Thermal Analysis of Engine Cylinder Block with Fins using FEM

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Abstract - *Engine chambers are exposed to extreme temperature changes and thermal stresses, making them an important part of the engine. Fins are placed on the outside of the cylinder's body to increase heat dissipation through convection. This study compares the heat exchange between engine cylinders with rectangular-shaped fins and those with circular-shaped fins. The engine cylinder is made up of two shapes (circular and rectangular) with tube-shaped cross-sections in order to improve heat dissipation. We increased the rate at which heat can be exchanged by optimising all aspects. The temperature variations inside the fins made in two types of geometries (Circular area shaped fin, and Rectangular area shaped fin) were investigated using material AA1060 and AA 6082, and consistent state heat exchange examination was studied using a FEM software ANSYS to investigate and approve results. The temperature variations in different Engine cylinder areas are evaluated using FEM, and the results are compared to experimental results obtained in Ansys for the same material and fin area. The goal of this study is to use wind flow to increase the rate at which heat is dissipated.*

***Key Words*: Engine cylinder, Thermal analysis, FEM, ANSYS, Fins, Aluminium alloy.**

1.INTRODUCTION

The cylinder is one of the most important engine components that is subjected to extreme temperature changes and thermal stress. Fins on the surface of the cylinder aid in cooling and heat transfer. Fins are mechanical structures that use convection and conduction to cool buildings. Extending the fins on an IC engine is widely accepted as a way to improve heat transfer. It's much easier to build an air-cooling system than it is to build a water-cooling system. The fins in an air-cooled engine must be used effectively to maintain a consistent temperature in the cylinder. Internal combustion engines use a combustion chamber for gas combustion. Pistons, turbine blades, and nozzles all gain power as a result of the combustion of high-temperature, high-pressure air. The element can be moved using this force, resulting in useful mechanical energy over a large area. Although water-cooled engines have largely replaced air-cooled engines, air-cooled engines are still used in all two wheels because they are lighter and take up less space

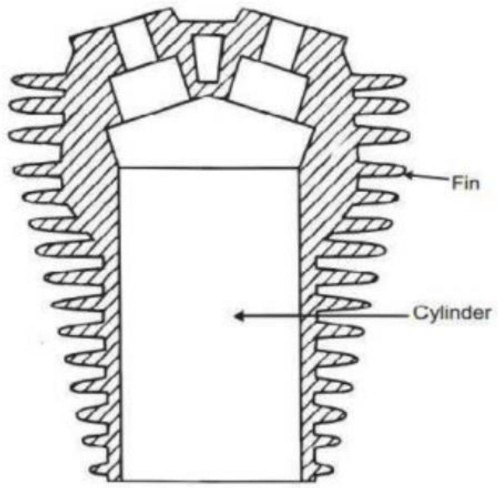

Figure 1: Engine cylinder

The buoyant forces created by temperature variations cause liquid convection, which creates a stream of liquid. Low-control-density gadget thermal management has relied on natural heat sink convection for a long time. The absence of shifting components and intensity usage, as well as the need for assistance in this cooling approach, are all causes for concern. It's also simple to use, has a high level of efficiency, and is reasonably priced. Natural convection is important for thermal transfer in a variety of devices, including electronics, which has been the subject of ongoing research for centuries. Fig.1.6 shows the image of the functions of the heat sinks commonly utilized. Some applications can be listed.

2. HEAT TRANSFER FINS

A fin is required to increase convection in a given area. Heat dissipation can be increased by increasing the temperature difference between the item and the environment, increasing the convection heat switch coefficient, or increasing the item's surface area. There are times when changing the initial options is impractical due to their high cost. The addition of a fin to an item, as an alternative, may be a cost-effective way to address heat transmission issues. Fins of various shapes and lengths are used in engineering programmes to increase heat transfer rates, and they include.

- Rectangular fin
- Triangular fin
- Trapezium fins

- Circular segmental fins.

Fins are used to increase heat transfer from surfaces in a variety of engineering applications. Typically, a metal blend with high thermal conductivity, such as copper, is used in the fin. It's possible that the blade's fins are more efficient at transmitting heat because they're in direct contact with a moving liquid, allowing it to cool or warm the body by expanding heat away from the bulk. Cooling balances are used in a wide range of applications, and we use their shape and outline to characterise a few design criteria.

