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Heat Transfer Performance of Cylinder Block with Fin for Perforated Fins and Various Materials

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Abstract— In the IC engine, the combustion takes place in the engine cylinder block from the mixing of air-fuel. And after burning of air-fuel in cylinder block the temperature distribution takes place and this process goes continuously. The heat transfer depends upon the velocity of the air, ambient temperature, the geometry of the fin, and the surface of the fin. Throughout most cases, the design of the system restricts heat transfer across fins. The principle of convection and conduction is utilised to cool various structures through fins. Numerical simulations are carried out for two different fin materials: AL 2014 T6 and AL6061 T6. The heat transfer effect may be varied by changing geometry and changing material for different thermal conductivities, using perforations on the fin.The maximum temperature drop is 25.87 0C with holes and maximum total Heat flux is 440.11 w/m2.The design of the model is done in CATIA V5 software and thermal analysis is done in ANSYS R19.

Keywords:-Heat transfer enhancement,Engine cylinder, Convection, FEM, Perforated fins, CFD.

I. INTRODUCTION

Inside the cylinder of an IC engine, combustion of fuel, changing the chemical energy of the fuel into mechanical energy.Only 25 to 30% [7]of the total generated thermal energy converts into useful work and rest of it rejected into the surrounding. The produced energy raises the temperature of the engine to 600oC, which can cause oil film to burn between moving components, ending in seizing or welding.As a result, this temperature must be kept within safe ranges. The goal of this research is to see how heat is dissipated by fins made up of various materials and designs. The heat transfer rate of fins has to be investigated.The research will lead us to various cylinder experiments that have been carried out to improve fin efficiency by modifying fin material characteristics, environmental circumstances surrounding fins, and fin geometry by employing perforations.The analysis's main objective is to improve the fins heat transfer performance by adjusting certain parameters and geometry. Usually, fins are analyzed by considering a uniform design with a heat exchange coefficient on the surface.In any case, optimization by separate researchers found that it is not stable, but moves around the spectrum of the fines. It is basically a direct result of non-uniform interference in the interface between the fines induced by fluid transfer. Increasing the heat exchange region increases the heat dissipation efficiency, but increasing fluid flow resistance induces a reduction in heat exchange. The primary objective of the analysis is on a two-wheeler engine.

The conduction heat transfer[1,13] from inner wall to fin surface is given as:-

$$Q = k\,(T_w - T_{fin})$$

The convection heat transfer [1]from fin surface toatmosphere air by free and forced air is given as:-

$$Q = h_f\,(T_{fin} - T_{air})$$

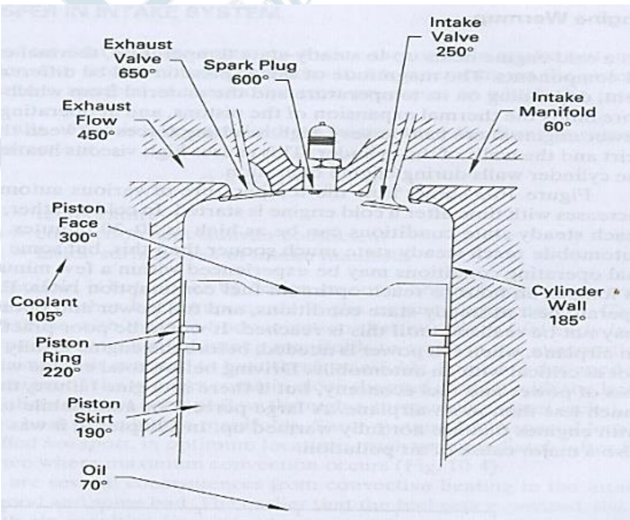

Figure 1: Engine Cylinder[2]

II. PROJECT METHODOLOY

1) Choose engine cylinder blocks whose engine specifications are closely related.
2) Generate the CAD models for these cylinder blocks using CATIA V5 software.
3) Define boundary conditions, and assumptions in the analysis.
4) Calculation of thermal loads the blocks are subjected to.
5) Analysis of these blocks using Ansys software.
6) Comparison of results from Ansys.

