Thermal Performance Analysis of Engine Cylinder Fins: Design and Simulation Study

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Abstract. Effective engine cooling is essential for maintaining the performance and durability of internal combustion engines. The present study examines the thermal efficiency of engine cylinder fins by design, modeling, and simulation. Multiple fin configurations—fillet corners and drafted edges—were examined through Solidworks simulation, concentrating on two materials, Aluminum 6061 alloy and grey cast iron, with differing thicknesses (2.5 mm and 4 mm). The simulation assessed heat dissipation, temperature distribution, and overall thermal efficiency in natural convection settings. It is found that grey cast iron has enhanced thermal retention, but Aluminum 6061 alloy presents benefits in terms of weight and manufacturability. The present study highlights the importance of fin geometry, indicating that drafted edges provide more uniform heat distribution than fillet corners. Thus, the optimization of engine cooling system design was performed by integrating performance with material expenses.

Keywords. Engine Cooling, Cylinder Fins, Thermal Analysis, Aluminium Alloys, Grey Cast Iron, Computational Simulation

1 Introduction

Heat management is crucial in internal combustion engines for maintaining performance, dependability, and durability [1]. Only a portion of the heat produced by fuel combustion is transformed into productive work during operation, whereas a considerable amount of heat is lost via cylinder walls, exhaust gases, and friction [2]. Excessive heat accumulation may result in engine damage, diminished efficiency, and operational faults, including banging and

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pre-ignition in the absence of an efficient cooling system. Thus, the optimization of cooling systems has emerged as a focus of research in existing engines in the search of enhanced efficiency and environmental adherence.

Cylinder fins are crucial for heat dissipation in air-cooled internal combustion engines. These fins enhance the surface area for thermal transfer, facilitating the conduction of heat from the engine cylinder to the ambient air via convection [3]. The geometry, material, and thickness of fins substantially affect their thermal performance. Aluminum alloys are used as fins due to their excellent thermal conductivity and lightweight properties. However, gray cast iron provides superior heat retention and endurance at elevated temperatures [4].

The present study examines the thermal performance of cylinder fins by numerical modeling and simulation. Also, this research employs Solidworks software to analyze several fin configurations, including filleted corners and drafted edges, using materials like Aluminum 6061 alloy and grey cast iron. Thus, the study evaluates the effects of design modifications and material attributes on temperature distribution, heat dissipation, and overall thermal efficiency by simulating real-world operating situations. Further, the results provide significant insights into the ideal design of cylinder fins, enhancing engine cooling systems and informing future research in this field.

2 Literature Review

Earlier studies have investigated the design and optimization of engine cylinder fins to enhance heat management in internal combustion engines [4-11]. Karthikeyan et al. studied the effect of geometry, shape, and surface roughness of fins on heat transmission in air-cooled motorcycle engines [12]. They employed Autodesk Inventor 2015 and Autodesk Nastran 2015 software for model development and simulation. Further, they examined heat transfer rates through variations in fin geometry and surface roughness. In another study, Shareef et al. assessed the thermal characteristics of engine cylinders by altering fin geometry, material, and profile through Ansys Workbench and SolidWorks models, concentrating on the improvement of heat transport and dissipation [13,17]. Motorcycle cylinder blocks lacking a radiator cooling system generally employ fins to dissipate heat from combustion, thus averting overheating and preserving performance. Thermal analysis was employed Zainal & Hadi Susilo to examine heat transmission on surfaces such as fins, cylinder blocks, and mold blocks [14-16]. Autodesk Fusion 360 software was used by researchers to develop an engine cylinder with fins of different material. The optimal material for enhanced heat transfer rate was as cast iron containing 2% nickel, having fin spacing 4 mm and a cylinder perforation diameter of 4 mm. In another study, Devraja and Chaturvedib performed a thermal performance analysis of engine cylinder fins by evaluating different shapes, including Rectangular, Triangular, Convex, and Tapered fins [11]. A 3D model was generated in SolidWorks, and steady-state simulations are performed using Ansys software. The fin was constructed from Al6063 material. The objective of their study was to improve heat dissipation rates by modifying the surface area. The results were analyzed to determine the geometry that produces the highest heat flux. They further examined the thermal performance of engine cylinder fins by altering their shapes, specifically Rectangular, Triangular, Convex, and Tapered fins. The study seeks to improve heat dissipation rates utilizing air as the working fluid and Al6063 as the fin material. The findings facilitate the identification of the geometry that optimizes heat flux for enhanced engine cooling efficiency. Khan and Chourasia[10] examined the thermal performance of engine cylinder fins, underscoring their significance in improving heat transmission and cooling the engine cylinder. They examined effect of materials and thicknesses of the fins on their thermal efficiency. Their research attempts to measure heat transfer rates within the engine cylinder using a thermal study, which is crucial for managing thermal stresses and temperature variations in automotive applications. Researchers examined the thermal efficiency of engine cylinder fins through the analysis of diverse fin designs, such as rectangular, trapezoidal, and triangular segmental extensions. These designs were contrasted with fins lacking extensions, demonstrating a 5-13% enhancement in heat transfer rate. The main aim of the research was to increase the surface area in contact with the coolant, which enhance convection and total heat transfer efficiency. Thus, their research offered insights for optimizing fin designs to enhance thermal performance in engine applications [8]. Nasir examined the thermal efficacy of engine cylinder fins by modeling them, emphasizing the influence of fin geometric parameters (such as length and thickness) on cooling performance [7]. Their results demonstrated best performance with a fin thickness ranging from 4 to 5 mm, a length of 30 mm, and a total of 7 fins. The analysis indicated that these dimensions substantially improve heat transfer rates and decrease thermal resistance, hence enhancing the overall cooling efficiency of the engine cylinder block. Kumar and Pandey performed a thermal performance evaluation of engine cylinder fins by developing a parametric model in SolidWorks software and performing thermal analysis using Ansys software [6]. They analyzed heat dissipation in the cylinder block with and without grooves, contrasting transient and steady-state conditions. Their research aimed to improve heat transfer rates by designing fins, assessing various materials, and analyzing modified designs to accurately evaluate temperature fluctuations. Narwariya et al. examined the influence of fin geometry on the thermal efficiency of a two-wheeler engine cylinder, emphasizing the significance of extended surface design in improving heat transfer [5]. They employed transient thermal analysis to determine an optimal fin design under ambient circumstances, authenticating results with previous research. They utilized Al6061 Alloy due to its superior thermal conductivity (180 W/mK) to construct the cooling surfaces, with the objective of enhancing the heat transfer of the engine cylinder.

From the review of literature, it is observed that numerous research gaps persist unresolved even though substantial amount of research on engine cylinder fins. Prior research has shown the possibility for adjusting fin parameters, namely form, thickness, and material, to improve engine cooling efficiency. However, extensive comparisons of various configurations are still scarce. Further, most research concentrate on particular materials or geometric arrangements, lacking a thorough comparison across various combinations under uniform conditions. The impact of fin thickness on thermal retention and heat dissipation efficiency has been examined. However, the compromises regarding material cost, weight, and manufacturability are frequently neglected. Moreover, most studies utilize steady-state models, resulting in a deficiency in comprehending the rapid thermal dynamics of fins during dynamic engine running. The influence of advanced geometry, such as drafted edges, on optimizing temperature dispersion across the fin surface remains inadequately explored, particularly in conjunction with varying material qualities. Therefore, the present research seeks to address these deficiencies by systematically evaluating the thermal performance of materials, thicknesses, and geometries under actual boundary conditions. Therefore the study offers a comprehensive understanding of their influence on engine cooling efficiency.

3 Methodology

3.1 Designing and Modeling

The design and modeling phase concentrated on developing 3D representations of engine cylinder fins to evaluate their thermal performance under simulated conditions. The CAD modeling was performed in Solidworks software, with dimensions obtained from a 150cc Hero Honda motorcycle engine as the foundational reference. Two distinct fin configurations were examined: fillet corners and drafted edges. Each design was constructed with two thickness variations—2.5 mm and 4 mm—to evaluate the impact of geometry and material thickness on thermal dissipation. This study utilized Aluminum 6061 alloy, recognized for its excellent thermal conductivity and lightweight properties, and grey cast iron, valued for its exceptional heat retention and durability. Essential design elements, including fin spacing, edge shape, and material properties, were integrated to guarantee authentic simulation results. The computer-aided design (CAD) models served as the basis for thermal analysis, enabling the examination of temperature distribution and heat loss across various configurations. The dimensions of engine fins are shown in Figure 1.