A balance is a surface that extends from a heat exchange study question. The rate at which heat is transferred from or to the environment can be increased by increasing the rate of convection. The amount of heat emitted by a protest is determined by the sum of convection, conduction, and radiation. The convection coefficient of heat exchange, or the surface area, increases as the temperature difference between the protest and the Earth grows. As a result, the expansion of the region obstructs heat flow. As a result, the aggregate territory (the base and balance surface area) has a lower heat-exchange coefficient than the base.

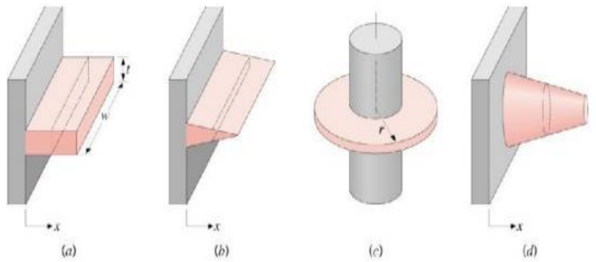

Figure 2: Use of extended surface or fin to enhance heat transfer.

3. RELATED WORKS

Different fin forms, fine pitch, fine setup, wind speed, content, and atmospheric circumstances all affect the heat-rejection engine cylinder, according to studies from the previous century. To better design and build stronger engine cooling fins, it's important to understand how the evolution of the cross-area affects heat exchange through expanded surfaces and the heat exchange coefficient.

D. Madhavi et. al. (2018) These cooling fins are intended to cool the 220cc engine cylinder. According to research, designing a 220cc motor is extremely difficult because increasing the ground area of the fin can increase the thermal dissipation speed. Heat conductivity was predicted using a parametric model of piston bore fins. In 3D modelling software, a parametric model is created using Solid functions. The fins are subjected to thermal analysis in order to determine how the temperature changes over time. The analysis is done with ANSYS. For analysis, various materials are used. The fin body is made of cast iron for the time being. In this study, the aluminium alloy 6082 is used as a substitute. The total heat flux of the aluminium alloy 6082 and zinc alloy fabrics used in the condenser and evaporator clearly exceeds that of the aluminium alloy 6082 and zinc alloy fabrics used in the condenser and evaporator, according to the study's findings. The best material for cylindrical fins is aluminium alloy.

Arjun Vilay et. al. (2018) The rectangular duct floor's time zone was used to investigate heat transfer and pressure loss from various heat sink forms. Two formed propellers are used in the shark fin, cylindrical (round) rectangle study. This study focused on cylindrical pin fins, which included horizontal thermal conductivity and rectangular longitudinal fins, with the goal of determining the best size and shape. No Nusselt calculations for Laminar and Turbulent flow have yielded different outcomes. After the research is completed, an X-Y diagram and vector depicting laminar and turbulent flow rates, heat transfer, and strain loss can be used to illustrate the overall findings. According to the findings, rectangular fins are best for heat transfer, while large round Pin Fin surfaces with low pressure losses are best for increasing heat transfer rates. This conclusion is supported by the study's print data.

Mahendra Kumar Ahirwar et. al. (2018) The project's goal is to investigate and compare the heat characteristics of various design, content, and density options using 100 cc Hero Honda Motorcycle fins. Several attempts to model temporary heat conductivity with parametric cylinder designs with fins have been made. The aluminium alloy 6063 with a thermal conductivity of 200W/mk is currently used in production. A heat source with a temperature of 1000 degrees Celsius was used to analyse the intended designs. The energy transferred from an internal combustion engine's combustion chamber can be dissipated in three different ways. Transient thermal analyses of the engine cylinder were performed in order to improve heat transfer from the IC engine and optimise geometric parameters. The results of this project reveal a more efficient and faster rate of heat transfer from the cooling area in the IC engine, which is why ANSYS 17.0 software is recommended to replace the current model.

