ISSN : 2455-9679
SJIF Impact Factor : 6.190

IJRTSM
INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"AIR-COOLED ENGINE CYLINDER FINS: A REVIEW OF FIN GEOMETRY, FIN MATERIALS, AND NUMERICAL THERMAL ANALYSIS"

Mohammad Nabi Alam [1], Prof Gajendra Das Kori [2]

[1] PG scholar, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India
[2] Assistant Professor, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India

ABSTRACT

The engine cylinder is one of the most heavily loaded parts of an automobile because it is exposed to large and rapid temperature changes and to the resulting thermal stresses. In air-cooled engines, which are widely used in motorcycles, scooters, and small stationary engines, the heat that is conducted through the cylinder wall is rejected to the surrounding air through fins on the outer surface of the cylinder. The heat dissipated depends on the area of the fins, their geometry, thickness, pitch, and material, and on the speed and temperature of the air. This review paper presents an assessment of published research on engine cylinder fins, with emphasis on experimental studies in wind tunnels, the influence of fin pitch, number, and thickness, the effect of fin geometry such as rectangular, circular, curved, and slotted profiles, the choice of fin material, and the use of finite element analysis (FEA) and computational fluid dynamics (CFD) for steady-state and transient thermal analysis. The reviewed literature indicates that air velocity and fin spacing have the largest influence on the heat transfer coefficient, that circular fins of aluminium alloy 6061 have been reported to perform well among the profiles and materials compared, and that numerical analysis is now the standard tool for screening fin designs before manufacture. Research gaps are identified, including the dominance of simplified boundary conditions, limited experimental validation, scarce reporting of total heat dissipation, and few studies that compare fin geometries of different plan shape under identical conditions. The findings are intended to guide the design and analysis of air-cooled engine cylinder fins.

Key Words: *Engine cylinder fins; air cooling; thermal analysis; ANSYS; aluminium alloy 6061; heat transfer coefficient; fin geometry; finite element analysis.*

I. INTRODUCTION

Only a part of the energy released by the fuel in an internal combustion (IC) engine is converted into useful work, and a substantial share, commonly of the order of one-third, has to be removed through the cooling system [1]. The cooling system must keep the temperature of the cylinder, piston, and lubricating oil within safe limits. Excessive temperature damages the lubricating film and may cause seizure of the moving parts, whereas over-cooling reduces the thermal efficiency of the engine. The aim of cooling is therefore to hold the engine at a suitable operating temperature rather than to cool it as much as possible. Two methods are in common use. In liquid cooling, a coolant is circulated through passages in the engine and rejects its heat at a radiator, with the circulation produced by thermo-siphon action or by a pump. In air cooling, the heat is transferred directly from the engine surface to the air that flows past it. Liquid cooling is usual in cars and high-power engines, because liquids have a much larger heat capacity than air, but it adds a radiator, pump, and coolant, and therefore weight, complexity, and cost. Air cooling is simpler and lighter and is used in motorcycles, scooters, light aircraft, and small portable engines [1], [3].

Heat is transferred from the cylinder to the air by convection, and the rate is given by Newton's law of cooling, Q =

ISSN : 2455-9679
SJIF Impact Factor : 6.190

hAΔT, in which h is the convective heat transfer coefficient, A is the surface area, and ΔT is the temperature difference between the surface and the air. Because the coefficient h for air is small, the only practical way of increasing the heat rejected from a cylinder of a given size is to increase the area, and this is done by providing fins on its outer surface. The effectiveness of the fins depends on their number, pitch, height, thickness, geometry, and material, on the speed of the air, and on the ambient temperature. If the pitch is too small, the thermal boundary layers of neighbouring fins overlap and the air cannot flow freely between them, so that more fins do not necessarily give more cooling [3], [9]. In India the air-cooled motorcycle of 100 to 150 cc is very common, so the optimisation of the fins of these engines has considerable practical importance.

