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MODELING AND CFD ANALYSIS OF ENGINE CYLINDER FINS

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Abstract: In an internal combustion engine, the cylinder head (often informally abbreviated to just head) sits above the cylinders on top of the cylinder block. It closes in the top of the cylinder, forming the combustion chamber. This joint is sealed by a head gasket. In most engines, the head also provides space for the passages that feed air and fuel to the cylinder, and that allow the exhaust to escape. The head can also be a place to mount the valves, spark plugs, and fuel injectors.

The major automobile component subject to high temperature variation and thermal stress is engine cylinder. Fins are used on the surface of engine cylinder to increase the heat transfer rate. Heat rejection rate in engine cylinder fins can be enhanced by increasing its surface area. The objective of the present investigation is to examine the thermal properties by varying geometry, and material cylinder fins using solid works and Ansys work bench and the models are created by changing the geometry like (i) no of fins (ii) fin thickness (iii) gap between fins,

In this thesis 3 different types of boundary conditions (static, thermal, flow) were applied and calculated results like deformation, stress, strain, safety factor, total temperature distribution, heat flux values, after calculating all these results finally thesis can concluded with optimum fins shape and their materials with suitable graphs and table

Introduction

Cylinder head

In an internal combustion engine, the cylinder head (often informally abbreviated to just head) sits above the cylinders on top of the cylinder block. It closes in the top of the cylinder, forming the combustion chamber. This joint is sealed by a head gasket. In most engines, the head also provides space for the passages that feed air and fuel to the cylinder, and that allow the exhaust to escape. The head can also be a place to mount the valves, spark plugs, and fuel injectors.

Fins

The term extended surface is commonly used in reference to a solid that experiences energy transfer by conduction and convection between its boundary and surroundings, a temperature gradient in x direction sustains heat transfer by

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conduction internally at the same time, there is heat dissipation by convection into an ambient at $T\infty$ from its surface at temperature TS, given as

$$Q = h\,As\,(T_S - T_\infty)$$

Where h=convection heat transfer coefficient

AS =Heat transfer area of a surface

When the temperatures TS and $T\infty$ are fixed by design considerations, there are only two ways to increase the heat transfer rate:(i) to increase the convection coefficient h, (ii) to increase the surface area A. in this situations, in which an increase in h is not practical or economical, because increasing h may require the installation of pump or fan or replacing existing one with larger one, the heat transfer rate can be increased by increasing the surface area. For heat transfer from a hot liquid to a gas, through a wall, the value of heat transfer coefficient on the gas side is usually very less compared to that liquid side (hgas<<<<hliquid) .to compensate low heat transfer coefficient, the surface area on the gas side may be extended for a given temperature difference between surface and its surroundings. These extended surfaces are called fins. The fins are normally thin strips of highly conducting metals such as aluminum, copper, brass etc. The fins enhance the heat transfer rate from a surface by exposing larger surface area to convection. The fins are used on the surface where the heat transfer Coefficient is very low. Total heat produced by the combustion of charge in the engine cylinder may not convert into useful power at the crankshaft. So loss of heat approximately at the cylinder walls is 30% due to cooling. If this heat is not removed from the cylinders it would result in the pre-ignition of the charge and also damage the cylinder material. as well as the lubricant may also burn away, so that causing the piston may seizing keeping the above factor in view , it is observed that suitable heat must be maintained in the cylinder. So that excess heat removed by adding the fins to the cylinder walls.

Problem identification

Indian two-wheeler market is the world's second biggest market. Among the three segments (motorcycles, scooters and mopeds) of the Indian two wheeler market, major growth trends have been seen in the motorcycle segment over the last four to five years due to its resistance and balance even on bad road conditions. In Indian motorcycles, Air-cooling is used due to reduced weight and simple in construction of engine cylinder block. As the air-cooled engine builds heat, the cooling fins allow the wind and air to move the heat away from the engine. **Low rate of heat transfer through cooling fins is the main problem in this type of cooling.** The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations and thermal stresses. In order to cool the cylinder, fins are provided on the surface of the cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins, it is helpful to know the heat dissipation inside the cylinder. The principle implemented in the project is to increase the heat dissipation rate by using the invisible working fluid, nothing but air. We know that, by increasing the surface area we can increase the heat dissipation rate, so designing such a large complex engine is very difficult. The main purpose of using these cooling fins is to cool the engine cylinder by air. The main aim of the project

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is to analyze the thermal properties by varying geometry, material of cylinder fins.