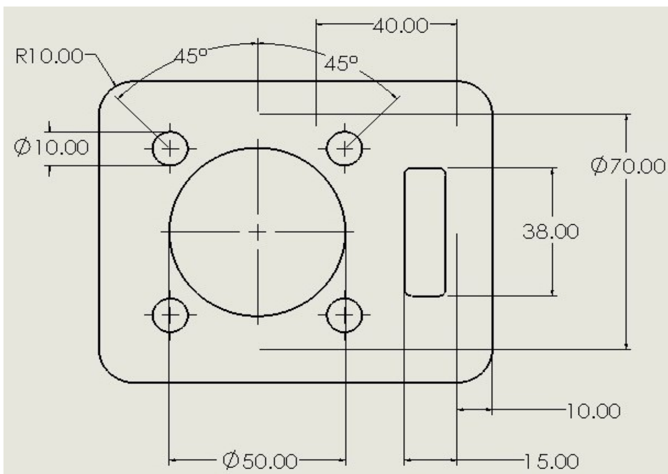


Fig. 1. Cross-sectional view of the engine fins

Fins thickness of width 2.5 mm and radius of 10 mm for its fillets were kept constant for first 8 set of readings as shown in Figure 2.

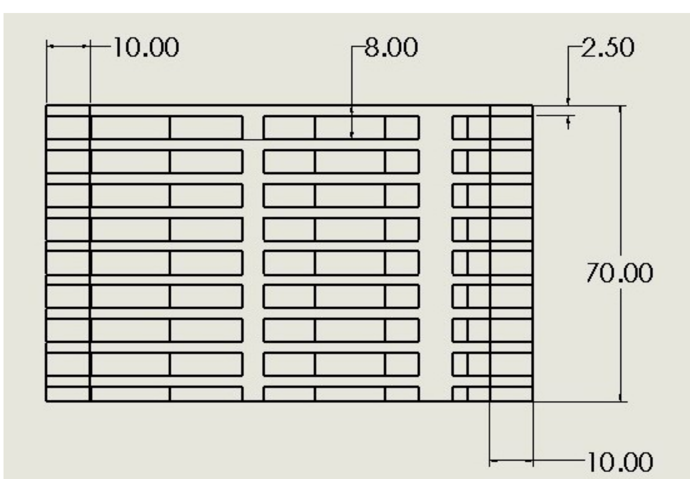


Fig. 2. Side view of the selected fin thickness and radius of fin

While the preliminary dimension remained same, fin thickness and fillet radius values were replaced with new fin thickness of 4 mm and a drafted outward edge angle of 45 degrees as shown in Figure 3. These were kept constant for another set of 8 readings.

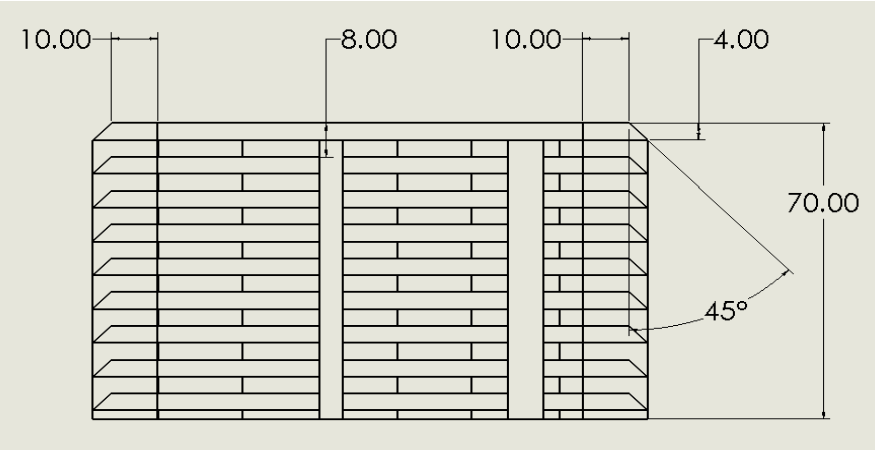


Fig. 3. Side view of the selected fin thickness and drafted edge angle

The final CAD 3D model as shown in Figure 4 is an approximate representation from previously studied models with new specifications.

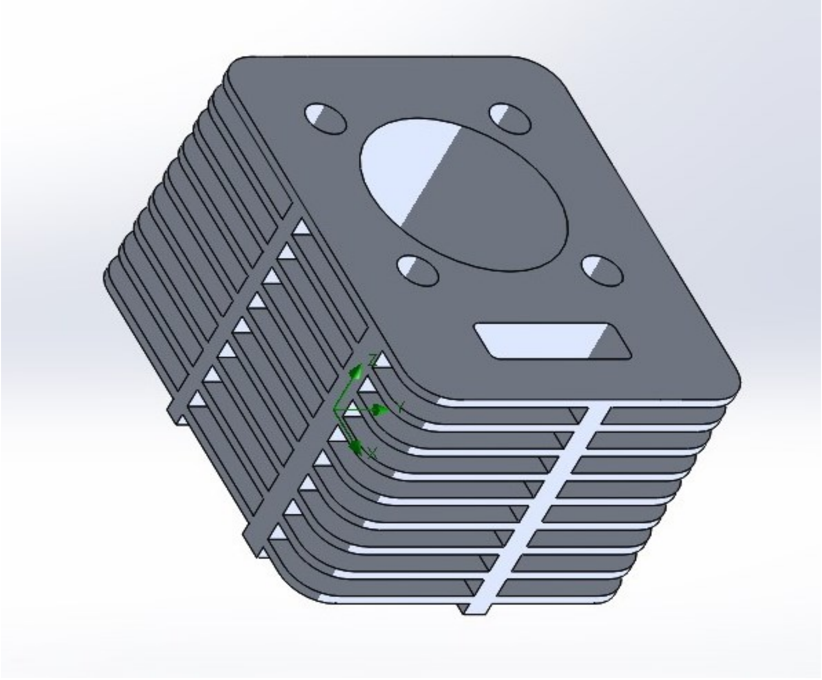


Fig. 4. CAD representation of the engine cylinder fins

3.2 Simulation Framework

The simulation framework was created to assess the thermal efficacy of the engineered engine cylinder fins under authentic settings. The thermal study was configured in Solidworks Flow Simulation with established boundary conditions, incorporating natural convection having air as the cooling medium. The computational domain included both the solid fin structures and the adjacent fluid to ensure precise modeling of heat transfer interactions. Essential elements including ambient air pressure and temperature, gravitational settings, and heat generation rates were integrated to replicate working conditions. The fins were composed of Aluminum 6061 alloy and grey cast iron, each designated with their corresponding thermal and physical parameters, such as thermal conductivity and density. The meshing was meticulously optimized to achieve a compromise between computational economy and simulation accuracy, culminating in a total of 35,963 cells enabling precise heat flow computations. The framework also entailed applying different rates of heat generation to the cylinder walls to replicate the thermal conditions of a functioning engine. This comprehensive simulation framework yielded essential insights into temperature distribution, heat dissipation, and overall thermal efficiency across various fin shapes and materials.

3.2.1 Materials for engine fins

Al6061 is an aluminum alloy containing magnesium and silicon as alloying elements. It has good mechanical properties and is heat treatable and weldable. It is the widely used alloy for aluminum extrusion. This allows the molding of complex shapes with very smooth surfaces that are popular in visible architectural applications such as window frames, door frames, roofs and sign frames. The mechanical and thermal properties of aluminum alloy are shown in Table 1.

Table 1. Properties of Aluminum alloy 6061 [15]

Property	Value	Units
Elastic Modulus	69000	N/mm^2
Poisson's Ratio	0.33	N/A
Shear Modulus	26000	N/mm^2
Mass Density	2700	kg/m^3
Tensile Strength	124.084	N/mm^2
Compressive Strength	-	N/mm^2
Yield Strength	55.1485	N/mm^2
Thermal Expansion Coefficient	2.4e-05	/K
Thermal Conductivity	170	W/(m·K)

With proper alloying and processing, aluminum alloys can be obtained at various strengths. Some aluminum alloys have a strength of up to 300 MPa, which is stronger than some steels. The strength can be selected to meet the requirements of the product. Also, aluminum can't fail in brittle manner. Aluminum alloys are particularly suitable for low temperature applications because they increase strength at low temperatures without compromising quality. Aluminum conducts more heat than other common metals. It has about three times the thermal conductivity of steel. It is important in either heating or cooling heat exchange

applications and is commonly used in the chemical, petroleum, aircraft, and automotive industries.
The compressive strength of grey cast iron is very high which is nearly 34 times the tensile strength. It is suitable for steel and ideal for pressure parts (base, etc.). The hardness of grey cast iron can meet the wear resistance requirements of common engineering machine parts. The mechanical and thermal properties of grey cast iron are shown in Table 2.

