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DESIGN MODIFICATIONS OF CYLINDER HEAD FINS FOR TWO-WHEELER ENGINE THROUGH GEOMETRICAL AND MATERIAL ANALYSIS

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Abstract —**The main aim of this work is to analyse and simulate engine fin geometry and type of material used for two wheeler engine for Honda SP 125 cylinder fins on temperature distribution and heat flux. we have used fins with various geometries such rectangular, rectangular with slot circular, circular with slot, angular, longitudinal fins of 2.5 mm thickness. Results showed as circular with perforation has good heat transfer rate as well as good power to weight ratio. Depending on this geometry, materials Aluminium 6082, AL204, cast iron, Mg alloy, AZ31, Beryllium oxide materials were analysed and models developed in ANSYS 16.2 version Then Finite Element Analysis (FEA) done on all models using ANSYS software for parameters like he heat distribution and heat flux and results from each model are noted. Beryllium oxide material gives better heat transfer rate. The 3D model is created in SolidWorks and analysis is done using ANSYS Software in steady state conditions. The result is compared to find the best geometry which gives the maximum heat flux.**

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

I. INTRODUCTION

The thermal management of internal combustion engines, particularly in two-wheeled vehicles, is critical for ensuring operational efficiency, reliability, and durability. Among various cooling methods, air-cooling systems dominate the design of two-wheeler engines due to their simplicity, cost-effectiveness, and robustness. These systems primarily rely on the cylinder head fins to dissipate heat generated during the combustion process

The geometry, number, size, and material of the fins significantly influence the engine's cooling performance. Optimizing these parameters is a delicate balance: while increasing the number of fins or their surface area can enhance heat dissipation, it also contributes to increased engine mass, which negatively impacts the power-to-weight ratio—a critical factor in two-wheeler performance. Moreover, fin thickness, spacing, and arrangement must be designed carefully to avoid obstructing airflow, which would otherwise reduce the efficiency of convective heat transfer

Recent studies have demonstrated the advantages of perforating the fins to promote turbulence and disrupt thermal boundary layers. Among the various perforation shapes, circular perforations have shown superior thermal performance compared to rectangular or triangular designs, achieving better mass reduction and higher heat transfer rates. Furthermore, the use of high thermal conductivity materials, such as aluminium alloy 6063-T6, has proven to significantly enhance cooling efficiency while maintaining mechanical integrity.

In light of these considerations, this research aims to systematically investigate the design modifications of cylinder head fins for two-wheeler engines through geometrical and material analysis. By employing computational modelling and simulation techniques, this study explores various fin configurations, material selections, and perforation patterns to propose optimized designs that maximize heat dissipation while minimizing weight and manufacturing complexity. The findings are expected to contribute not only to the technical advancement of engine cooling systems but also to broader objectives related to fuel efficiency, emission reduction, and sustainable transportation.

A Fins: A Fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the Heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to the object, however, increases the surface area and can sometimes be economical solution to heat transfer problems. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples.

The temperature distribution within an SI engine is extremely important for proper engine operation to maximize the thermal efficiency of an engine; it has to be operated at specific

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thermal condition Actually Fins are provided because, they provide a channel for cooling the engine whenever it gets hot. Fins doesn't let the engine to burn out. The fins provided on the engine cylinder depends on the capacity of the engine. Higher the capacity of the engine, more number of fins provided on the surface of the engine block.. This condition is controlled by cooling process of fins that tends to remove the heat that is highly critical in keeping an engine and engine lubricant from thermal failure and thermal effects.

II. LITERATURE REVIEW

Chandrakant R et al. did numerical simulation of the finned cylinder presented to improve the heat dissipation rate of an engine. The model is prepared using Autodesk Fusion 360 whereas ANSYS is used to conduct steady-state thermal analysis. Numerical simulations are carried out for two different fin materials: Aluminium alloy 204 and 6061.The effect of fin geometry with varying fin thickness, pitch as well as orientation is also analysed and a detailed comparison for temperature distribution, total heat flux is presented. Our numerical results show that Aluminium alloy 6061 performed better than the existing configuration with significant improvements in both, heat transfer as well as in power to weight ratio.