Pradeep Kumar et. al. (2018) The thermal analysis of an engine block with fins was put to the test in this study. Thermal analysis of cylinder block caps is a good way to figure out how much heat the cylinder dissipates. Fins, which are mechanical components, are used in convectional cooling systems. The majority of their design is hampered in some way by the system's configuration. However, by modifying certain parameters and geometry, it is still possible to improve heat transfer. The most common types of fin geometry are rectangular and circular fins. A lot of experimental work has been done to improve the performance of fines in internal combustion engines. The engine block fins model was created using ANSYS 14.5 3D software, and the transient state temperature variability with gaps was calculated using a continuous thermal analysis on the fins and block. ANSYS software was used to analyse thermal conductivity.

S. Karthik et. al. (2018) This report summarises the final products for various applications. Fins can be used as economizers, heat exchangers, and numerous other applications. Internal combustion engines use cylinder blocks to create the wall of a combustion chamber, which is where air and fuel mixtures are ignited. The cylinder wall is exposed to high temperatures during the combustion cycle, and heat is transferred through the cylinder blades. If the heat is not properly absorbed, the engine's performance will suffer. How quickly heat moves through the fins is determined by the fabric's thermal conductivity and other properties. A standard Pin-Fin sample is used for analytical purposes. By confirming that the ANSYS 16.1 operation is functioning properly. The evaluation output can be fed into an Artificial Neural Network to generate the required metal material characteristics. With the help of this system, choosing the right finishing products for different applications becomes a lot easier.

Raviulla et. al. (2018) The main goal of this research is to compare the heat transfer properties of different cylinder fin geometries. When evaluating the heat output of filters with large temperature differences between the fine foundation and the surrounding fluid, the temperature-dependent thermal conductivity of the fine material must be taken into account. As a result of Lava Kumar's efforts, Researchers were able to reduce the weight of the fin body while increasing the heat transfer rate and fin effectiveness by changing the fin shape to a triangular form.

4. FINITE ELEMENT ANALYSIS

The technique of finite elements is a helpful asset to achieve the numerical configuration of a wide range of construction problems. The method is general enough to handle any complicated form or geometry under different restriction and stacking circumstances for any material. The all-inclusive declaration of the restricted element approach is in line with the examination prerequisite of the current complicated construction frameworks and buildings where closed form agreements of balancing circumstances are not usually available. Moreover, it is an efficient plan device by which fashioners can execute parametric design by considering distinct structural instances (distinct forms, equipment, loads, etc.) and break them down to select the perfect framework.

The technique arose as a method of studying stress in an complex airframe framework in the aerospace industry. It comes from what was known as the approach of matrix examination used in the design of the aircraft system. The method has made the two experts and experts more prominent. The main concept of a restricted element approach is to isolate a body or structure into small parts of restricted dimensions called "finite parts." The first body or structure is then considered to be a collection of these components associated with a limited number of joints called nodal or hubs.

It is possible to decompose structures and bodies into smaller components, each of which is regarded a limited component, with the original body or structure being understood as a collection of tiny components that are tied together by nodal points or hubs. Due to a lack of information about which components are genuinely present in the continuum, it is possible to generate an estimate of a field variable inside a limited component by assuming the presence of certain elements. All of the conjecture capacity models, also called as initiation models, are expressed in terms of estimations of the hubs field component. Nodal field estimations are often reliant on the conditions of the frame. Finite element method finds its implementation in the domain of concrete construction in the completion of the static examination of bases, casings and towers. The structure's dynamic inquiry is to obtain standard frequencies, modes, and structure response to regular loads. In the static and dynamic depiction of its frameworks, for instance, nuclear weight ships, control framework and dynamic response of reactor section regulating systems. Indeed, even the Biomedical construction uses a method of restricted components for the examination of skull effects. Limited element approach can be linked to examining exhumation, subterranean openings and vibrant inquiry of dam storage frameworks under Geomechanics.

5. MODELLING OF ENGINE CYLINDER

In SolidWorks, this problem has been fully resolved. Finite element analysis can be used to simulate the mathematical behavior of a structure in the real world (FEA). The model includes nodes, elements, material properties, real constants, and boundary conditions, as well as nodes, elements, material properties, and real constants. Specific boundary conditions will then be applied to specific nodes, followed by a final analysis.