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III. MATERIAL PROPERTIES

Engine cylinder materials:-Thermal analysis of cylinder block was analyzed with ANSYS software. In these simulations different alloys has been considered by taking the conductivity, density and specific heat as major material properties for thermal analysis. Materials that are used for present analysis are aluminium AL 2014 T6[5] and AL 6061 T6[6,8]. We are taking these material in consideration because in aluminium alloys they have highest thermal conductivity, which is important for heat transfer.

Aluminium alloys properties:-

Material	Composition	Tensile Strength (MPa)	Young's Modulus (GPa)	Density (kg/m³)	Specific Heat (KJ/Kg⁰C)	Thermal conductivity (W/mK)
AL2014T6	Al 95.6-95.8, Mg 0.2-0.8, Si 0.5-1.2, Fe 0.7max, Ti 0.15max, Zn 0.2 max.	483	72.4	2800	0.880	154
AL6061 T6	Al 95.6-95.8, Mg 0.2-0.8, Si0.4-0.8, other each Max0.005, balanced Al	310	73	2700	0.896	167

DESIGN AND ANALYSIS OF ENGINE CYLINDER

a) Modelling of Engine cylinder Model:-

To carry out the finite element analysis of the engine cylinder models when the engine temperature is transferred to the air via the engine cylinder. CATIA V5 R19 software was used to produce the 3D model.The inner diameter of cylinder is 30mm[10] and length of fins is taken as 25 mm and the diameter of perforated holes on fin is 3mm. and the number of holes on one is takes as 48.The distancebetween any two fins is 7mm[10]. Thermal analysis is performed on 3D model to get the final results. Experimental analysis of Engine Cylinder Models is performed by ANSYS, which is a collaborator of commercially used engineering simulation software package providing a whole enterprise that spans the whole form of physics, giving the best use of almost all fields of thermal engineering resources that a design methodology desires.

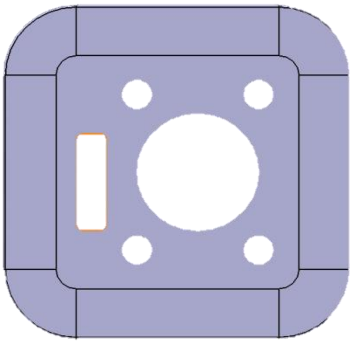


Figure : 1. (a) Front view of engine cylinder without fins

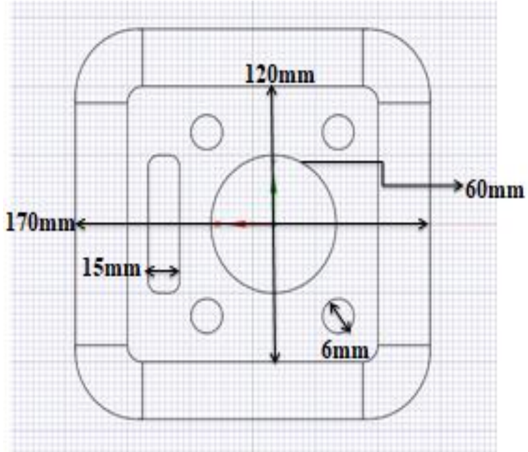
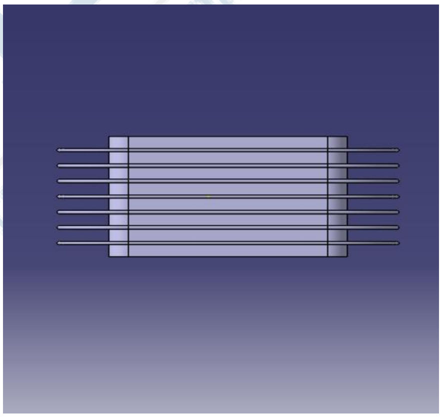


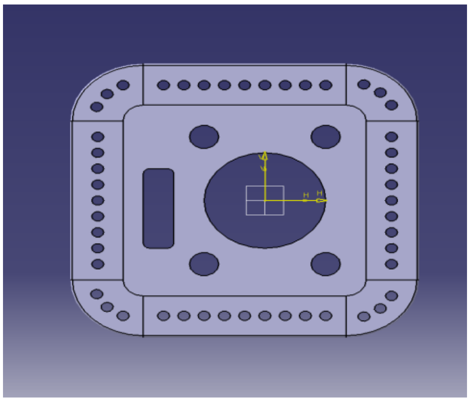
Figure : 1. (b) 2D view with specifications

b) Perforation in fins:-

The perforation of fins with a radius of 3mm was considered in this thermal analysis. Furthermore, the perforations allow in the reduction of fins, resulting in reduced engine weight. In addition, increasing heat transfer and maximizing temperature drop through engine cylinder fins, as well as increasing airflow through fins.