Sroka ZJ et al. Heat transfer modelling and simulation were carried out in a single-cylinder, four-stroke, air-cooled engine to evaluate the heat transfer rate of the engine block. The modelling studies of cylinders with different numbers of fins and different geometry were performed using the SolidWorks computer platform. The tested components were made of 6063-T6 aluminium alloy castings. The simulation concerned different numbers of fins as well as changing the geometry of fins with circular and rectangular perforations. The results of the studies showed the possibility of improving the power to mass ratio for cylinder efficiency and heat transfer rate. It was shown that a large number of fins leads to an increased heat transfer rate, but it affects the overall engine efficiency due to the increase in the total engine mass. Circular perforation is a better design solution than rectangular perforated fins with the same cross-section. Circular perforation provides a lower engine cylinder mass and gives more than 4 % better heat transfer rate. The perforation size was tested using circular perforations with a diameter of 7.14 mm, 8.5 mm and 10 mm. With a 7.14 mm diameter perforation, the heat transfer rate increases slightly compared to the other tested ones, while a 10 mm diameter perforation provides the best mass reduction.

S.K. Mohammad Shareef et al. The main aim of the present numerical investigation is to assess the thermal properties of engine cylinder by varying geometry, material and profile of cylinder fins using Ansys workbench. The models are created with the aid of SolidWorks. In the present work, the optimization of engine cylinder fins by using cast iron, copper alloy and Al6082 material are examined numerically by taking fin profile as rectangle, circular and angular.

Nihal Chavan et al. In this study we selected efficient materials and geometry of the fins in order to achieve optimum heat transfer, the thermal analysis of the selected materials and geometry lead us to the average heat flux values, comparison of which helped stipulate the best material and geometry. The average heat flux of the Aluminium 7075 is observed as maximum compared to other Aluminium alloys chose for this study.

P.L Rupesh et al. The present work focuses on the design of fins of circular and tapered shapes for a 2-stroke engine. The temperature distribution and the heat dissipation along the fin surface of two shapes has been observed by a steady state thermal analysis. Alusil and Silumin has been selected as the fin materials and a computational evaluation has also been done using FEM. A better shape of the fin along with a suitable material has been selected based on the results observed by FEM and on comparison with the existing shape and material of the fin.

N. Muthuram et al. This research aims to enhance the effectiveness of engine cooling systems through the fin design, which may involve incorporating slots to expand the surface area and improve overall efficiency. The analysis involved two fin geometries, rectangular and cylindrical fins, made of Aluminium 1100 material. The design models are created using the computer-aided design software PTC CREO Parametric 6.0., and steady-state thermal analysis and modal analysis were performed using ANSYS 2023 R1. The steady-state thermal analysis results indicate that the slotted cylindrical fin design demonstrated the highest heat transfer rate compared to the conventional fin design. The results from this study are expected to provide valuable performance in improving heat dissipation.

Sk. Avinash Kapil et al**.** The main objective of the paper is to analyse the thermal behaviour of cylinder fins by varying materials. In this work, cast iron is replaced by Aluminium Alloy and Gray Cast Iron. They concluded that Aluminium alloy is the best material for engine fins. Thermal analysis is
which indirectly increases the manufacturing cost of the component. done by using the dimensions of BAJAJ 150CC engine block.

Pulasari Srinivas and Vadlamudi Ravikumar In this paper the extended surfaces i.e. fins of Honda Shine & Bajaj Discover two wheeler automotives are tested to investigate effect on heat transfer rate by Cross-section, Fin Pitch, Fin Material and Fin Thickness. The parametric model of engine block fins has been developed in 3D BY Using catia software and thermal analysis is done on the with holes and without holes fins and to determine heat flux and temperature distribution Currently the material used for manufacturing cylinder fin body is Aluminium 2014 and grey cast iron proposed material is Aluminium 6061 addition in this Thesis, materials are also analysed. The thermal analysis is done using all three materials by changing geometries that is perforating to the actual model heat dissipation rate. Finally, they concluded the al6061 is suitable for cylinder fins because of better heat flux rate.

Mohan Das et al**.** The objective of this paper is to find out the cooling efficient by varying the Cylinder fin thickness. They found that fin thickness having 3mm giving more heat transfer than the fin thickness of 2.5mm and 2mm. They finally concluded that increasing the fin thickness, the heat transfer rate also increases.

Mukesh Kumar Singh and H.S. Sahu
The purpose of this paper is to find out which fin shape or structure is more suitable for engine cooling and which material give more heat transfer. They concluded that pin fins with slanted edges would be employed in heat sink which increases the heat transfer rate.