Basic Dimensions of Cylinder

Table 1: Dimensions of Cylinder block with fins

Dimensions	Circular Fins shape Cylinder	Rectangular Fins shape Cylinder
Bore diameter	70 mm	70 mm
Height of Cylinder	50 mm	50 mm
No. of Fins	9	9

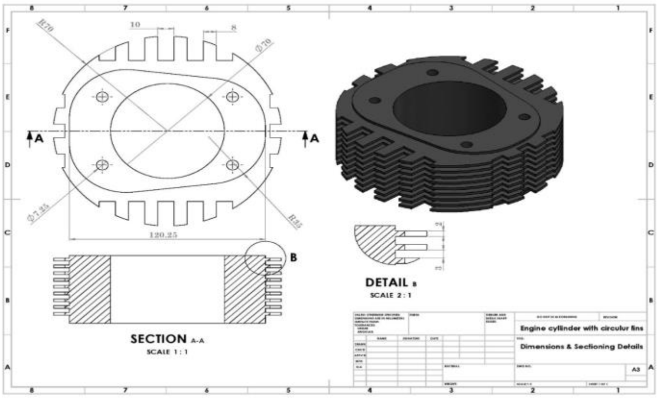

Figure 3: Engine Cylinder with Circular area of Fins

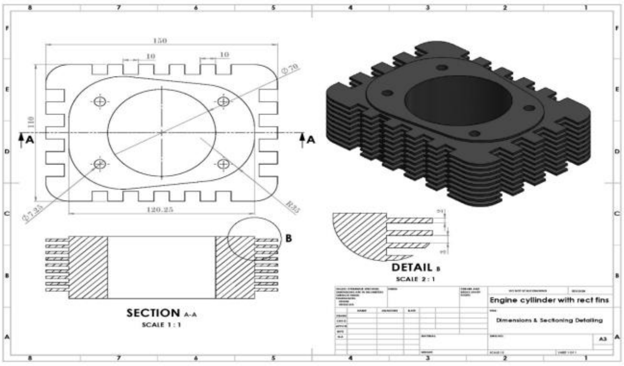

Figure 4: Engine Cylinder with Rectangular area of Fins

5.1. Material Properties

A thermal analysis of an engine cylinder made of aluminium alloy yielded analytical results. The composition of aluminium alloy is shown in Table 2.

Table 2: Material properties of Engine Cylinder Model

Parameters	**Units**	**Aluminum alloy (1060)**	**Aluminum alloy (6082)**
Density	(Kg/m^3)	2700	2710
Young's Modulus	(MPa)	69000	71000
Coefficient of thermal expansion	(1/K)	2.3×10^{-5}	2.3×10^{-6}
Poisson's Ratio	-	0.33	0.35
Ultimate Tensile Strength	(MPa)	310	330
Thermal conductivity	(W/m-K)	200	170

Purpose of these two materials selections

Normally, alluminum alloys are used to make fins. Heat transfer rate and thermal conductivity are the two most significant attributes to consider when choosing materials for engine fins. To guarantee maximum heat transfer rates, the ideal material to use is one with the greatest thermal conductivity. Thermal resistance, corrosion resistance, and material weight are other essential considerations, particularly at high temperatures. In general, the purpose of the fins is to enhance the surface area available for convectional heat transmission. Heat transfer rate and thermal conductivity are two of the most significant factors to consider when choosing materials for engine fins.

5.2. Meshing of Engine Cylinder

The mesh of the finite volume method considers points forming a set of cells. The finite element methods use sub volumes, known as elements with nodes to define the variables. The dependent variable values such as temperature, strain, speed, etc., are used for any aspect. The consistency of the CFD result depends heavily on the mesh quality.

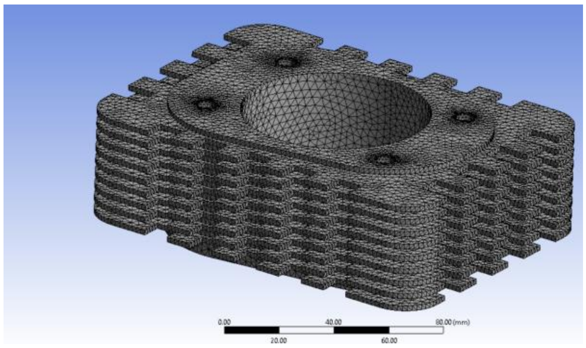

Figure 5: Meshed model of Recangular type fin shape engine cylinder

Table 3: Mesh details of Recangular type fin shape engine cylinder

Details of "Mesh"	
Display Style	Use Geometry Setting
Defaults	
Sizing	
Use Adaptive Sizi...	Yes
Resolution	7
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Fine
Initial Size Seed	Assembly
Bounding Box Di...	192.61 mm
Average Surface ...	178.43 mm^2
Minimum Edge L...	2.0 mm
Quality	
Inflation	
Advanced	
Statistics	
Nodes	242639
Elements	132954