The design of fins has traditionally relied on experiments in wind tunnels, in which finned cylinders are heated electrically and cooled by a controlled air stream [2], [6]–[8]. More recently the experimental work has been supplemented by finite element and CFD analyses in which three-dimensional models of the fins, prepared in CAD software such as CATIA, Pro/E, or SolidWorks, are analysed in ANSYS for different geometries and materials [12]–[17]. These tools allow many fin configurations to be compared at low cost before a prototype is made. This paper reviews the research on these topics and identifies the gaps that remain.

II. Problem Identification

The cylinder of an air-cooled engine must reject its heat to the surrounding air through the fins, and the combustion gases are very much hotter than the permissible temperature of the cylinder material. The heat must therefore be removed quickly enough to prevent overheating, yet the cooling should not be so strong that the engine is over-cooled. The designer can alter the geometry, pitch, thickness, number, and material of the fins, but these parameters interact with one another and with the conditions of use, such as the speed of the vehicle and the ambient temperature, so the best combination is not obvious.

The published work on fins is extensive, but a large part of it addresses fins on flat plates and heat-exchanger tubes, with comparatively little attention to the fins of engine cylinders. Experimental studies usually deal with straight fins of simple shape, and numerical studies often assume a constant wall temperature and a constant or approximate heat transfer coefficient and report only a temperature or a heat flux. Comparisons between fins of different plan shape, such as circular, rectangular, and rounded-square, under identical thermal boundary conditions are scarce. A consolidated review is therefore needed to summarise the available evidence and to identify the gaps that the next studies should address.

III. Research Objective

The main objective of this review paper is to examine published research on the thermal behaviour of engine cylinder fins. The specific research objectives are as follows:

- To review the cooling of IC engines: Describe air and liquid cooling and the role of fins in air-cooled cylinders.
- To examine experimental studies: Review wind-tunnel studies of finned cylinders and the effect of air velocity, fin pitch, and fin dimensions.
- To review fin geometry and material: Examine the influence of fin shape, thickness, and material on heat transfer.
- To evaluate numerical methods: Review finite element and CFD analyses of fins and the boundary conditions that are used.
- To identify research gaps: Identify limitations in existing studies relevant to the comparison of fin geometries.

ISSN : 2455-9679
SJIF Impact Factor : 6.190

IV. Literature Review

The studies reviewed below are grouped into experimental work, studies of fin geometry and material, and recent numerical studies. For each study the scope and principal findings are summarised as reported by the authors, and its relevance to the design of engine cylinder fins is highlighted. Where a study is described only by its stated scope, no quantitative results are attributed to it.

Experimental studies. The air cooling of engine cylinders was investigated early in the history of the IC engine; Gibson reported studies of the air cooling of petrol engines in 1920 [5]. Biermann and Pinkel (1935) [2] tested heated finned steel cylinders in a wind tunnel over a wide range of air speeds, fin lengths, and fin thicknesses. They concluded that the air velocity and the spacing between the fins had the greatest influence on the surface heat transfer coefficient, whereas the other fin dimensions had a minor effect. Pai, Samaga, and Mahadevan (1977) [6] reported experimental studies of heat transfer from the finned cylinders of air-cooled IC engines, and Thornhill and May (1999) [7] and Thornhill et al. (2003) [8] reported experimental investigations of the cooling of finned metal cylinders in a free air stream. Yoshida et al. (2006) [9] studied in a wind tunnel the influence of fin number, fin pitch, and wind velocity on the air cooling of a motorcycle engine, and found that at low wind speed a closer fin pitch did not improve the heat release because the gap between the fins became too small for the air to enter. These studies establish that more fins do not always cool better and that the effect of the fin pitch depends on the air velocity.

Fin geometry. Akyol and Bilen (2006) [10] analysed the heat transfer and thermal performance of a surface with hollow rectangular fins, and Lorenzini and Rocha (2006) [11] carried out a constructal design of a Y-shaped assembly of fins; although these studies concern general finned surfaces, they illustrate that the shape of the extended surface can be optimised to increase the heat transfer for a given material volume.