Table 2. Properties of Grey cast iron

Property	Value	Units
Elastic Modulus	66178.1	N/mm^2
Poisson's Ratio	0.27	N/A
Shear Modulus	50000	N/mm^2
Mass Density	7200	kg/m^3
Tensile Strength	151.658	N/mm^2
Compressive Strength	572.165	N/mm^2
Yield Strength		N/mm^2
Thermal Expansion Coefficient	1.2e-05	/K
Thermal Conductivity	45	W/(m·K)

Grey cast iron is a brittle material with low toughness and plasticity. It has excellent damping characteristics and excellent damping characteristics. It is widely used in the casting of machine tools and the casting of internal combustion engines with damping requirements. Also, it has excellent wear resistance in the sliding state and is widely used for brake linings, brake drums, cylinder liners, piston rings, machine beds with guide rails, etc.

3.2.2 Boundary conditions

After designing and modelling, the thermal analysis of the fin was performed in Solidworks Flow Simulation. The first step was creating a new project with the specified parameters and values. The 'Analysis type' was selected as 'Heat conduction in solids' as shown in Figure 5.

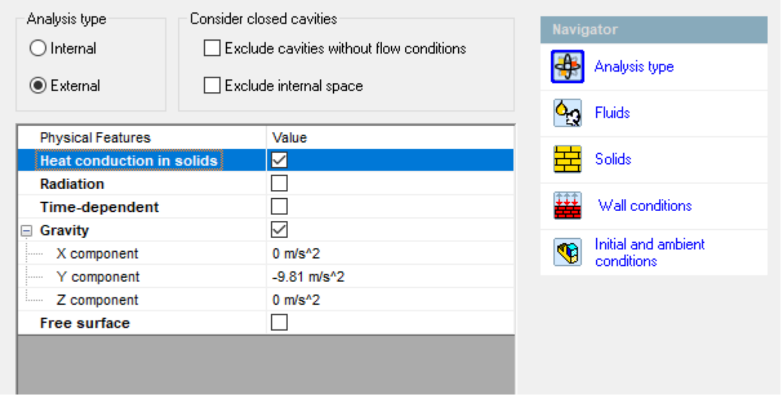


Fig. 5. Selecting the analysis type

The next parameter is the gas (or fluid) with which the fins will come in contact. It was taken to be air since real life simulation can be performed as shown in Figure 6.

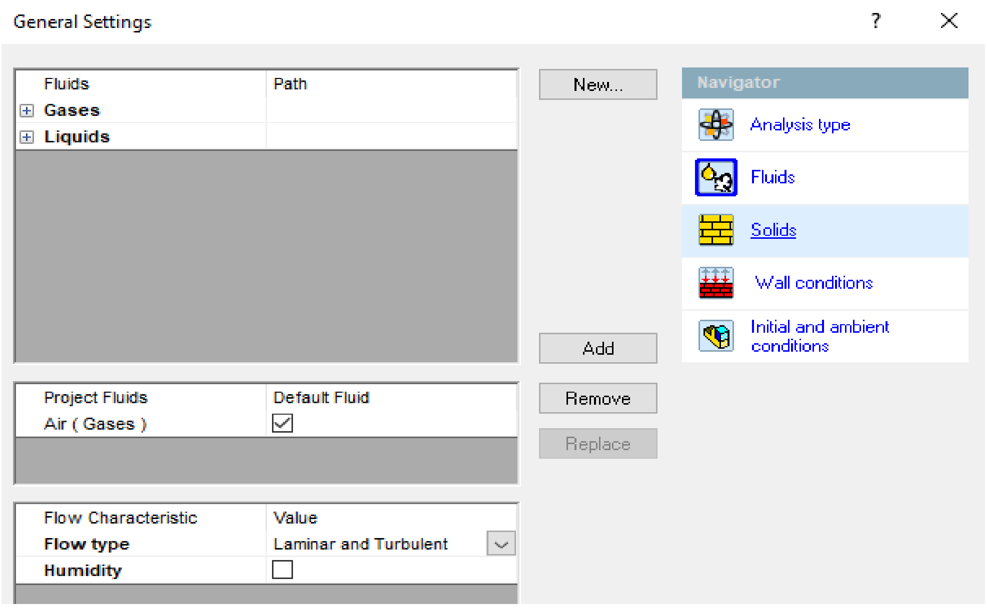


Fig. 6. Selecting the required fluid

For ambient conditions, the fins will be observed under natural convection. This implies that there will not be any forced convection where certain velocity is required. So, velocity was set at zero with values of pressure and air kept at its normal atmospheric temperatures. For natural convection, hot air rises up and cool air flows downwards. This was done using the gravitational settings and the default domain parameters as shown in Table 3 and Table 4 respectively.

Table 3. Gravitational settings

Component	Value
X component	0 m/s^2
Y component	-9.81 m/s^2
Z component	0 m/s^2

Table 4. Domain parameters

Parameter	Value
Thermodynamic parameters	Static Pressure: 101325.00 PaTemperature: 25.00 °C
Velocity parameters	Velocity vector Velocity in X direction: 0 m/s Velocity in Y direction: 0 m/s Velocity in Z direction: 0 m/s
Solid parameters	Default material: Aluminum Alloy 6061 (or Grey Cast Iron)

Lastly, create a computational flow domain (CFD) around the fins structure so that whatever parameter was set before applies accurately inside it as shown in Figure 7. The domain size as shown in Table 5 was assumed and kept constant throughout the whole experiment.

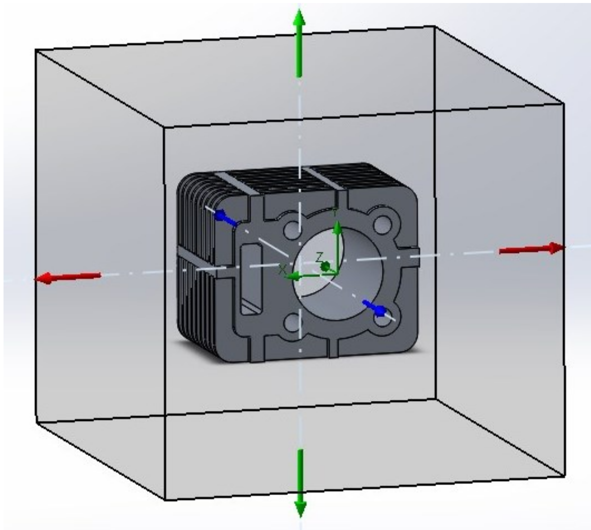


Fig. 7. Computational Domain

Table 5. Computational Domain Sizing

Parameter	Value
X min	-0.100 m
X max	0.120 m
Y min	-0.100 m
Y max	0.100 m
Z min	-0.080 m
Z max	0.150 m
X size	0.220 m
Y size	0.200 m
Z size	0.230 m

3.2.3 Meshing

Meshing is an important stage in design analysis. The software's automatic mesh generates mesh grids based on global element sizes, tolerances, and local mesh control settings. Mesh setting controls allow you to specify different element sizes for elements, faces, edges, and vertices. The software calculates the overall dimensions of the model elements based on its volume, area and other geometric data. The model geometry and dimensions, element sizes, mesh tolerances, mesh controls and contact criteria all affect the size of the generated mesh (number of nodes and elements).

The analysis accuracy and calculation duration depend on the mesh size and orientation. The flow simulation meshing is different because it considers the entire domain during meshing process which means the solid and the fluid surrounding the solid will also be involved. The total number of cells generated is 35963 of which 22560 cells are fluid and 13403 cells are solid as shown in Figure 8.