In the finite method of volume mesh, points forming a group of volumes called cells are considered. The methods of the finite elements are called elements with sub-volumes that have nodes to define them. The variables, including temperature, strain, distance, etc., for every dimension. The CFD outcome quality is very dependent on the mesh size. Too many cells will lead to long solver runs and too little to inadequate tests.

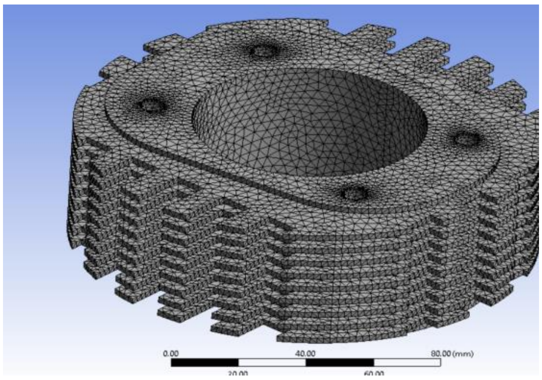

Figure 6: Meshed model of Circular type fin shape engine cylinder

Table 4: Mesh details of Circular type fin shape engine cylinder

Details of "Mesh"	
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizi...	Yes
Resolution	7
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Fine
Initial Size Seed	Assembly
Bounding Box Di...	203.8 mm
Average Surface ...	193.49 mm²
Minimum Edge L...	1.5833 mm
Quality	
Inflation	
Advanced	
Statistics	
Nodes	186505
Elements	102414

5.3. Applying boundary conditions

To maximize convection, the Engine Cylinder Model boundary conditions are shown in Figures 7 and 8, with a maximum temperature of 700 °C and convection conditions of 22 °C applied to the outer surface of the Engine cylinder. The maximum and minimum temperatures are ideal for maximum heat transfer. The boundary conditions of the Engine Cylinder Model are depicted in the diagram.

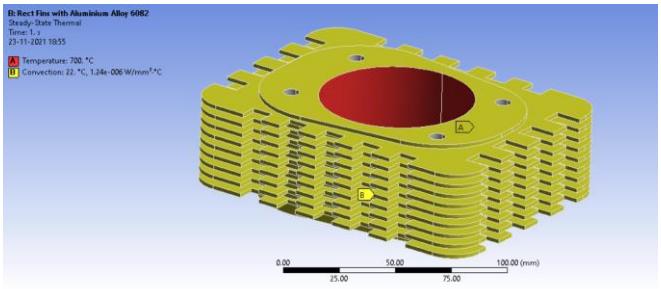

Figure 7: Applied Boundary conditions on Cylinder with Rectangular Fins area

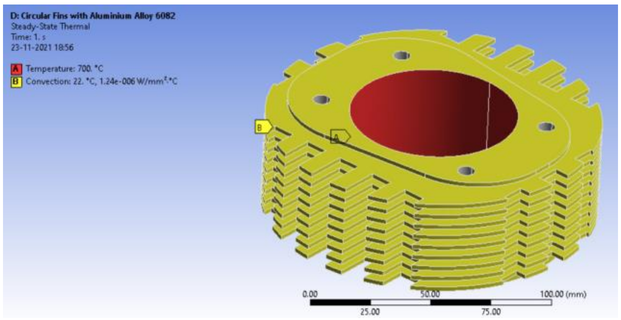

Figure 8: Applied Boundary conditions on Cylinder with Circular area of Fins

The performance of Engine Cylinder models was compared in a rectangular versus a circular region as part of the Ansys Thermal Analysis. In this study, engine cylinder fins with rectangular and circular surfaces are compared. The outer surface of an engine cylinder is fitted with circular and rectangular heat exchange fins to determine the best heat transfer improvement. By optimizing the heat exchange rate in all possible ways, a higher heat exchange rate can be achieved.