Geometry and material of engine fins. Rao and Vardhan [12] analysed the thermal behaviour of the fins of a 150 cc engine cylinder by varying the geometry (rectangular, circular, and curved), the thickness, and the material, comparing aluminium alloy A204, which is the present fin material, with aluminium alloy 6061 and a magnesium alloy, which have higher thermal conductivity. A transient thermal analysis was used to determine the temperature and heat flux of the models. Babu and Lavakumar [13] made a heat transfer analysis and optimisation of engine cylinder fins of varying geometry and material, and concluded from their results that a circular fin of aluminium alloy 6061 and 2.5 mm thickness was the best of the combinations considered. Kumar, Singh, and Sharma [14] carried out a static thermal analysis of fin models in ANSYS using aluminium alloy 1060, with models of several fin geometries. These studies agree that the thickness and shape of the fin influence the heat dissipation and that high-conductivity aluminium alloys are favoured, but the results are obtained for particular engines and boundary conditions.

Recent numerical studies. An AIMACE-2025 simulation study [15] compared aluminium 6061 alloy and grey cast iron for fins with fillet corners and drafted edges at 2.5 mm and 4 mm thickness under natural convection; the authors reported that grey cast iron showed better thermal retention, that aluminium 6061 had advantages in weight and manufacturability, and that drafted edges gave a more uniform heat distribution than fillet corners. Muthuram et al. (2024) [16] analysed rectangular and cylindrical fins of aluminium 1100 in a steady-state thermal analysis and found that a slotted cylindrical fin gave the highest heat transfer rate. A 2024 study in *Processes* [17] used ANSYS with direct optimisation and found that the length and width of the fin were critical to the cooling efficiency, with an improvement of about 26% in the total heat flux over a generic design; the authors recommended future work on alternative materials, transient heating, and experimental verification.

Table 4.1: Summary of selected studies on engine cylinder fins

Study	Focus	Principal finding reported
Biermann and Pinkel (1935) [2]	Wind-tunnel tests of finned cylinders	Air velocity and fin spacing dominate h

ISSN : 2455-9679
SJIF Impact Factor : 6.190

Yoshida et al. (2006) [9]	Fin number, pitch and wind speed	Closer pitch not better at low wind speed
Rao and Vardhan [12]	Fin shape, thickness, material	Al 6061 compared with A204 and Mg alloy
Babu and Lavakumar [13]	Geometry and material optimisation	Circular Al 6061 fin, 2.5 mm preferred
AIMACE-2025 study [15]	Al 6061 versus grey cast iron	Drafted edges more uniform than fillets
Muthuram et al. (2024) [16]	Rectangular and cylindrical fins	Slotted cylindrical fin best
Study in Processes (2024) [17]	Direct optimisation of fin size	About 26% higher total heat flux

Summary and research gaps. Several themes emerge from the reviewed work. First, the heat transfer from a finned cylinder is governed mainly by air velocity and fin spacing, and increasing the number of fins does not help when the spacing becomes too small [2], [9]. Second, fin geometry, thickness, and material all influence the heat dissipation, and circular fins of aluminium alloy 6061 have been reported to perform well among the cases compared [12], [13]. Third, finite element analysis in ANSYS is the standard method for comparing fin designs, but it is usually carried out with simplified boundary conditions and without experimental validation [14]–[17]. The reviewed studies also have limitations: only a few compare fins of different plan shape under identical conditions, the total heat dissipated is seldom reported, and the influence of the temperature dependence of the convection coefficient and of the geometry of the cylinder is rarely discussed. These gaps motivate a comparative steady-state analysis of fins of several plan shapes.