(c) Side view of engine cylinder with fins

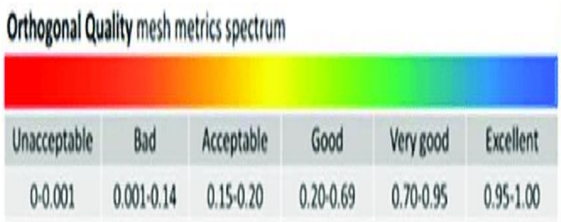


(d) top view with perforated fins

Figure 2:3D&2D Model of engine cylinder

c) Meshing of model in ANSYS software:-

In meshing for this model we take element size about 2mm for better analysis results[9]and physics preference is CFD(Computational Fluid Dynamics), solver preference is CFX type of meshing is tetrahedral mesh[12] for mesh input, and Average Orthogonal Quality after generating mesh is 76% which is consider as a very good mesh.



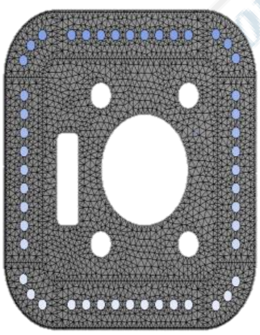
(a) Orthogonal Quality Mesh Scale

Details of "Mesh"

Sizing	
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.900000)
Smoothing	Medium
Mesh Metric	Orthogonal Quality
Min	0.16025
Max	0.99597
Average	0.76027
Standard Deviati...	0.1226