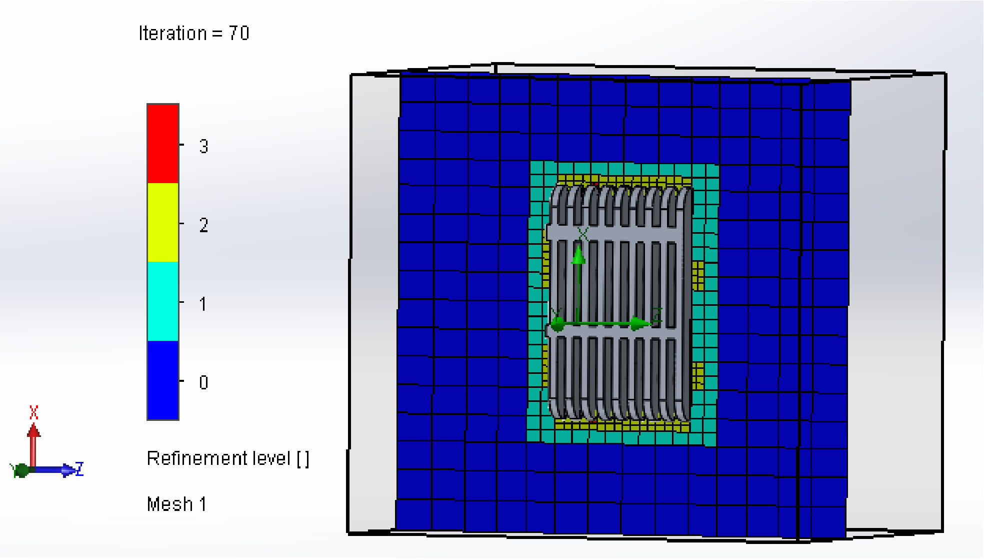


Fig. 8. Meshing process

3.2.4 Calculations for Rate of Heat Generation

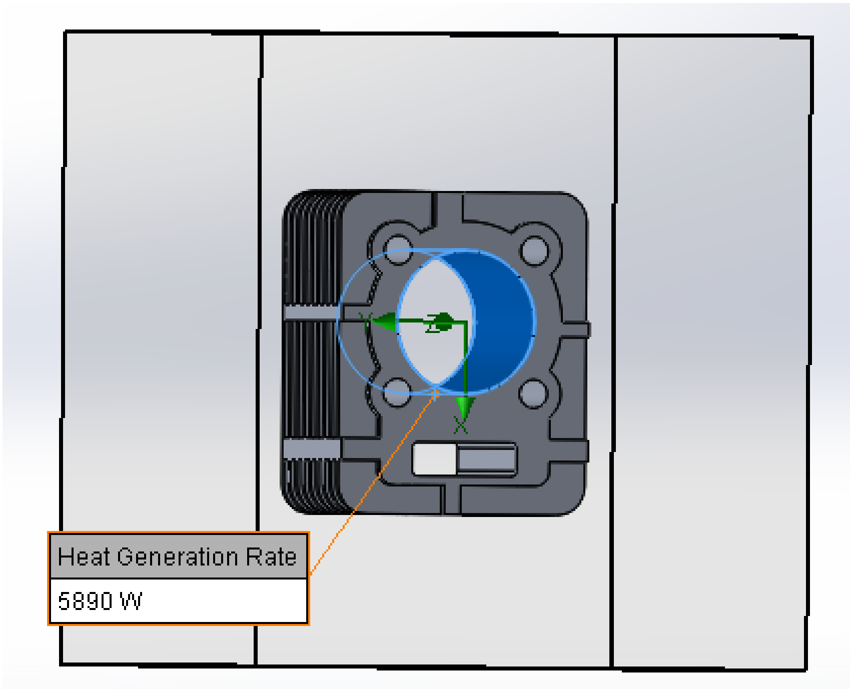
Indicated Power is the power developed by combustion of fuel in the cylinder of engine. The mean effective pressure is another quantity relating to the operation of a reciprocating engine and it is the measure of an engine's capacity to do work that is independent of engine displacement. This quantity of measure along with the previously selected length, diameter, and rotational speed is used in the formula below:

$$I_p = P_m \times A \times L \times N \qquad (1)$$

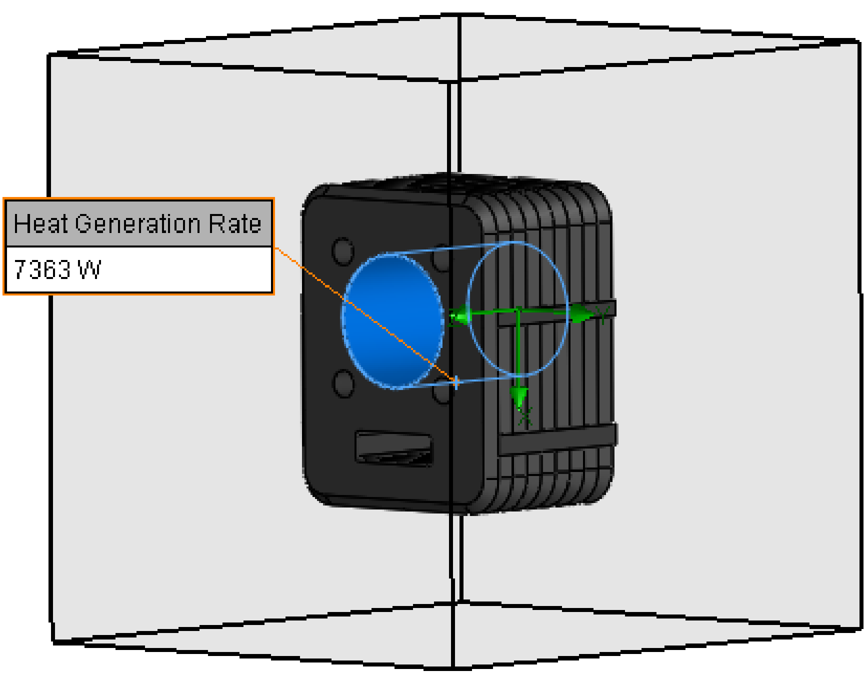
where,
I_p = Mean Effective Pressure
A= Area of Piston
L= Length of Stroke
N= Number of Power Strokes per Second

$$\eta_{it} = I_p/Q_g \qquad (2)$$

where,
η_{it} = Indicated thermal efficiency
Q_g= Heat generated
The heat generation values that were obtained after calculation were applied onto the internal part, the cylinder wall along which the piston reciprocates, where the combustion in an air-cooled engine takes place as shown in Figure 9.



(a)



(b)

Fig. 9. Rate of Heat generation applied

3.2.5 Validation study

The parameters and design considerations were taken from the research paper done by Karthikeyan et al. [12] and verified with almost similar inputs except for rate of internal heat generation because they had performed steady-state thermal analysis in Ansys as shown in Figure 10.

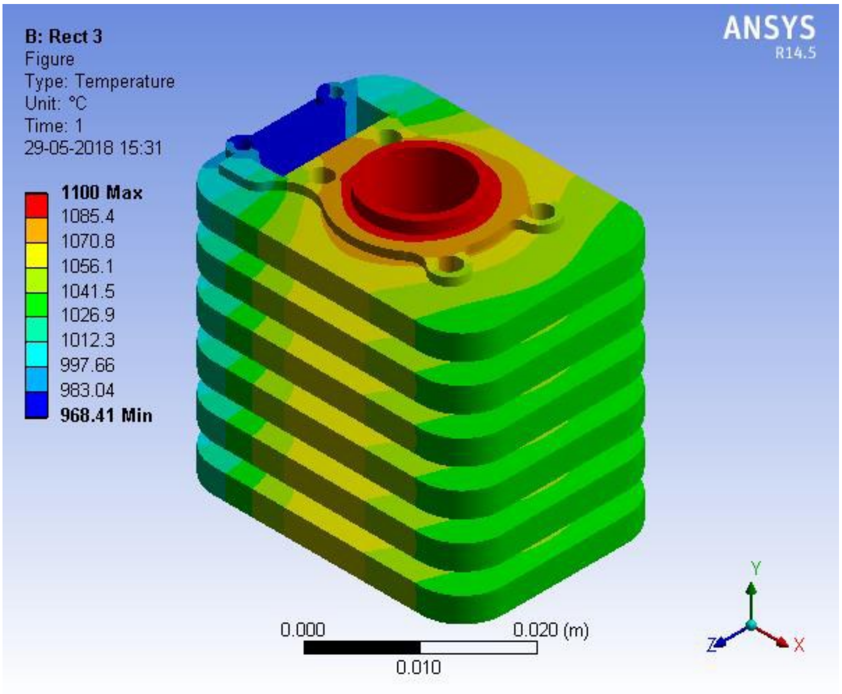


Fig. 10. Steady state thermal analysis output for the rectangular fin geometry with 2.5 mm thickness

The materials utilized was aluminum alloy 6061 for the rectangular shaped fin body with a fin thickness of 2.5 mm. Calculating the steady-state temperature of the fins using Ansys software and internal heat generation using Solidworks software respectively showed that the 2.5 mm thick fins had an indistinguishable temperature range between 957.61°C to 1100°C. It is observed that the 2.5 mm round shape fin have higher fin efficiency and better contact surface area.