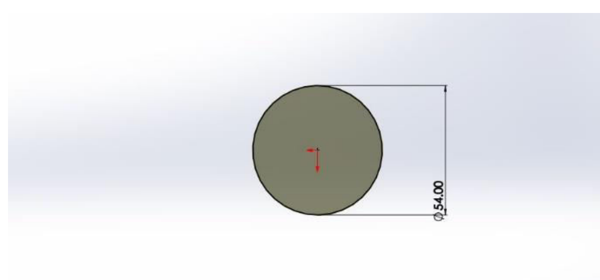
Aim of the project

The main aim of the project is to increase the heat transfer through cooling fins, to meet this aim here optimized curved cylinder fins by varying fins thickness, and their gap in between and also no of fins, here cad tool solid works were used to design object, and to analyses these models here 3 materials were chosen (al-6061, al-2024, al-5059), by using Ansys workbench here calculated each material/model maximum bearing capacity by applying static loads. And after using forced convection in Ansys fluent calculated each material/model heat transfer rate values, by knowing all these results with suitable graphs and tables finally conclude thesis with a suitable material for optimum model.

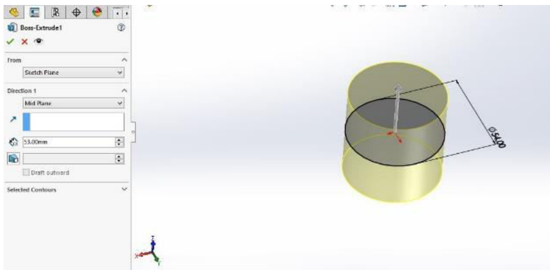
Literature review

Fernando Illan simulated the heat transfer from cylinder to air of a two-stroke internal combustion finned engine. The cylinder body, cylinder head (both provided with fins), and piston have been numerically analyzed and optimized in order to minimize engine dimensions. The maximum temperature admissible at the hottest point of the engine has been adopted as the limiting condition. Starting from a zero-dimensional combustion model developed in previous works, the cooling system geometry of a two-stroke air cooled internal combustion engine has been optimized in this paper by reducing the total volume occupied by the engine. A total reduction of 20.15% has been achieved by reducing the total engine diameter D from 90.62 mm to 75.22 mm and by increasing the total height H from 125.72 mm to 146.47 mm aspect ratio varies from 1.39 to 1.95. In parallel with the total volume reduction, a slight increase in engine efficiency has been achieved. **G. Babu and M. Lavakumar** analyzed the thermal properties by varying geometry, material and thickness of cylinder fins. The models were created by varying the geometry, rectangular, circular and curved shaped fins and also by varying thickness of the fins. Material used for manufacturing cylinder fin body was Aluminium Alloy 204 which has thermal conductivity of 110-150W/mk and also using Aluminium alloy 6061 and Magnesium alloy which have higher thermal conductivities. They concluded that by reducing the thickness and also by changing the shape of the fin to curve shaped, the weight of the fin body reduces thereby increasing the efficiency. The weight of the fin body is reduced when Magnesium alloy is used and using circular fin, material Aluminium alloy 6061 and thickness of 2.5mm is better since heat transfer rate is more and using circular fins the heat lost is more, efficiency and effectiveness is also more.

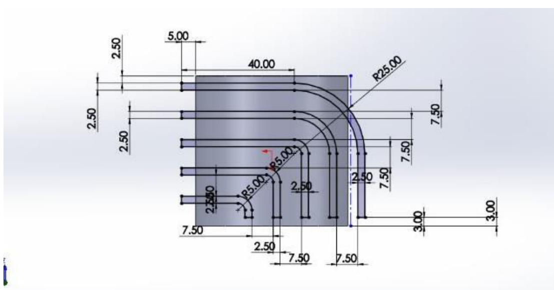
STEP BY STEP PROCESS TO CREATE CYLINDER FINS WITH THE HELP OF SOLID WORKS TOOL



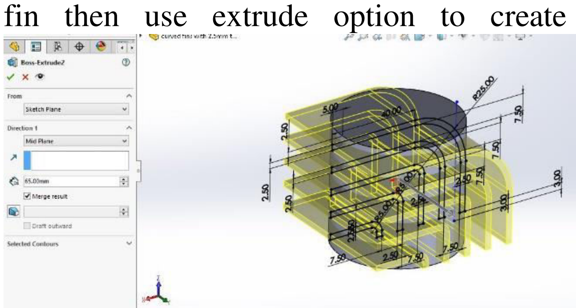
The above sketch should follow 3 conditions those are the sketcher should be closed and there should be no open end there should be no over lapping. By following these conditions we have to create our model. After completion of sketch click ok and we will get below model.

