aluminum alloys evaluated in the study.

P.L. Rupesh et al. focused their study on designing fins with circular and tapered profiles for a two-stroke engine. They conducted steady-state thermal analysis to observe temperature distribution and heat dissipation on both fin

shapes. The materials chosen for the fins were Alusil and Silumin, and computational evaluations were performed using the Finite Element Method (FEM). Based on the FEM results and comparisons with existing fin designs and materials, the study identified the most effective fin shape and material combination.

N. Muthuram et al. aimed to improve the efficiency of engine cooling systems by optimizing fin design, including the addition of slots to increase surface area and enhance heat dissipation. The study analyzed two fin shapes—rectangular and cylindrical—both fabricated from Aluminum 1100. The designs were developed using PTC CREO Parametric 6.0, while steady-state thermal and modal analyses were conducted with ANSYS 2023 R1. The thermal analysis revealed that the slotted cylindrical fins achieved the highest heat transfer rates compared to traditional fin designs. These findings are expected to contribute significantly to improved cooling performance.

Sk. Avinash Kapil et al. aimed to investigate the thermal performance of cylinder fins by experimenting with different materials. In their study, cast iron was replaced with Aluminum alloy and Gray cast iron for comparison. The results showed that Aluminum alloy outperformed the other materials as the most suitable choice for engine fins. The thermal analysis was conducted based on the dimensions of the BAJAJ 150CC engine block, though it was noted that material changes could indirectly lead to increased manufacturing costs.

Pulasari Srinivas and Vadlamudi Ravikumar examined the extended surfaces, or fins, of Honda Shine and Bajaj Discover two-wheelers to study the impact of cross-section, fin pitch, material, and thickness on heat transfer rates. A parametric 3D model of the engine block fins was created using CATIA software, and thermal analysis was performed on fins both with and without perforations to evaluate heat flux and temperature distribution. Currently, cylinder fins are manufactured using Aluminum 2014 and grey cast iron, while Aluminum 6061 was proposed as an alternative material. This study analyzed all three materials with variations in geometry, including perforations, to assess their effect on heat dissipation. The results concluded that Aluminum 6061 is the most suitable material for cylinder fins due to its superior heat flux performance.

Mohan Das et al. aimed to investigate the effect of cylinder fin thickness on cooling efficiency. Their study revealed that fins with a thickness of 3 mm exhibited higher heat transfer compared to fins with thicknesses of 2.5 mm and 2 mm. They concluded that increasing the fin thickness leads to an improvement in the rate of heat transfer.

Mukesh Kumar Singh and H.S. Sahu aimed to determine the most effective fin shape and material for engine cooling. Their study concluded that pin fins with slanted edges are the most suitable design for heat sinks, as they enhance the rate of heat transfer.

M.S.V. Kartheek et al. focused on modifying the fin profile, thickness, spacing between fins, and fin material in their study. They developed the models using Pro/Engineer software and performed the analysis with ANSYS. Their findings indicated that altering the fin geometry leads to improved thermal performance. We can enhance more cooling efficiency than straight fins but the drawback is that the manufacturing of curve geometry fin is difficult,

Rahul Gupta et al. aimed to identify the most suitable material for engine cylinder fins by conducting thermal analyses on both aluminum alloy and magnesium alloy. Their comparison showed that magnesium alloy, being less dense than aluminum, reduces the overall weight while providing comparable heat transfer performance.

R. Suresh et al. conducted a study where the engine cylinder material was changed from cast iron to Aluminum Alloy 6082, and thermal analyses were performed on both materials. Their results demonstrated that Aluminum Alloy 6082 provides higher heat transfer rates and heat flux compared to cast iron. The material substitution in the model took into account the differences in density and thermal conductivity.

G. Babu and M. Lava Kumar aimed to investigate the thermal characteristics of engine cylinder fins by varying their geometry and material. Their thermal analysis included Aluminum alloy 606, Aluminum alloy 204, and Magnesium alloy. The study concluded that curved fin geometries enhance heat transfer, and they recommended further research in this area.

### 3. METHODOLOGY

#### 3.1 ENGINE MODEL SELECTION-

This research focuses on conducting a thermal analysis of the cylinder head fins of the Honda SP 125 engine, a widely used two-wheeler model. The engine has a bore diameter of 50 mm and a stroke length of 70 mm. Its cylinder head includes seven cooling fins, each with a thickness of 2.5 mm and spaced at a pitch of 10 mm. These fins are manufactured using Aluminum 6061 alloy, known for its good thermal conductivity.