6. RESULTS AND DISCUSSION

The best design for the Engine Cylinder Fins was determined using static thermal analysis. The material properties of Engine Cylinder models were assigned to the two different shaped models in ANSYS to create Engine Cylinder models. Thermal analysis can be used to identify temperature-dependent changes in a material's physical properties. Using these methods, calculate changes in mass or energy in a material model. In a steady state scenario, an engine cylinder model with various piston heights and boundary conditions is shown. After the solution was processed, the temperature variations in rectangular and circular fin models were studied and graphed for comparison.

The Engine Cylinder model is made up of a mesh of measured parts from the basic frame. Every segment's displacement is thought to be calculated using basic polynomial profile capacities and nodal temperature. Strains and stresses are generated as far as the obfuscated nodal temperature is concerned. The balance conditions are organized into a grid that can be easily changed. The figures show temperature changes in engine cylinders under steady-state conditions with imposed boundary constraints. Heat builds up in the cylinder during the combustion process, causing the temperature to rise. After processing, the temperature and total heat flow of both rectangular and circular fins models were examined using thermal analysis. Plate fins, Engine cylinder with rectangular fins, and Engine cylinder with circular fins were studied as part of a structural and thermal investigation. Ansys conducted an analytic study of engine cylinder models.

Temperature distribution analysis of Engine Cylinder Models

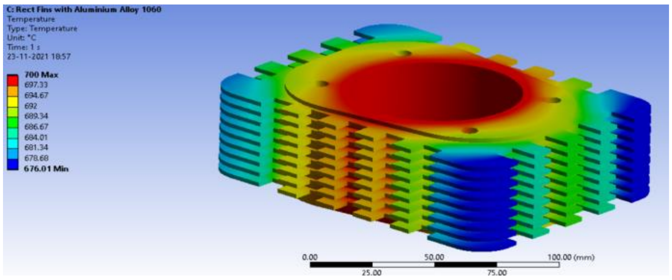

Fig 9: Temperature Distribution of Rectangular area of fins cylinder with AA 1060 material

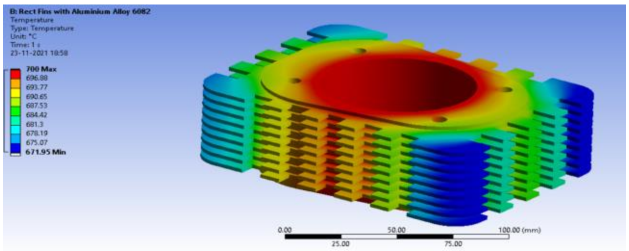

Fig 10: Temperature Distribution of Rectangular area of fins cylinder with AA 6082 material

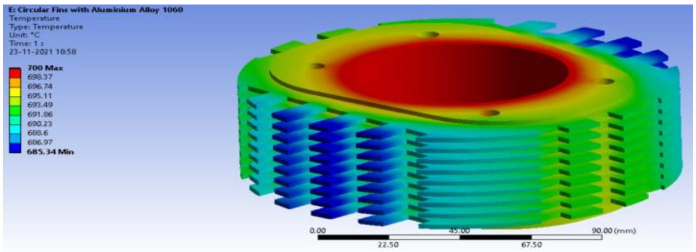

Figure 11: Temperature Distribution of Circular area of fins cylinder with AA 1060 material

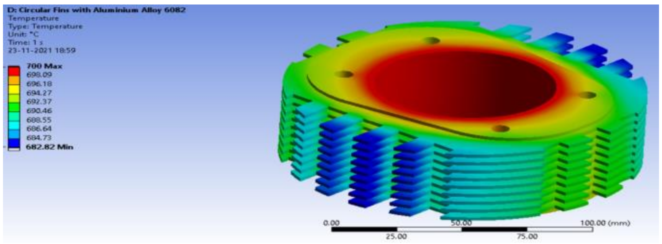

Figure 12: Temperature Distribution of Circular area of fins cylinder with AA 6082 material