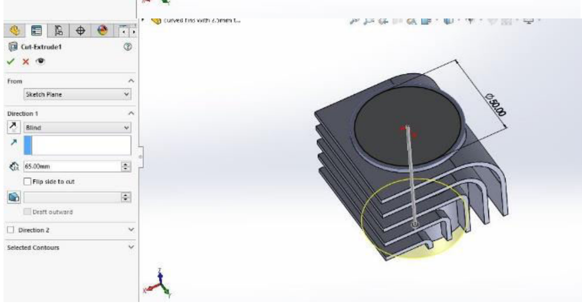


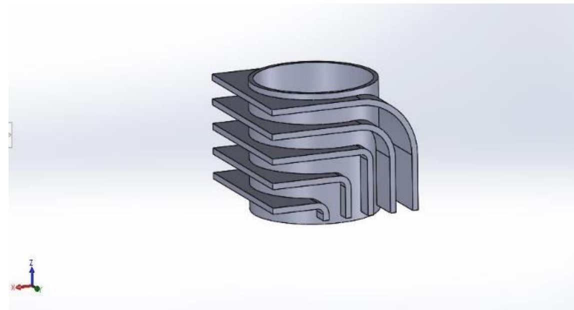
Then extrude it→53mm→ok



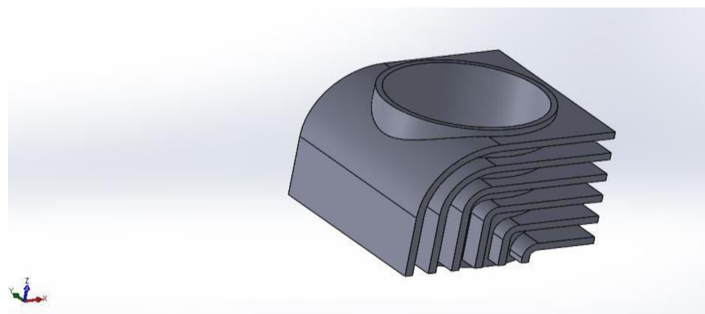
After creating cylinder, now need to create fins on it, to do this the above image represent the fins sketcher, here fin thickness is 2.5mm, and their gap is 7.5mm, and after creating this fin then use extrude option to create it,



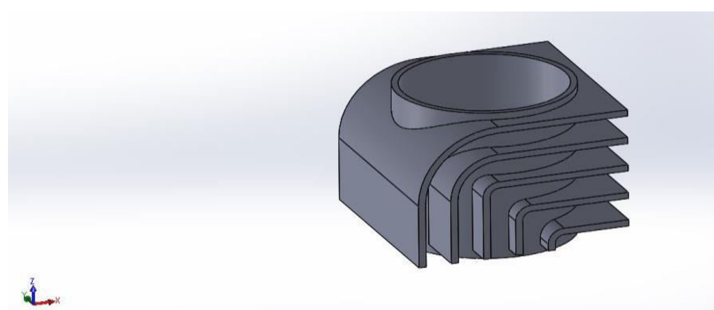




Curved fins 2.5mm thickness with 7.5mm fin to fin gap



Curved fins 2.6mm thickness with 5.5mm fin to fin gap



Curved fins 2.25mm thickness with 7.75mm fin to fin gap

After creating all these models save them, and to import into Ansys workbench here these objects should save in iges/step file format, after completing it Ansys process will start

Ansys analysis results

Material properties

Al-6061

Young's modulus: - 6.89*10^10 Pa

Poison ratio: 0.329

Density: 2700 Kg/m^3

Yield strength: 276Mpa

Thermal conductivity: 167 w/m-k

Al-2024

Ex: - 73.1*10^9 Pa

Poison ratio: 0.32

Density: 2780 Kg/m^3

Yield strength: 325 Mpa

Thermal conductivity: 121 w/m-k

Al-5059

Young's modulus: - 6.9*10^10 Pa

Poison ratio: 0.331

Density: 2690 Kg/m^3

Yield strength: 300Mpa

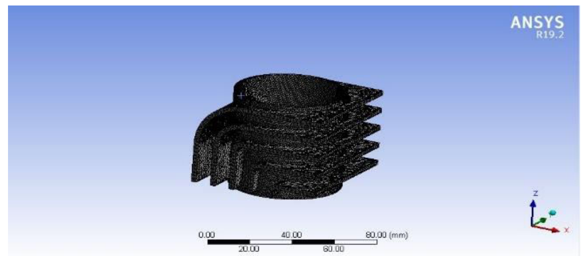
Thermal conductivity: 104 w/m-k

Geometry→ right click→ import geometry→ import iges format model

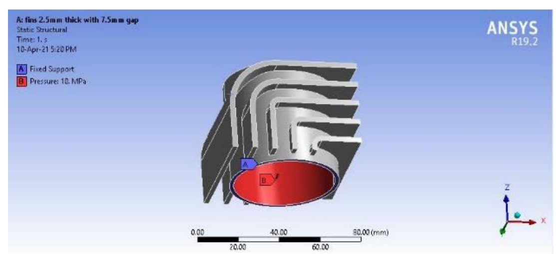
After importing model just click on geometry option then we will get selection of material. From engineering data here we already applied the above mentioned materials.