(b) Orthogonal Quality after mesh

(c) Size of mesh is 2mm



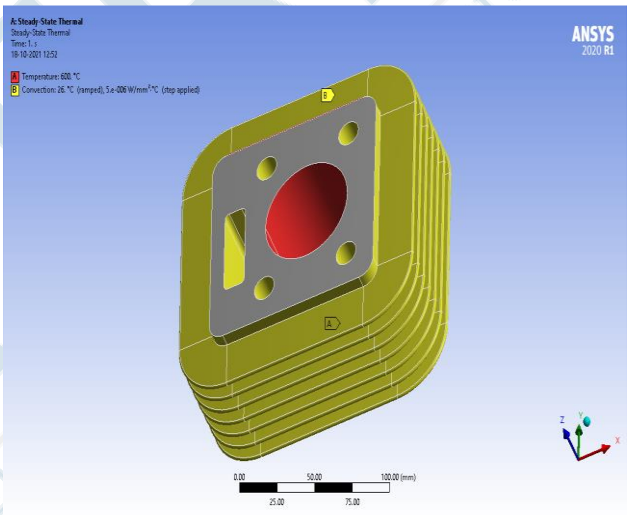
(d) Size of mesh is 5mm

Figure 3: Mesh model of cylinder block with holes

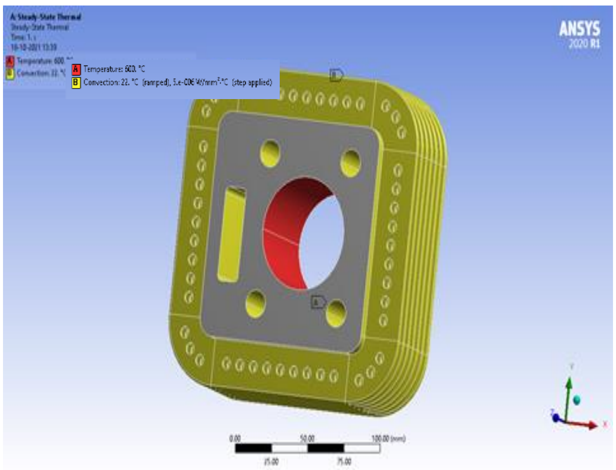
d) Applying boundary conditions:-

Figure 6 indicates the boundary conditions applied to the Engine Cylinder Model. The boundary conditions were applied to the Engine Cylinder Model with a maximum temperature of 600^0C insideThe literature work on engine cylinder fin cooling is abundant hence only recent literature is cited and presented here. GyanendraDhakar et al. [4], and convection conditions 22^0C(Ambient stagnant air temperature) were applied when convection was applied to the Engine Cylinder's outer surface to maximise maximum and minimum temperature, as well as maximum heat flow rate for high heat transfer.Figure indicates the limitations of the Engine Cylinder model applied.The inner temperature = 600^0C

The outer convection condition,
Film coefficient = 5w/m^2.^{0}C
Ambient temperature = 22^0C



(a) Without holes



(b) With holes

Figure 4: Boundary conditions

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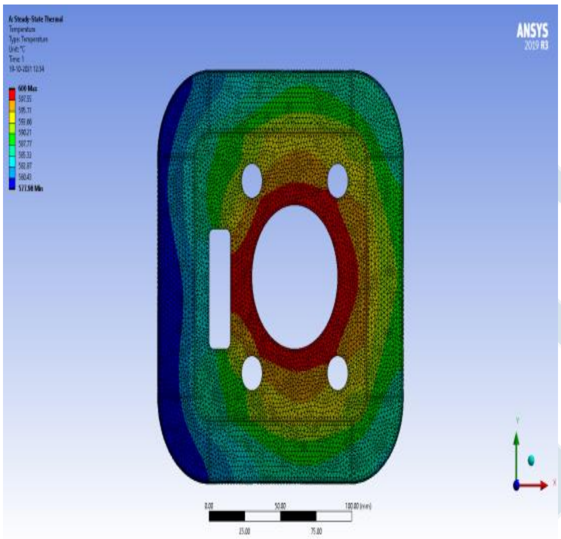
IV. RESULT AND DISCUSSION

ANSYS was used to analyse the thermal analysis of the cylinder block. The thermal conductivity, density, tensile strength, young's modulus and specific heat of aluminium alloys have been used as primary material parameters for thermal study in these simulations. Materials that are used for present analysis are aluminium alloys, Al2014 T6, Al6061 T6. Thermal analyses were carried out on all of these alloys at the same wind speed. The conductivity of a materials has a strong influence on the heat transfer mechanism; so, the final material selection is centred mostly on thermal conductivity and high strength in a light weight material.

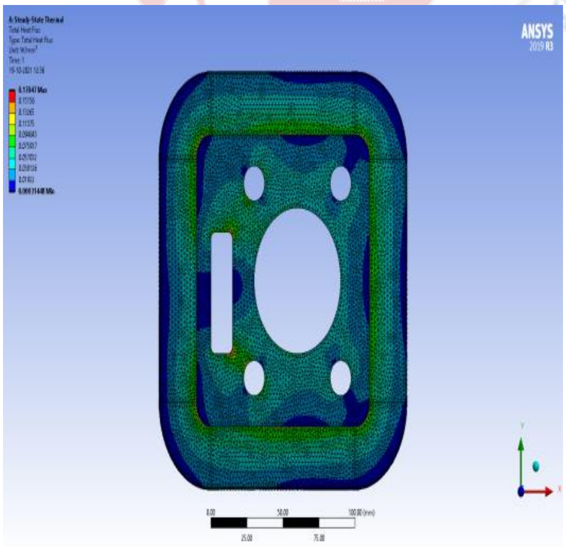
Temperature distribution analysis of Engine Cylinder Model

For AL2014 T6 at ambient temperature(22^{0}C)