The validation study confirmed the accuracy of the simulation framework by comparing its results with proven research findings. Parameters like material properties, fin geometry, and thermal boundary conditions were standardized according to the findings of Karthikeyan et al. [12] and other investigations to develop a foundation for comparison. A steady-state thermal analysis of 2.5 mm thick rectangular fins composed of Aluminum 6061 alloy was simulated in Solidworks software and compared with results from previous Ansys simulations. The comparison revealed negligible discrepancies, with temperature variations across the fin surfaces varied by less than 1.1%. This agreement validated the computational model and simulation configuration. The validation study validated previous research findings, enhancing the reliability of the methodology and showcasing its effectiveness in precisely evaluating the thermal performance of innovative fin designs and materials. Table 6 and Figure 11 showed the maximum and minimum temperatures across the fin body.

Table 6. Validation for temperature distributions across the engine fins

Temperature	Rectangular fin (Result of previous study)	Rectangular fin (Result of present paper)	Absolute percent deviation (%)
	2.5mm	**2.5mm**	
Minimum Temperature	970.02°C	980°C	1.028
Maximum Temperature	1100°C	1103.78°C	0.343

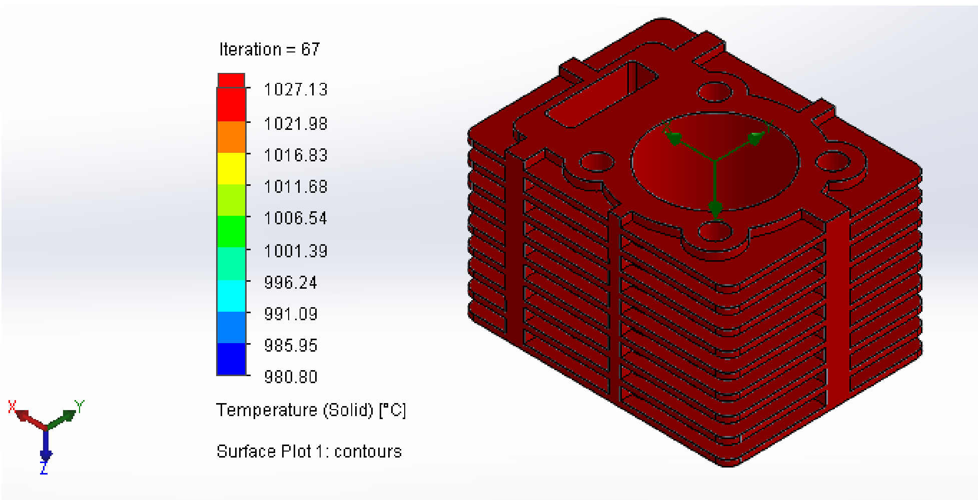


Fig. 11. Surface plot showing the maximum (red – along the top cylinder walls region) and minimum (blue-around the fins) values of combustion temperatures obtained

4 Results and Discussion

The thermal performance of engine cylinder fins was assessed by analyzing temperature distribution, heat dissipation, and total thermal efficiency across different fin shapes, thicknesses, and materials. Simulation findings demonstrated that grey cast iron fins maintained elevated combustion temperatures relative to Aluminum 6061 alloy in all configurations.

4.1 Temperature profiles for fillet edges of 2.5 mm thickness

At a fin thickness of 2.5 mm, fillet corner fins composed of grey cast iron reached a maximum surface temperature of 5430.78°C, whereas aluminum fins recorded 4933.62°C under equivalent conditions. This illustrates the exceptional heat retention properties of grey cast iron, rendering it appropriate for applications necessitating prolonged high-temperature performance. Aluminum fins distribute heat more uniformly, underscoring its promise for lightweight and effective cooling solutions. Table 7 and 8 lists the pre-processing and post-processing results which gives an insight related to effect of parameters on the output.

Table 7. Input parameters for different configurations

Sr. No.	Design	Thickness (mm)	Material	Rotational speed (rpm)
1	Fillet Corner	2.5	Aluminum 6061 Alloy	1200
2	Fillet Corner	2.5	Grey Cast iron	1500
3	Fillet Corner	2.5	Grey Cast iron	1200
4	Fillet Corner	2.5	Aluminum 6061 Alloy	1500
5	Fillet Corner	4	Aluminum 6061 Alloy	1200
6	Fillet Corner	4	Grey Cast iron	1200
7	Fillet Corner	4	Aluminum 6061 Alloy	1500
8	Fillet Corner	4	Grey Cast iron	1500
9	Drafted Edges (45 deg outward)	2.5	Aluminum 6061 Alloy	1200
10	Drafted Edges (45 deg outward)	2.5	Grey Cast iron	1500
11	Drafted Edges (45 deg outward)	2.5	Grey Cast iron	1200
12	Drafted Edges (45 deg outward)	2.5	Aluminum 6061 Alloy	1500
13	Drafted Edges (45 deg outward)	4	Aluminum 6061 Alloy	1200
14	Drafted Edges (45 deg outward)	4	Grey Cast iron	1200
15	Drafted Edges (45 deg outward)	4	Aluminum 6061 Alloy	1500
16	Drafted Edges (45 deg outward)	4	Grey Cast iron	1500

Following tabulated readings as given in Table 8 were obtained after the calculations.

Table 8. Post simulation values

Sr. No.	Design & Material	Thickness (mm)	Heat Generation (W)	Maximum Surface Temp (°C)
1	Fillet Corner - Aluminum 6061 Alloy	2.5	5890	4201.93
2	Fillet Corner - Grey Cast iron	2.5	7363	5430.78
3	Fillet Corner - Grey Cast iron	2.5	5890	4599.17
4	Fillet Corner - Aluminum 6061 Alloy	2.5	7363	4933.62
5	Fillet Corner - Aluminum 6061 Alloy	4	5890	4246.29
6	Fillet Corner - Grey Cast iron	4	5890	4597.87
7	Fillet Corner - Aluminum 6061 Alloy	4	7363	4959.52
8	Fillet Corner - Grey Cast iron	4	7363	5409.9
9	Drafted Edges (45 deg outward) - Aluminum 6061 Alloy	2.5	5890	4137
10	Drafted Edges (45 deg outward) - Grey Cast iron	2.5	7363	5352.49
11	Drafted Edges (45 deg outward) - Grey Cast iron	2.5	5890	4539.78
12	Drafted Edges (45 deg outward) - Aluminum 6061 Alloy	2.5	7363	4842.51
13	Drafted Edges (45 deg outward) - Aluminum 6061 Alloy	4	5890	4050.2
14	Drafted Edges (45 deg outward) - Grey Cast iron	4	5890	4404.85
15	Drafted Edges (45 deg outward) - Aluminum 6061 Alloy	4	7363	4716.81
16	Drafted Edges (45 deg outward) - Grey Cast iron	4	7363	5167.47

Table 9 lists temperature of fluid (air) and the solid (fins). Figure 12 and 13 shows the temperature distribution along the engine fins with material Aluminum 6061 Alloy and heat generation 7363W.