Meshing

After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object. Without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.



Static analysis Boundary conditions



Static structural →supports→fixed support→select bottom fins area

Pressure →10 Mpa

After completion of boundary conditions here we have to check results by solving. Just click on solve option and select results like deformation, strain, stress and safety factor values for the object.

Solution→solve→deformation

Solution→solve→stress

Solution→solve→safety factor

Static analysis

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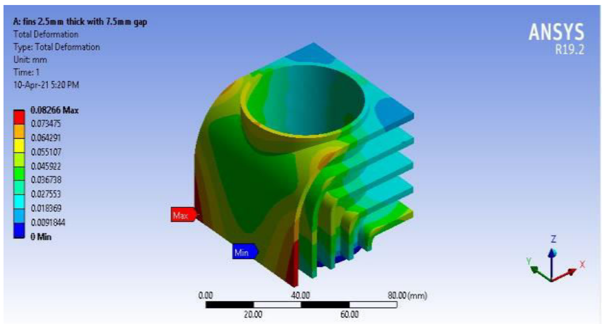
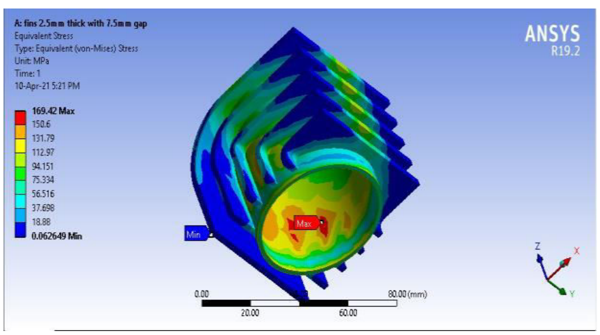
Curved fins with 2.5mm thickness and fin to fin gap 7.5mm

Al-6061

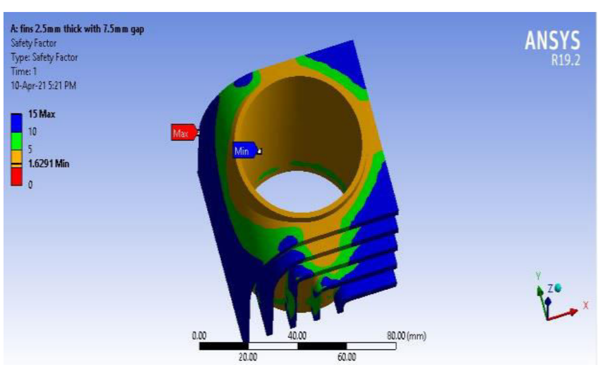
Deformation



Stress



Safety factor



Tables

COMPARISON AND DISCUSSION OF EACH CYLINDER FIN

Curved fins with 2.5mm thickness and fin to fin gap 7.5mm

	Al-6061	Al-2024	Al-5059
Deformation (mm)	0.08266	0.077911	0.08254
Stress (Mpa)	169.42	170.04	170.27
Safety factor	1.6291	1.9183	1.7707

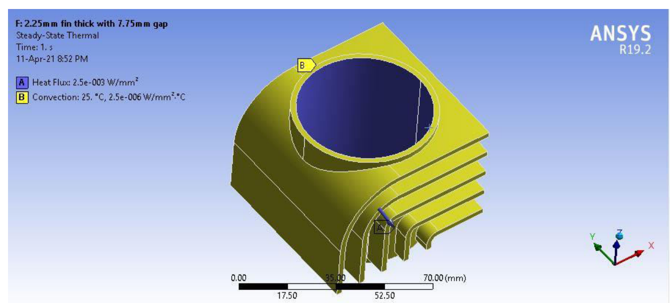
Curved fins with 2.6mm thickness and fin to fin gap 5.5mm

	Al-6061	Al-2024	Al-5059
Deformation (mm)	0.084668	0.079659	0.084768
Stress (Mpa)	164.78	164.75	164.98
Safety factor	1.6749	1.9727	1.8184