M.S.V. Kartheek et al**.** The primary objective of this paper is to change the fins profile, thickness and the distance between the fins and the material of the fin. They used model in Pro/Engineer software and analysis in Ansys. They concluded that the changing the fins geometry to curvy 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 a**l.** The primary aim of this paper is to find out which material is more suitable for engine cylinder fins. They performed thermal analysis on Aluminium alloy and Magnesium alloy and compared the results. They concluded that using magnesium alloy will decreases the weight as magnesium is less-denser than Aluminium and give similar heat transfer rate like Aluminium.

R. Suresh et al**.** In this paper they changed the engine cylinder material form Cast iron to Aluminium Alloy 6082 and did thermal analysis on both the materials. They finally concluded that Aluminium alloy 6082 give more heat transfer rate and heat flux than Cast iron. The material of the original model is changed by considering the densities and their thermal conductivity.

G. Babu and M. Lava Kumar The objective of this paper is to analyse the thermal properties by varying geometry and material of the engine cylinder fins. They did the thermal analysis on Aluminium alloy 606, Aluminium alloy 204 and Magnesium alloy. They concluded that using curve geometry will give more heat transfer and said that more research to be done on it.

III. METHODOLOGY

A Engine Model Selection-

Specification of Honda SP 125 Engine The present analysis focuses on the Honda SP 125 engine, a widely used two-wheeler model, for the thermal analysis of cylinder head fins. The engine parameters used are: bore diameter of 50 mm, stroke length of 70 mm, with fins of 2.5 mm thickness and 10 mm fin pitch. The cylinder head incorporates seven fins made of Aluminum 6061 alloy.

Table -1: Honda SP 125

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

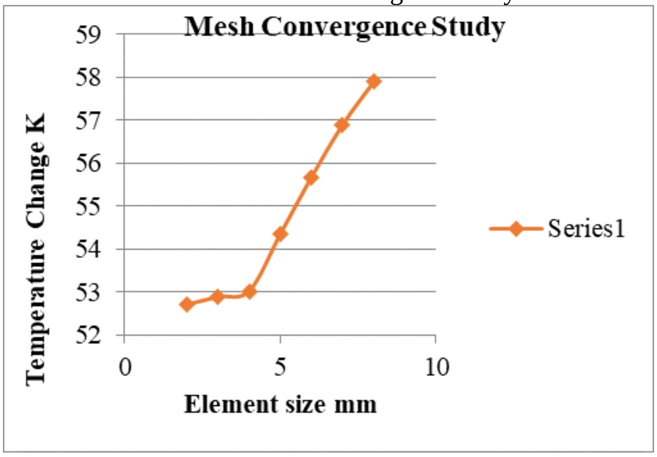
B Mesh Convergence Study –

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

A mesh convergence analysis was performed to determine the optimum element size for finite element simulations. Mesh sizes ranging from 2 mm to 8 mm were evaluated, and the corresponding temperature changes were recorded. It was observed that there was minimal variation in temperature changes between mesh sizes of 2 mm, 3 mm, and 4 mm. Therefore, a mesh element size of 3 mm was selected for further simulations to balance computational efficiency and solution 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 simulations were carried out in ANSYS Workbench using the following boundary conditions:

- Internal engine surface temperature: 500 °C
- Ambient temperature: 25 °C

Convective heat transfer coefficient: stagnant air conditions assumed Transient thermal simulations were performed to capture the temperature distribution and heat flux across the different fin configurations.

3.5 Evaluation Parameters
Each fin configuration was evaluated based on:

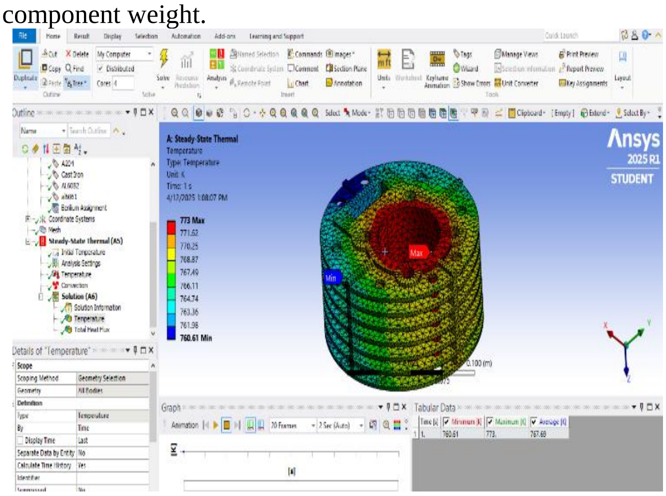
- Temperature change (ΔT)
- Heat flux (W/m²)
- Heat transfer rate (W/m²K)
- Mass (in grams)
- Power-to-weight ratio (calculated as heat transfer rate divided by mass)