Table 9. Minimum and Maximum Values

Name	Minimum	Maximum
Temperature (Fluid) [°C]	24.02	4933.55
Temperature (Solid) [°C]	4457.89	4933.62

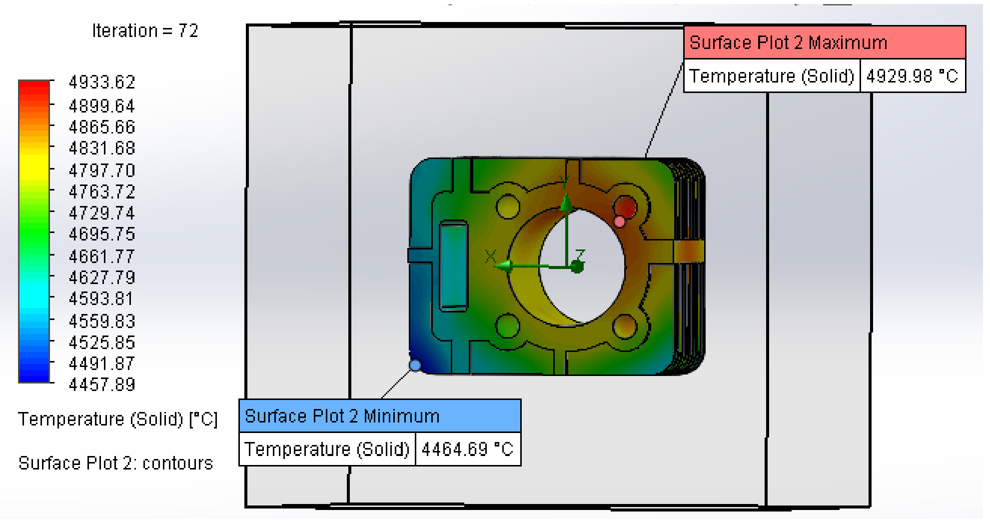


Fig. 12. Surface plot showing the maximum (red – along the top cylinder walls region) and minimum (blue-around the fins) values of combustion temperatures obtained

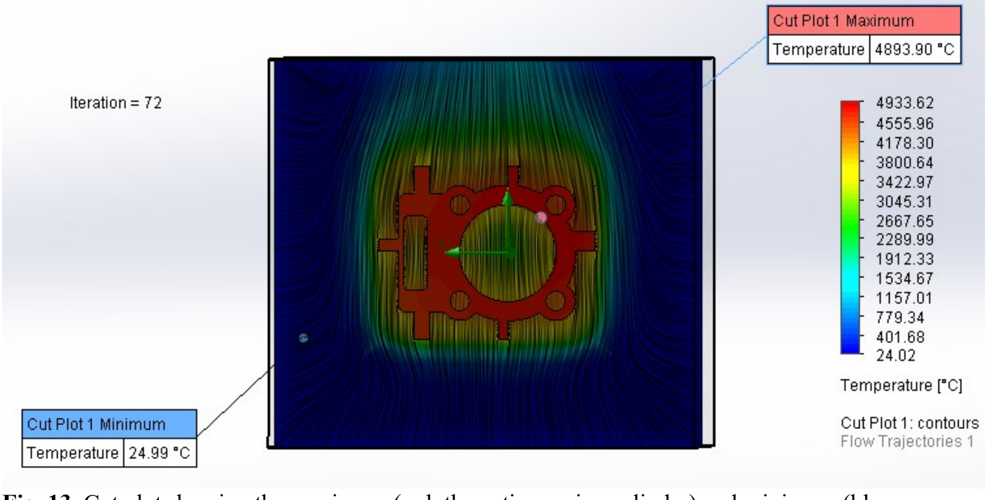


Fig. 13. Cut plot showing the maximum (red–the entire engine cylinder) and minimum (blue-surroundings) values of fluid obtained. This shows the temperature of the fluid (air) throughout the combustion process

4.2 Temperature profiles for fillet edges of 4 mm thickness

Table 10 lists temperature of fluid (air) and the solid (fins). Figure 14 and 15 shows the temperature distribution along the engine fins. The material used is Grey cast iron and heat generation 5890 W.

Table 10. Minimum and Maximum Values

Name	Minimum	Maximum
Temperature [°C]	24.92	4597.87
Temperature (Fluid) [°C]	24.92	4597.55
Temperature (Solid) [°C]	3546.07	4597.87

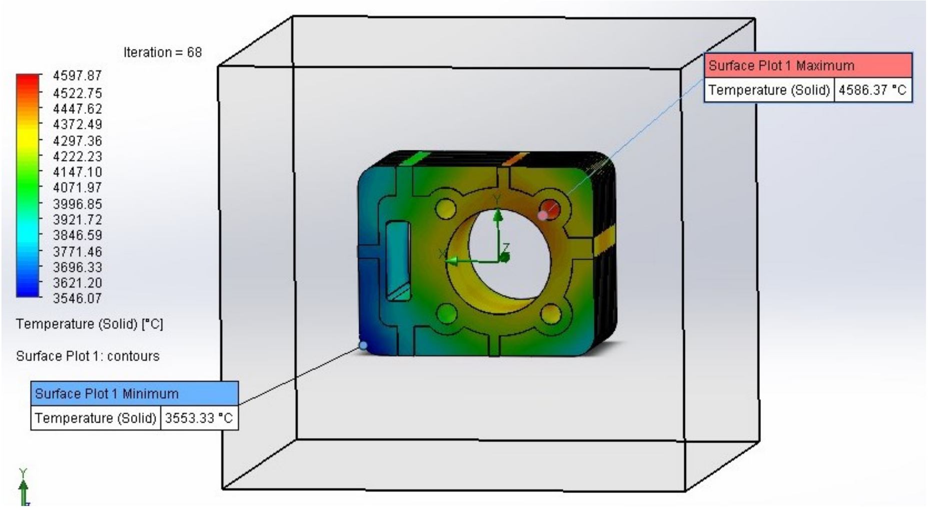


Fig. 14. Surface plot showing the maximum (red – along the top cylinder walls region) and minimum (blue-around the fins) values of combustion temperatures obtained

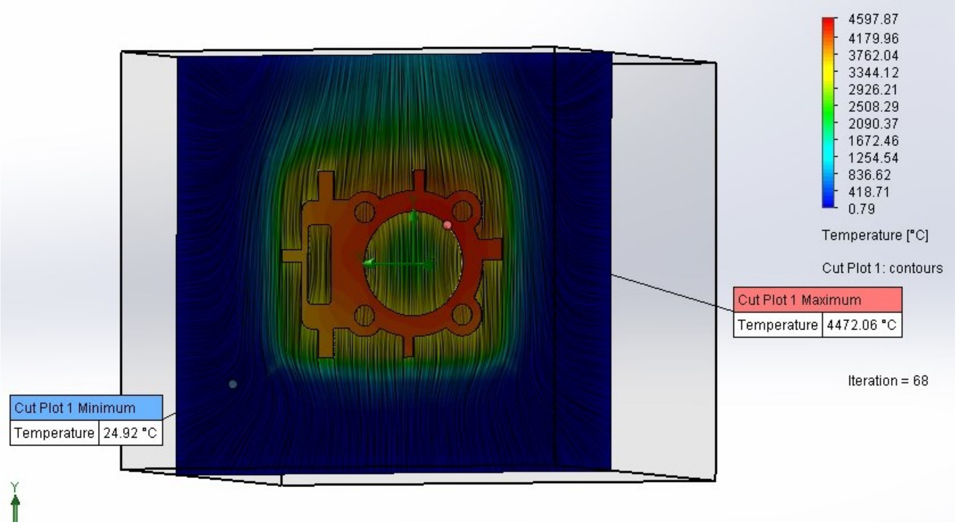


Fig. 15. Cut plot showing the maximum (red–the entire engine cylinder) and minimum (blue-surroundings) values of fluid obtained. This shows the temperature of the fluid (air) throughout the combustion process

4.3 Temperature profiles for drafted edges of 2.5 mm thickness

Table 11 lists temperature of fluid (air) and the solid (fins). Figure 16 and 17 shows the temperature distribution along the engine fins. The material used is Aluminum 6061 Alloy and heat generation 5890 W.

Table 11. Min/Max Values

Name	Minimum	Maximum
Temperature [°C]	25.00	4137.00
Temperature (Fluid) [°C]	25.00	4136.99
Temperature (Solid) [°C]	3757.43	4137.00

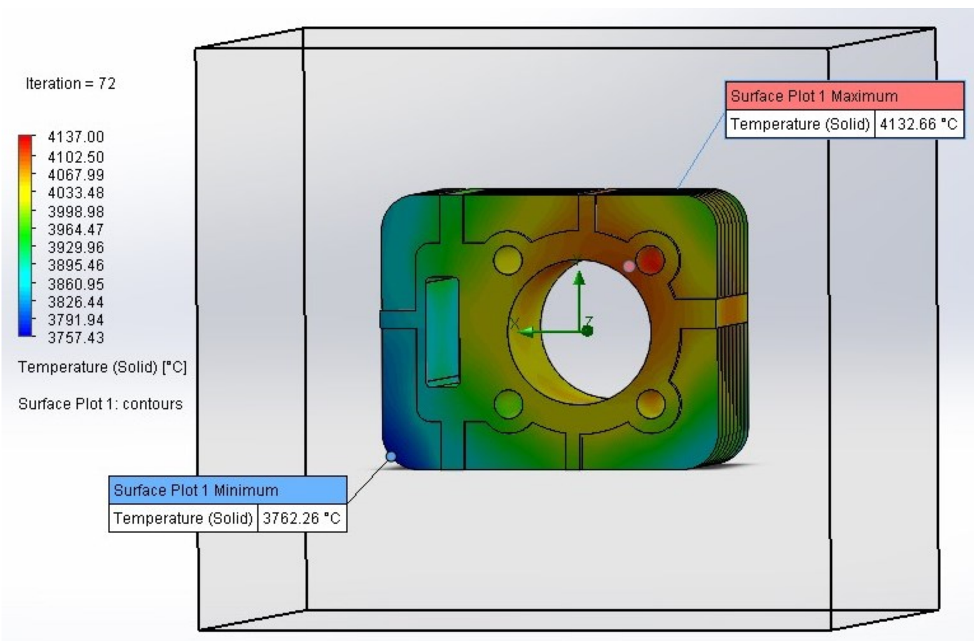


Fig. 16. Surface plot showing the maximum (red – along the top cylinder walls region) and minimum (blue-around the fins) values of combustion temperatures obtained