For 2mm thickness fin perforation:-

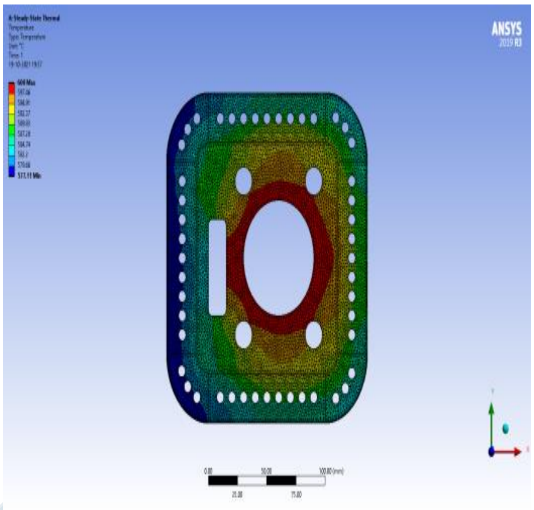


(a) Temperature distribution

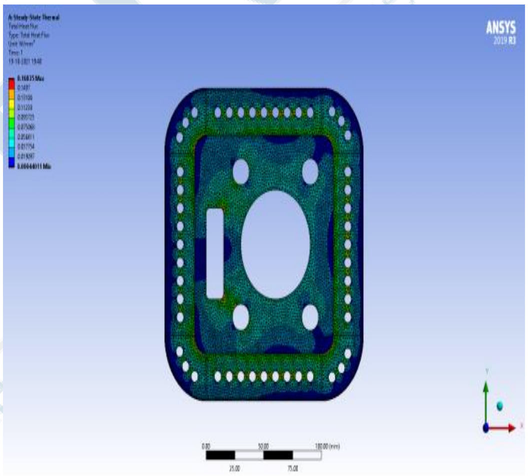


(b) Heat flux

For 2mm thicknesswith fin perforation:-



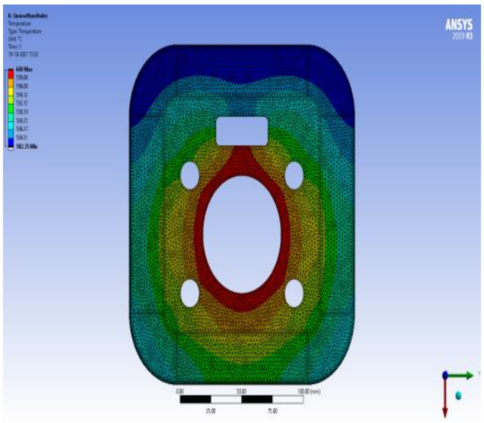
(c) Temperature distribution



(d) Heat flux

Figure 5: for 2mm thickness fins

For 3mm thicknesswithout finperforation:-



(a) Temperature distribution

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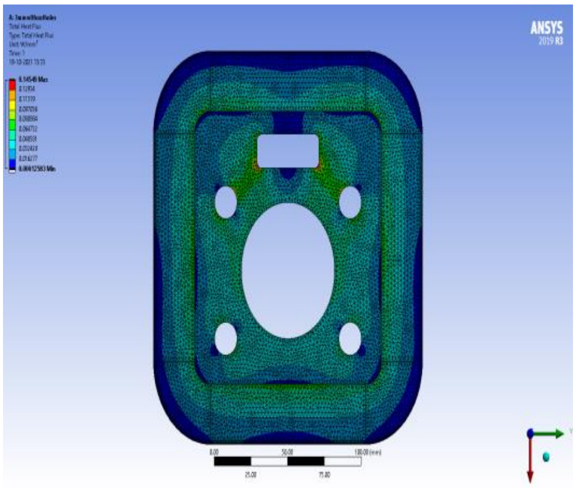
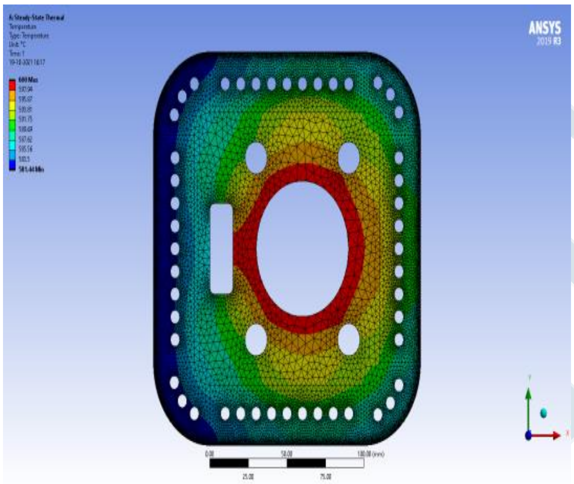
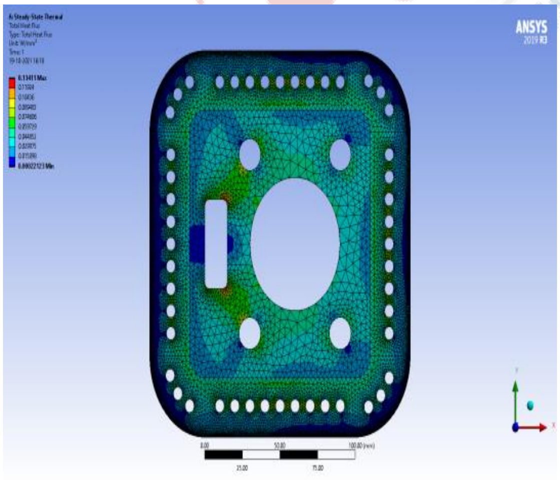