Sr.No	Type	4 Stroke,SI
1	Displacement	124cc
2	Max Net Power	8kW @ 7500 rpm
3	Max Net Torque	10.9 N-m @ 6000 rpm
4	Fuel System	PGM-FI
5	Compression Ratio	10.0:1
6	Bore X Stroke	50.0 X 70 mm

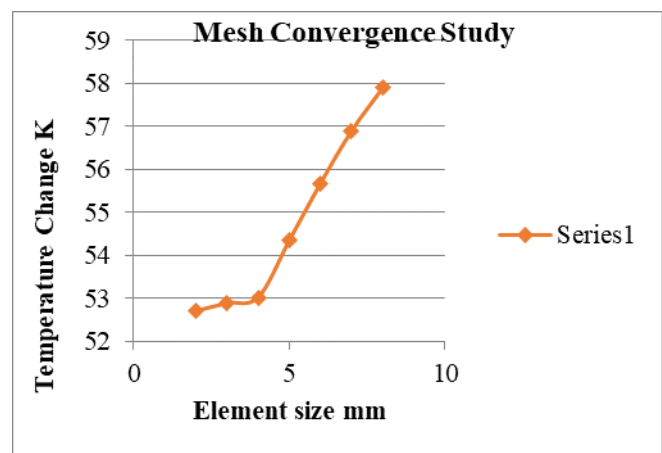
#### 3.2 MESH CONVERGENCE STUDY -

Table -1: Honda SP 125 Standard Engine fin model specification

Sr. No	Engine parameter	Value
1	Bore Diameter	50mm
2	Stroke Length	70mm
3	Fin thickness	2.5 mm
4	Fin Pitch	10mm
5	Number of fins	7

To identify the optimal element size for finite element analysis, a mesh convergence study was conducted. Mesh sizes varying from 2 mm to 8 mm were assessed, with corresponding temperature variations recorded for each. The results indicated that temperature differences were negligible for mesh sizes of 2 mm, 3 mm, and 4 mm. Consequently, a 3 mm mesh size was chosen for subsequent simulations as it offered a good compromise between computational efficiency and accuracy..

Chart -1: Mesh convergence study



#### 3.3. GEOMETRICAL VARIATIONS

Six different fin geometries were modelled and analysed:

- Rectangular fins
- Rectangular fins with slots
- Circular fins
- Circular fins with perforations
- Angular fins
- Longitudinal fins

All fins were modelled with a uniform thickness of 2.5 mm using Aluminium 6061 as the base material.

### 3.4 Boundary Conditions and Simulation Setup

The thermal simulations were conducted in ANSYS Workbench, applying specific boundary conditions. The internal surface of the engine was set to a temperature of 500 °C, while the surrounding ambient temperature was maintained at 25 °C. A convective heat transfer coefficient was used based on stagnant air conditions. Transient thermal analysis was employed to observe the temperature distribution and heat flux across various fin designs.

### 3.5. EVALUATION PARAMETERS

Each fin configuration was evaluated based on:

- Temperature change ( $\Delta T$ )
- Heat flux ( $W/m^2$ )
- Heat transfer rate ( $W/m^2K$ )
- Mass (in grams)
- Power-to-weight ratio (calculated as heat transfer rate divided by mass)

### 3.6. MATERIAL STUDY

Following the results of the geometrical analysis, the circular fin design featuring perforations was chosen for further material evaluation, as it exhibited a high heat transfer rate along with a favorable power-to-weight ratio.

The materials evaluated included:

- Aluminium 6082
- Aluminium A204
- Cast Iron
- Magnesium Alloy AZ31
- Beryllium Oxide

The performance of each material was evaluated by simulating parameters such as heat flux, temperature variation, heat transfer efficiency, and the resulting weight of the component.

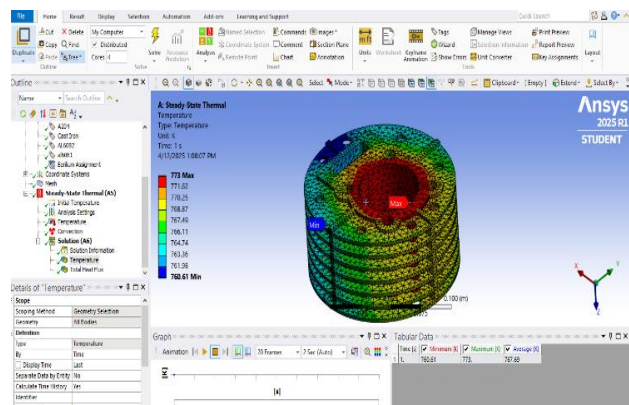


Fig-1 Temperature Contour of Circular Fin with hole  
BeO Beryllium Oxide

### 3.7 Result Interpretation

The simulation outcomes were assessed using the previously mentioned evaluation criteria. The optimal fin and material combination was determined by balancing thermal efficiency—reflected in a high heat transfer rate—and mechanical factors such as reduced weight and enhanced durability.