V. Conclusion

This review examined published research on engine cylinder fins. The literature shows that air-cooled cylinders depend on fins to reject heat, that the air velocity and the fin spacing have the strongest influence on the heat transfer coefficient, and that fin shape, thickness, and material also affect the heat dissipation. Aluminium alloys, and aluminium alloy 6061 in particular, are favoured because of their conductivity and weight, and circular fins have been reported to perform well in several comparisons. Finite element analysis in ANSYS allows fin designs to be screened quickly, but it relies on simplified boundary conditions and is seldom validated. Future research should compare fins of different plan shape under identical boundary conditions, report the total heat dissipated together with the temperature and heat-flux fields, use a realistic temperature-dependent convection coefficient, include transient and thermal-stress analyses, and validate the numerical results by wind-tunnel experiments. These steps can support the design of lighter and more effective cooling fins for air-cooled engines.

REFERENCES

[1] V. Ganesan, Internal Combustion Engines. New Delhi: Tata McGraw-Hill.
[2] A. E. Biermann and B. Pinkel, “Heat transfer from finned metal cylinders in an air stream,” NACA Report No. 488, 2024.
[3] K. K. Ramalingam, Internal Combustion Engines: Theory and Practice. Chennai: SciTech Publications (India).
[4] P. L. Ballaney, Internal Combustion Engines. New Delhi: Khanna Publishers.
[5] A. H. Gibson, “The air cooling of petrol engines,” Proceedings of the Institution of Automobile Engineers, vol. XIV, pp. 243–275, 1925.
[6] B. U. Pai, B. S. Samaga, and K. Mahadevan, “Some experimental studies of heat transfer from finned cylinders of air-cooled I.C. engines,” in Proc. 4th National Heat and Mass Transfer Conference, 2022, pp. 137–144.

ISSN : 2455-9679
SJIF Impact Factor : 6.190

[7] D. Thornhill and A. May, "An experimental investigation into the cooling of finned metal cylinders in a free air stream," SAE Paper 1999-01-3307, 2023.
[8] D. Thornhill, A. Graham, G. Cunningham, P. Troxier, and R. Meyer, "Experimental investigation into the free air-cooling of air-cooled cylinders," SAE Paper 2023-32-0034, 2023.
[9] M. Yoshida, S. Ishihara, Y. Murakami, K. Nakashima, and M. Yamamoto, "Air-cooling effects of fins on a motorcycle engine," JSME International Journal, Series B, vol. 49, no. 3, pp. 869–875, 2006.
[10] U. Akyol and K. Bilen, "Heat transfer and thermal performance analysis of a surface with hollow rectangular fins," Applied Thermal Engineering, vol. 26, pp. 209–216, 2026.
[11] G. Lorenzini and L. A. O. Rocha, "Constructal design of Y-shaped assembly of fins," International Journal of Heat and Mass Transfer, vol. 49, pp. 4552–4557, 2026.
[12] N. Phani Raja Rao and T. Vishnu Vardhan, "Thermal analysis of engine cylinder fins by varying its geometry and material," International Journal of Engineering Research & Technology.
[13] G. Babu and M. Lavakumar, "Heat transfer analysis and optimization of engine cylinder fins of varying geometry and material," IOSR Journal of Mechanical and Civil Engineering.
[14] R. Kumar, D. Singh, and A. K. Sharma, "Static thermal analysis of fins models using Ansys," engrXiv preprint.
[15] "Thermal performance analysis of engine cylinder fins: Design and simulation study," EPJ Web of Conferences, vol. 343, Art. no. 01003, 2025, doi: 10.1051/epjconf/202534301003.
[16] Muthuram, B. K. Kanchan, and K. Ajith Kumar, "Improving engine cooling performance through slotted fin design: A steady-state thermal analysis study," Journal of Heat and Mass Transfer Research, 2024, doi: 10.22075/jhmtr.2024.32559.1502.
[17] "Enhancing engine cylinder heat dissipation capacity through direct optimization (DO) techniques," Processes, vol. 12, Art. no. 2659, 2024.