(b) Heat flux

For 3mm thicknesswith fin perforation:-



(c) Temperature distribution

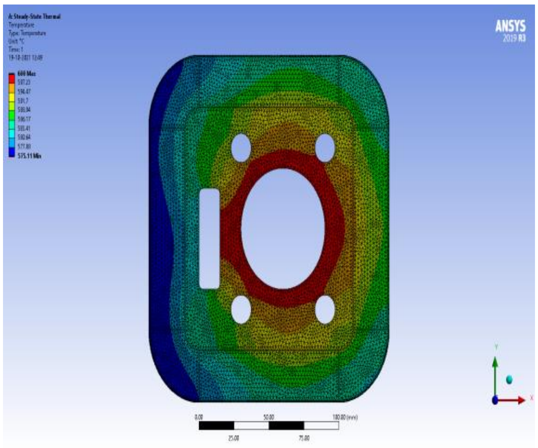


(d) Heat flux

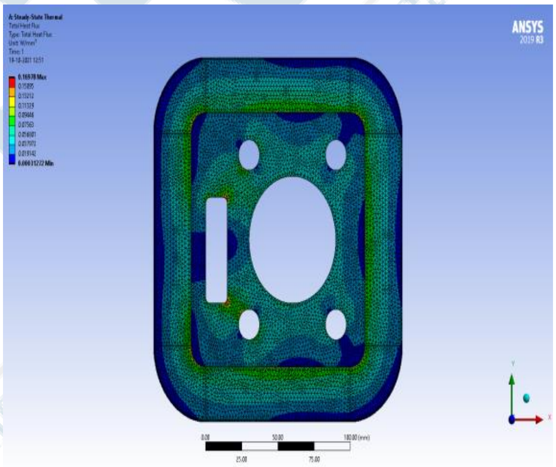
Figure 6: for 3mm thickness fins

For AL 6061 T6 at ambient temperature (220C):-

For 2mm thicknesswithout fin perforation:-

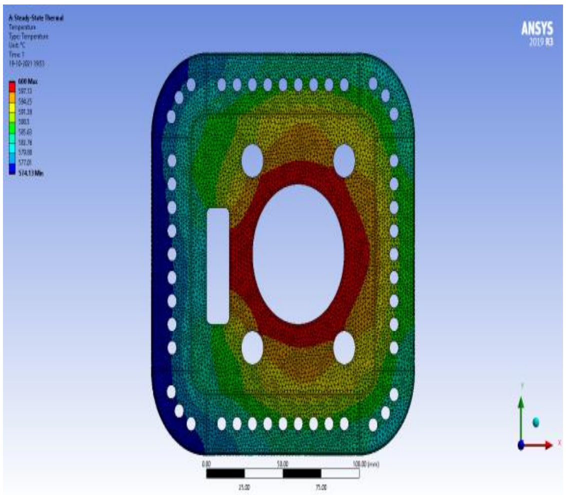


(a) Temperature distribution



(b) Heat flux

For 2mm thicknesswith fin perforation:-



(c) Temperature distribution

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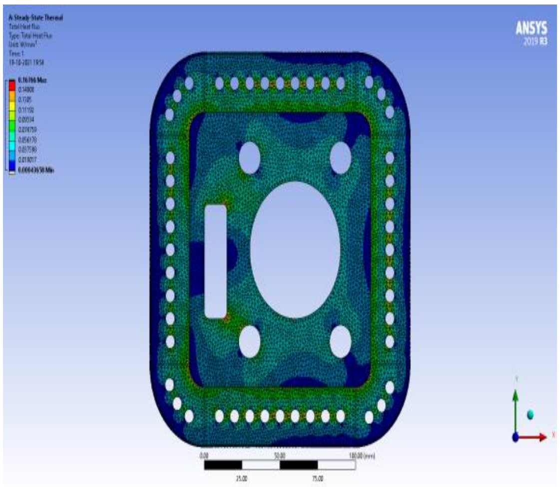
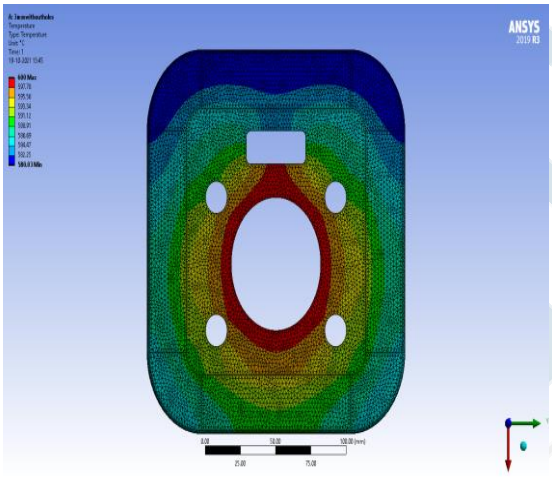