## 4. RESULTS

Table -2 Thermal Performance of Different Fin Shapes

Fin Shape	Temperature Change (K)	Heat Flux ( $W/m^2$ )	Heat Transfer Rate ( $W/m^2K$ )	Mass (g)	Power/Weight Ratio
Rectangular	26.9	226,420	8417.1	995	8.04
Rectangular with Slot	28.68	229,990	8019.17	950	8.42
Circular	20.35	182,210	8953.8	920	8.69

Among the fin designs evaluated, the circular fin with perforations provided the most effective balance between thermal performance and power-to-weight ratio. While the angular and longitudinal fins showed relatively higher power-to-weight ratios, they fell short in terms of overall heat transfer efficiency when compared to the circular fin.

## 5. MATERIAL STUDY RESULTS

Additional analysis was carried out on the top-performing design—circular fin with perforations—by testing it with various material options.

Table -3 Thermal Performance for Different Materials (Circular Fin with Perforations)

Material	Thermal Conductivity ( $W/mK$ )	Heat Flux ( $W/m^2$ )	Temperature Change (K)	Heat Transfer Rate ( $W/m^2K$ )	Weight (kg)
Aluminium 6082	180	182,470	19.3	9454.4	0.903
Aluminium A204	156	179,630	26.28	6843.0	0.9335
Cast Iron	80	173,560	41.15	4217.74	2.4
Magnesium Alloy AZ31	96	176,140	34.84	5055.7	0.6
Beryllium Oxide	285	185,290	12.39	14,954.8	1.0

## 6 KEY OBSERVATIONS

- **Beryllium Oxide** demonstrated the highest heat transfer rate (14,954.8 W/m<sup>2</sup>K) but came at a higher cost and moderate weight penalty.
- **Aluminium 6082** emerged as a highly suitable material offering an excellent balance of high heat transfer rate, moderate cost, and low weight.
- **Magnesium Alloy AZ31**, although very lightweight, exhibited a comparatively lower heat transfer capability.

## 7. FINAL SELECTION

Taking into account thermal efficiency, ease of manufacturing, weight, and cost-effectiveness, the perforated circular fin constructed from Aluminium 6082 emerged as the most suitable and efficient choice for use in two-wheeler engine systems.

## 8. CONCLUSIONS

This study aimed to enhance the design of cylinder head fins for the Honda SP 125 two-wheeler engine by exploring both geometric and material modifications, using comprehensive simulations in ANSYS. Among the different fin shapes assessed, the circular fin with perforations delivered the best results, offering a high rate of heat dissipation along with a superior power-to-weight ratio. The addition of perforations improved airflow and induced greater turbulence, which significantly increased cooling effectiveness. In the material evaluation phase, Aluminum 6082 emerged as the most appropriate option due to its excellent thermal conductivity, mechanical strength, low weight, and cost-efficiency. While Beryllium Oxide showed better thermal characteristics, its high cost and handling challenges make it less practical. As a result, the optimized design—circular perforated fins made from Aluminum 6082—proves to be a highly efficient and affordable solution for enhancing thermal regulation in two-wheeler engines, thereby improving performance, lowering emissions, and boosting fuel economy.

## 9. FUTURE SCOPE

- While the simulation findings provide strong support for the suggested fin design improvements, there are still multiple aspects that warrant additional research:
- **Experimental Validation:** Performing live engine experiments to confirm the simulation results under real-world conditions, including changes in speed, load, and environmental temperature.
- **Advanced Materials:** Investigating advanced lightweight materials and composite options, like

graphene-enhanced alloys or hybrid materials, to further enhance thermal conductivity.

- **3D Printed Fin Structures:** Examining the use of additive manufacturing techniques to produce intricate, biomimetic fin designs that maximize airflow while minimizing weight.
- **Forced Convection Analysis:** Expanding the research to incorporate forced convection conditions to better represent the cooling effects during high-speed operation of two-wheelers.
- **Vibration and Fatigue Analysis:** Analyzing the durability of the optimized fin designs by examining their mechanical performance under prolonged engine vibrations and repeated thermal cycling.

Pursuing these future research avenues could pave the way for innovative cooling solutions, driving improvements in two-wheeler engine performance and promoting sustainability.

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