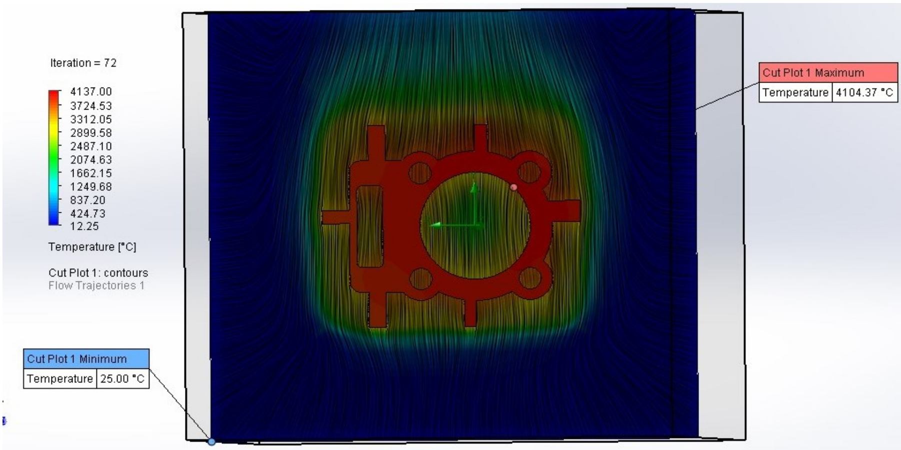


Fig. 17. Cut plot showing the maximum (red–the entire engine cylinder) and minimum (blue-surroundings) values of fluid obtained. This shows the temperature of the fluid (air) throughout the combustion process

4.4 Temperature profiles for drafted edges of 4 mm thickness

Table 12 lists temperature of fluid (air) and the solid (fins). Figure 18 and 19 shows the temperature distribution along the engine fins. The material used is Grey cast iron and heat generation 7363 W.

Table 12 Min/Max Values

Name	Minimum	Maximum
Temperature [°C]	24.04	5167.47
Temperature (Fluid) [°C]	24.04	5167.20
Temperature (Solid) [°C]	3804.54	5167.47

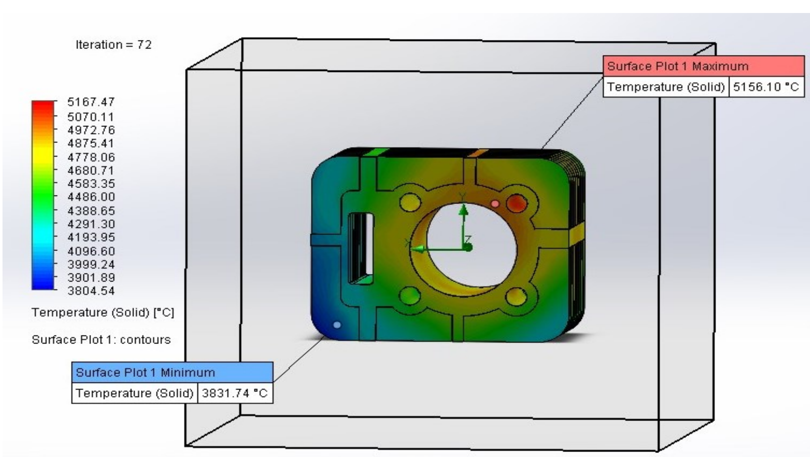


Fig. 18. Surface plot showing the maximum (red – along the top cylinder walls region) and minimum (blue-around the fins) values of combustion temperatures obtained

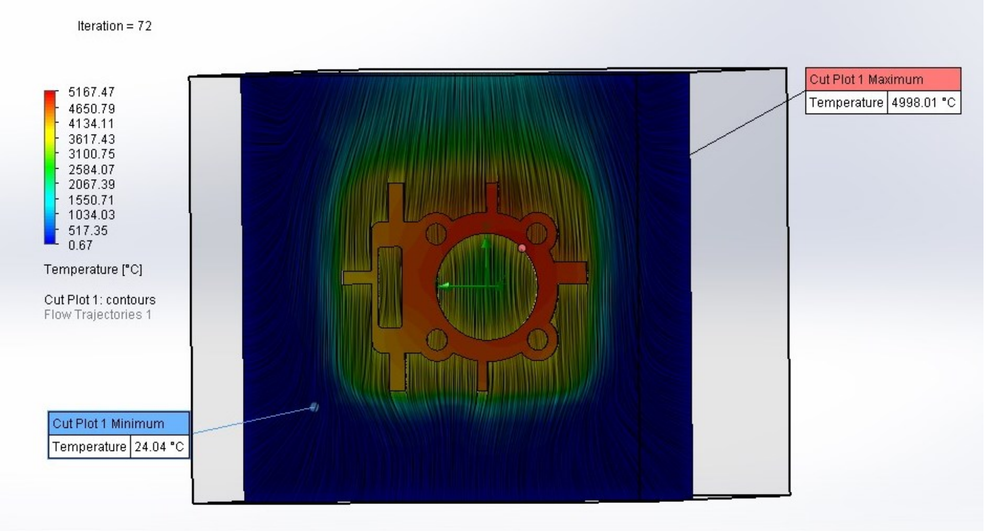


Fig. 19. Cut plot showing the maximum (red–the entire engine cylinder) and minimum (blue-surroundings) values of fluid obtained. This shows the temperature of the fluid (air) throughout the combustion process

4.3 Comparison study

The results acquired after calculations and simulations were performed for grey cast iron and aluminum alloy 6061 with fillet and draft models. For a fin thickness of 2.5 mm, fillet corner fins made of grey cast iron was able to produce the maximum amount of temperature and dissipate the heat much better than other designs and material involved at 1200 rpm as shown in Figure 20. Since the thickness of fins is less, it is preferred to select a model which is able to handle lesser wear and tear to increase its longevity.

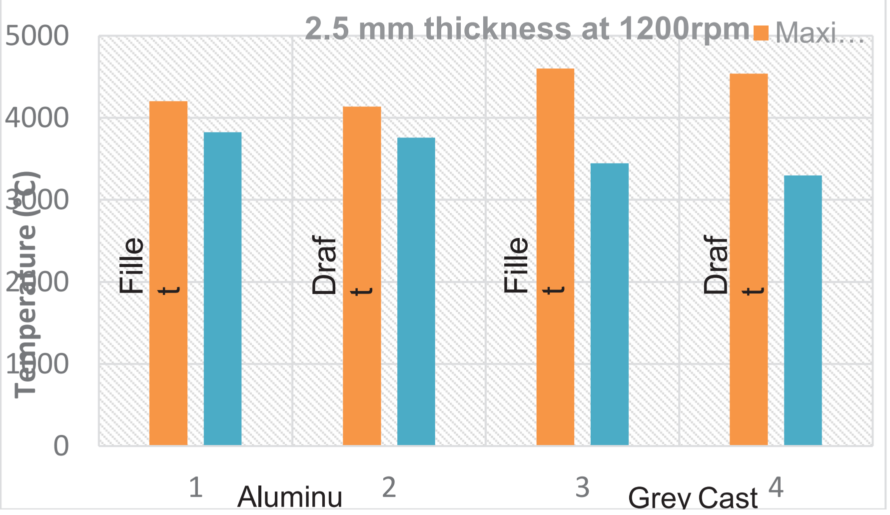


Fig. 20. Comparison of fillet and draft design temperatures for aluminum and grey cast iron with 2.5 mm thickness at 1200rpm

For a fin thickness of 4 mm, fillet corner fins made of grey cast iron was able to produce the maximum amount of temperature. But drafted edge fins made of similar material was able to retain the high combustion temperatures and disperse heat much slower at 1200 rpm as shown in Figure 21. Here, since the thickness is more, this model will be able to give much better fin efficiency.