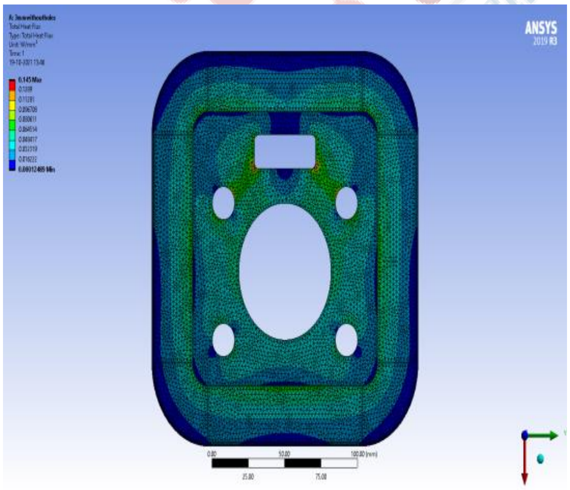
(d) Heat flux

Figure 7:for 2mm thickness fins

For 3mm thickness without fin perforation:-

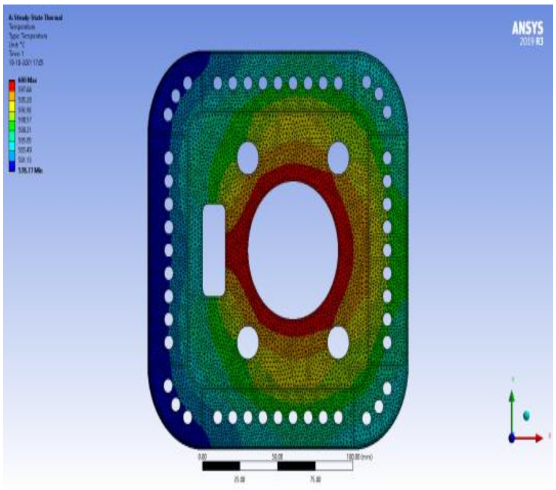


(a) Temperature distribution

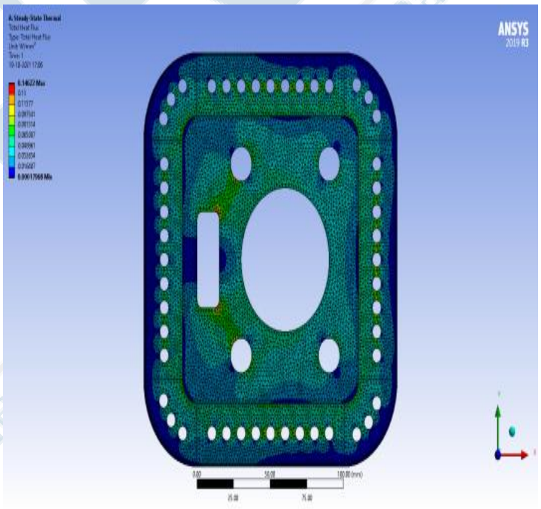


(b) Heat flux

For 3mm thicknesswith fin perforation:-



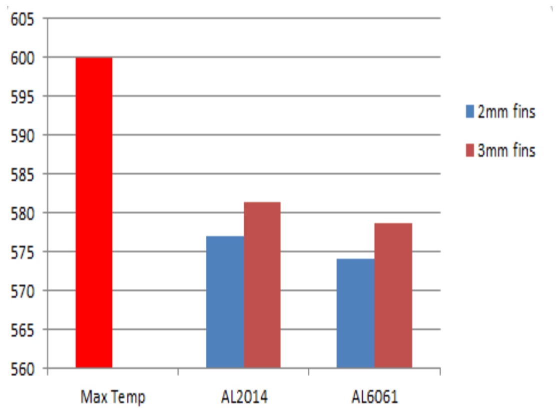
(c) Temperature distribution



(d) Heat flux

Figure 8: for 3mm thickness fins

Graph comparison between 2mm and 3mm thickness fins:-



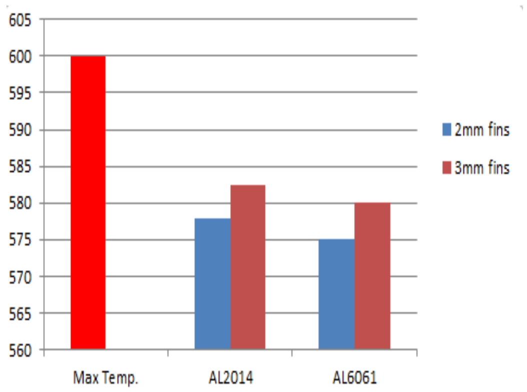


Figure 9: Temperature Distribution at 2mm&3mm models of Engine Cylinder with fin hole and without holes(Units 0C)

As per above study it is concluded that engine cylinder with circular holes in fins gives maximum heat transfer because Engine cylinder with Aluminium Alloy Al6061 T6 (for 2mm thick) material found minimum temperature is 574.13 °C [4]when maximum temperature is 600 °C. And maximum total Heat flux is 440.11 w/m^2 [4]is given in Al2014 T6 for 2mm thick fins. So we concluded that in comparison between 2mm and 3mm thick fins the 2mm thick fin gives better results for temperature distribution and for temperature the Al6061 T6 is gives better results for better Heat transfer rate.

Figure 10: Total Heat Flux at 2mm & 3mm models of Engine Cylinder with fin hole and without holes (Units w/m^2)

V. CONCLUSION

According to the above analysis, we discover that fins geometry profiles with circular holes provide higher heat transfer outcomes than engine cylinders without holes. As we raise the thickness of the fins from 2 mm to 3 mm, we see that the temperature range reduces. We can reduce heat transmission by increasing the thickness of the fins in the engine cylinder.

- The maximum temperature drop is 25.87 ^{0}C with holes on 2mm thick and Al6061 T6 material
- Minimum temperature distribution founds on 3mm plate fin without circular holes and Al2014 T6 material
- The maximum Total Heat flux founds on 2mm plate fin with circular holes and on material Al2014 T6
- The Maximum total heat transfer rate we will get is 440.11 w/m^2.
- Minimum heat transfer rate founds on 3mm without holes for material Al6061 T6
- The mesh for the analysis of model is done by using tetrahedral mesh. and size of every mesh component is taken as 2mm for better mesh quality and it give us 76% orthogonal mesh quality which is consider as very good quality as per ANSYS 2019 R1

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