Heat Flux of Engine Cylinder Models

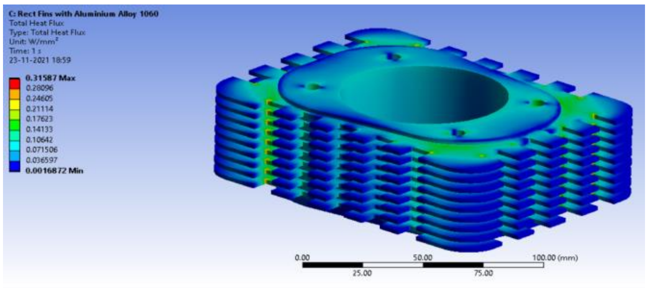

Figure 13: Heat Flux of Rectangular area of fins cylinder with AA 1060 material

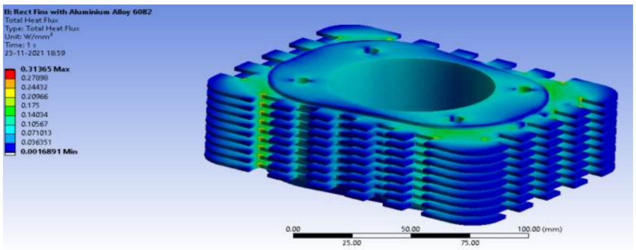

Figure 14: Heat Flux of Rectangular fins area of cylinder with AA 6082 material

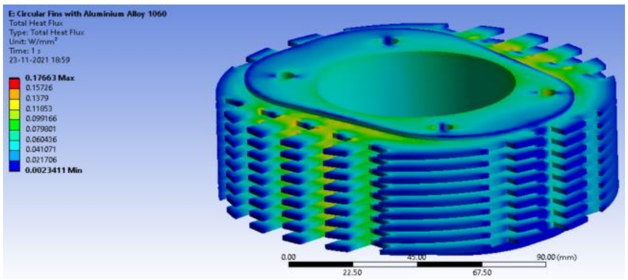

Figure 15: Heat flux of Circular fins area of cylinder with AA 1060 material

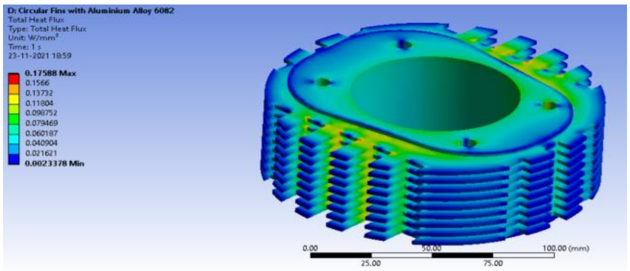

Figure 16: Heat flux of Circular area of fins cylinder with AA 6082 material

Table 5: Temperature Variations of Engine Cylinder Models

Engine Cylinder Types	Maximum Temperature (^oC)	Minimum Temperature (^oC)	Temperature Drop (^oC)
Aluminum alloy 6082 cylinder with Rectangular area of fins	700	671.95	28.05

Aluminum alloy 1060 cylinder with Rectangular area of fins	700	676.01	23.99
Aluminum alloy 6082 cylinder with Circular area of fins	700	682.82	17.18
Aluminum alloy 1060 cylinder with Circular area of fins	700	685.34	14.66