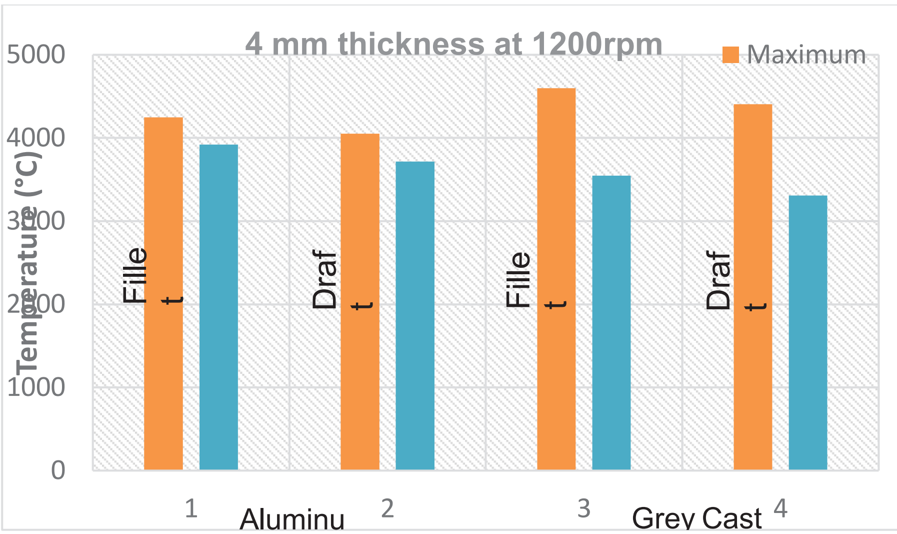


Fig. 21. Comparison of fillet and draft design temperatures for aluminum and grey cast iron with 4 mm thickness at 1200rpm

For a fin thickness of 2.5 mm, grey cast iron fillet corner fins were able to produce the maximum amount of temperature and dissipate the heat much swiftly than other designs and material involved at 1500 rpm as shown in Figure 22. Since the thickness of fins is less and the rate of heat generation is much higher, it is favorable to select a model which is able to handle both higher and lower temperatures simultaneously.

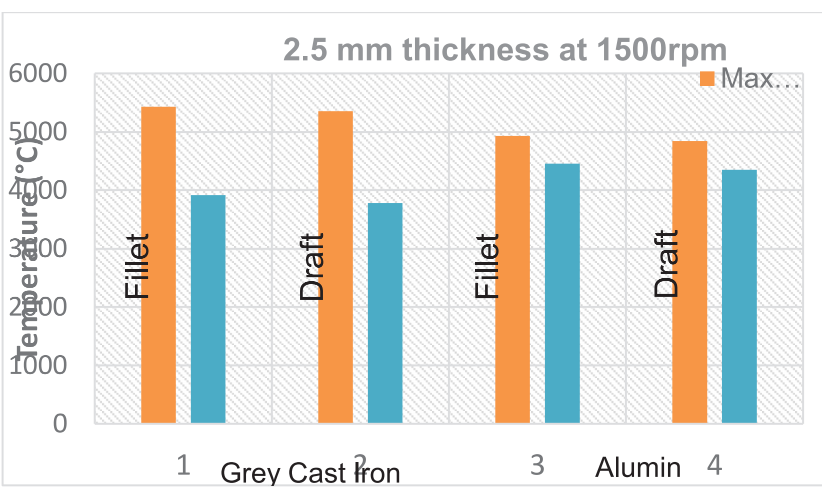


Fig. 22. Comparison of fillet and draft design temperatures for aluminum and grey cast iron with 2.5 mm thickness at 1500rpm

When fin thickness was increased to 4 mm, grey cast iron fillet corner fins made of was able to produce the maximum amount of temperature. But in this case, the difference between maximum and minimum temperature was higher in drafted edges made of grey cast iron at 1500 rpm as shown in Figure 23. So, this means that the drafted edges were much better in thermal and fin efficiency because of their ability to maintain the higher combustion temperatures.

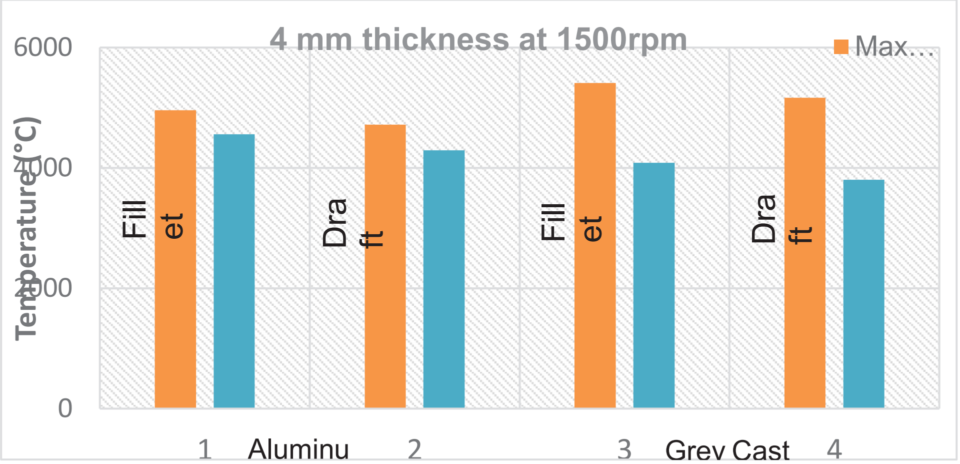


Fig. 23. Comparison of fillet and draft design temperatures for aluminum and grey cast iron with 4 mm thickness at 1500rpm

The analysis of fin geometries demonstrated that drafted edges yielded a more uniform temperature distribution than fillet corners. This was especially apparent in the instance of aluminum fins, where the maximum temperature differential between the upper and lower sections of the fin was reduced for drafted edges. Furthermore, augmenting the fin thickness from 2.5 mm to 4 mm improved thermal retention for both materials, with grey cast iron exhibiting a superior maximum surface temperature (5167.47°C) compared to aluminum (4716.81°C) at 1500 rpm. Nevertheless, the augmented material volume and corresponding expenses linked to thicker fins must be taken into account when determining ideal designs. The findings underscore the significance of geometry in enhancing heat dissipation efficiency. It is observed that beveled edges provide superior thermal performance for applications subjected to continuous thermal loads.

These findings emphasize the compromises among material characteristics, fin configuration, and operational efficacy. Although grey cast iron offers excellent thermal retention, its increased density and machining complications depict it less suitable for weight-sensitive applications. Conversely, Aluminum 6061 alloy provides superior heat conductivity and lightweight benefits, although this results in reduced thermal retention. The study reveals that geometry significantly influences thermal performance, with drafted edges better than fillet corners in heat distribution. These insights offer a thorough comprehension of the interaction between material and design characteristics, directing the selection of ideal configurations to improve engine cooling efficiency. Further research may expand this methodology to investigate additional materials, forced convection conditions, and diverse fin configurations.

5. Conclusion

The present study provides an in-depth examination of the thermal performance of engine cylinder fins, highlighting the effects of material, geometry, and thickness on heat dissipation and thermal efficiency. The findings show that grey cast iron fins are proficient in maintaining elevated combustion temperatures, rendering them suitable for applications necessitating extended thermal stability. Whereas Aluminum 6061 alloy fins exhibit enhanced heat dissipation and lightweight properties, promoting effective cooling in designs where weight is a critical factor. Among the analyzed shapes, drafted edges shown superior efficacy in attaining uniform temperature distribution relative to fillet corners. The fin thickness significantly influenced thermal retention, with 4 mm fins offering superior performance at elevated material costs. These findings improve fin designs for superior engine cooling systems and underscore the trade-offs associated with material and geometry selection. Further research may investigate supplementary materials, forced convection conditions, and diverse fin designs to enhance cooling efficiency and expand the relevance of these results. Also, there are many designs, fin thicknesses, and materials for investigation for future research. There is still opportunity to keep improving the fin efficiency by including new input parameters, such as pitch of fins and multiple boundary conditions like forced convection.

Conflict of Interest

There is no conflict of interests.

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