3.6 Material Study
Based on the geometrical analysis results, the circular fin with perforations, which demonstrated both high heat transfer rate and favourable power-to-weight ratio, was selected for further material analysis.

The materials evaluated included:

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

Each material's performance was analysed by simulating heat flux, temperature change, heat transfer rate, and corresponding component weight.



Temperature Contour of Circular Fin with hole **BeO** Beryllium Oxide

3.7 Result Interpretation
The simulation results were compared based on the above evaluation parameters
The best fin and material combination was identified based on a trade-off between thermal performance (high heat transfer rate) and mechanical considerations (low mass and high durability).

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IV RESULTS

Table -2 Thermal Performance of Different Fin Shapes

Fin Shape	Temperature Change (K)	Heat Flux (W/m²)	Heat Transfer Rate (W/m²K)	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
Circular Perf	20.77	176,290	8487.72	900	8.88

The circular fin with perforations achieved an optimal balance between a high heat transfer rate and a high power-to-weight ratio. Although the angular and longitudinal fins exhibited higher power-to-weight ratios, their overall thermal efficiency was considerably lower compared to circular fins .

V . MATERIAL STUDY RESULTS

Further analysis was conducted for the best-performing geometry (circular fin with perforations) using different materials. The results are shown in Table 3

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

Material	Thermal Conductivity (W/mK)	Heat Flux (W/m²)	Temperature Change (K)	Heat Transfer Rate (W/m²K)	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

VI KEY OBSERVATIONS

- **Beryllium Oxide** demonstrated the highest heat transfer rate (14,954.8 W/m²K) 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.

VII FINAL SELECTION

Considering thermal performance, manufacturability, weight considerations, and economic factors, the **circular fin with perforations** made of **Aluminium 6082** was identified as the most efficient and practical design for two-wheeler engine applications.

VIII. CONCLUSIONS

This research focused on optimizing the design of cylinder head fins for a two-wheeler engine (Honda SP 125) through geometrical and material modifications, supported by detailed computational analysis using ANSYS. Among various geometrical configurations evaluated, the circular fin with perforations demonstrated the most favourable performance, achieving a high heat transfer rate combined with an improved power-to-weight ratio. The incorporation of perforations enhanced the airflow and promoted greater turbulence, significantly boosting the overall cooling efficiency. Further material analysis revealed that Aluminum 6082 was the most suitable material choice, offering excellent thermal conductivity, structural integrity, lightweight properties, and cost-effectiveness. Although Beryllium Oxide exhibited superior thermal performance, its practical application is limited due to higher cost and material handling complexities. Therefore, the optimized combination of circular perforated fins made from Aluminum 6082 presents a highly effective, economically viable solution to improve the thermal management of two-wheeler engines, contributing to enhanced engine performance, reduced emissions, and improved fuel efficiency.

IX. FUTURE SCOPE

Although the simulation results strongly validate the proposed fin modifications, several areas remain open for further investigation:

- **Experimental Validation:** Conducting real-time engine testing to validate simulation findings under dynamic operating conditions (e.g., varying speeds, loads, and ambient temperatures).
- **Advanced Materials:** Exploring newer lightweight materials and composites, such as graphene-reinforced alloys or hybrid structures, for further improving heat transfer performance.
- **3D Printed Fin Structures:** Investigating the potential of additive manufacturing to create complex, biomimetic fin geometries optimized for maximum airflow and minimum weight.
- **Forced Convection Analysis:** Extending the study to include forced convection scenarios to simulate high-speed two-wheeler motion more realistically.
- **Vibration and Fatigue Analysis:** Studying the long-term mechanical behavior of optimized fin structures under engine vibrations and thermal cycling to ensure durability.

The implementation of these future directions can lead to the development of next-generation cooling technologies, advancing two-wheeler engine designs towards higher performance and sustainability.

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