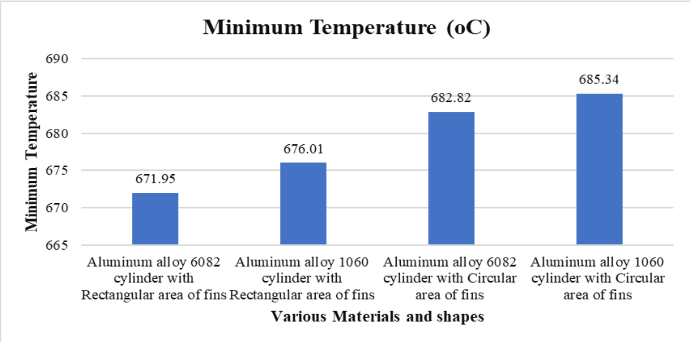

Figure 17: Temperature Variations in Models of Engine Cylinder

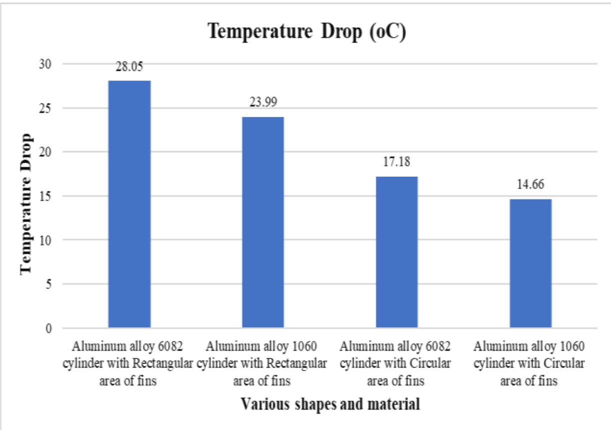

Figure 18: Temperature Variations in Models of Engine Cylinder

Engine cylinders made of AA 6082 material have the lowest minimum temperature of 671.95 °C, while those made of AA 1060 have the lowest minimum temperature of 676.01 °C with rectangular-shaped fins, according to the research. A cylinder with circular area fins made of AA 1060 material had a minimum temperature of 685.34 °C.

According to the research, rectangular-shaped fins in an engine cylinder transfer heat better than circular-shaped fins. The maximum temperature was also highest in the engine cylinder with rectangular fins.

Table 6: Heat Flux Found on All conditions of Engine Cylinder Models

Engine Cylinder Types	**Heat flux (w/mm^2)**
Aluminium alloy 6082 cylinder with Rectangular area of fins	0.313
Aluminium alloy 1060 cylinder with Rectangular area of fins	0.315
Aluminium alloy 6082 cylinder with Circular area of fins	0.175
Aluminium alloy 1060 cylinder with Circular area of fins	0.176

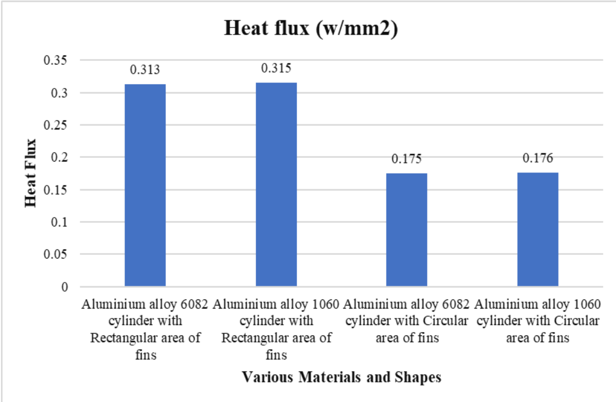

Figure 19: Comparison of Heat flux of Engine Cylinder

An engine cylinder with circular fins has a lower heat transfer rate of 0.143 W/mm2, while an engine cylinder with rectangular fins has a higher heat transfer rate of 0.258 W/mm2, according to the comparison chart. Based on the results of this comparison, the engine cylinder with rectangular fins has a higher heat transfer rate than the engine cylinder with circular fins.

7. CONCLUSIONS

In comparison to the circular-shaped engine cylinder with aluminium alloy Al 1050, total heat flux in the rectangular-shaped engine cylinder with aluminium alloy Al 1060 was found to be 0.315 W/mm2. In the cylinders of engines with rectangular-shaped Al 6082 fins and circular-shaped Al 6082 fins, temperatures of 671.95C and 682.820C, respectively, were found. As a result, rectangular fins in the engine cylinder can be concluded to be more effective at transferring heat. As a result, the engine cylinder with a rectangular Fins profile transfers heat more efficiently than the engine cylinder with a circular Fins profile.

Rectangular fins on the engine cylinder cooled the best, and aluminium alloy provided the best heat transfer results.

Overall, ANSYS 14 FEM is used for the analysis. Advanced materials and various designing and analysis tools can be used to conduct further research. The following are the outcomes of the research presented here:

- Thermal analysis of fins has been completed by modifying certain parameters such as geometry and engine cylinders within the circular area with rectangular fins and engine cylinders.

- We can easily conclude that using 6082 engine cylinders is the best option because rectangular shape fins made of Aluminum alloy 6082 have a significantly higher temperature drop and heat transfer rate than circular area shaped fins.

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