Curved fins with 2.25mm thickness and fin to fin gap 7.75mm

	Al-6061	Al-2024	Al-5059
Deformation (mm)	0.088438	0.083212	0.088508
Stress (Mpa)	167.42	167.38	167.64
Safety factor	1.6486	1.9417	1.7895

Thermal analysis results



Heat flux → select all inner areas →2.5e-3 w/mm^2

Coefficient of film→2.5e-6 w/mm^2,*c

Bulk temperature → 25*c

Curved fins with 2.5mm thickness and fin to fin gap 7.5mm

Al-6061

Total temperature

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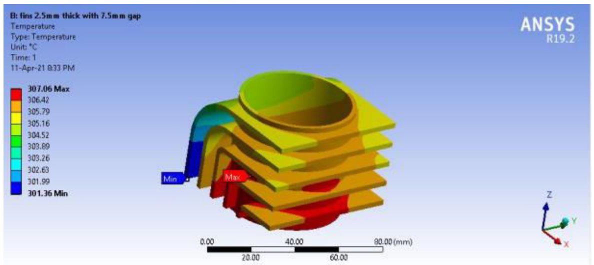
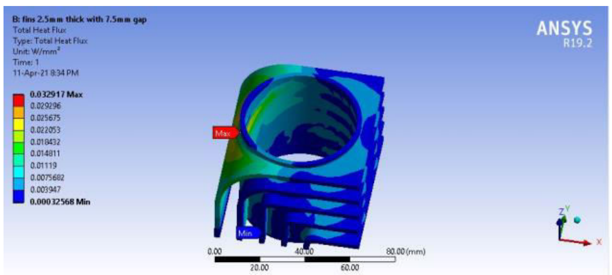


Heat flux



Thermal analysis results comparison and discussion

Curved fins with 2.5mm thickness and fin to fin gap 7.5mm

	Al-6061	Al-2024	Al-5059
Total temperature maximum (*C)	307.06	301.55	301.78
Total temperature minimum (*C)	301.36	293.93	293.4
Heat flux (w/mm^2)	0.032917	0.032311	0.032268

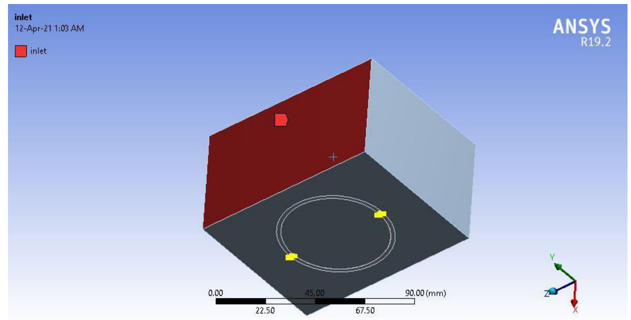
Curved fins with 2.6mm thickness and fin to fin gap 5.5mm

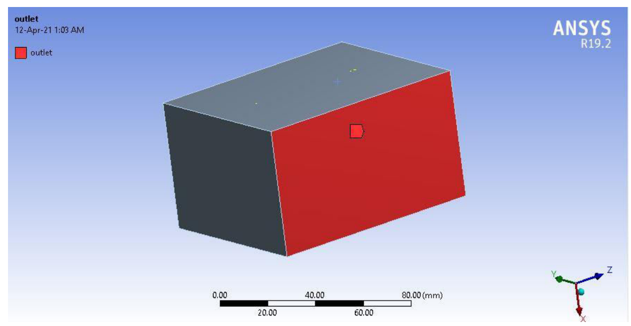
	Al-6061	Al-2024	Al-5059
Total temperature maximum (*C)	272.02	272.51	272.7
Total temperature minimum (*C)	267.37	266.13	265.69
Heat flux (w/mm^2)	0.027657	0.027561	0.027527

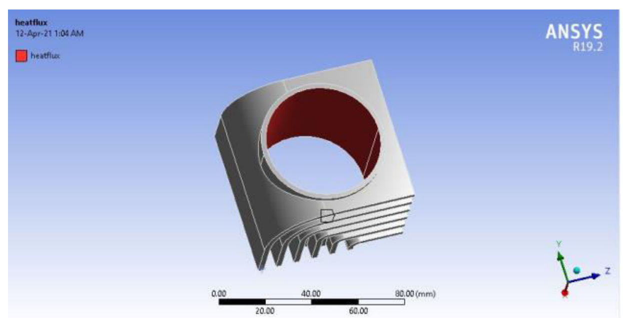
Curved fins with 2.25mm thickness and fin to fin gap 7.75mm

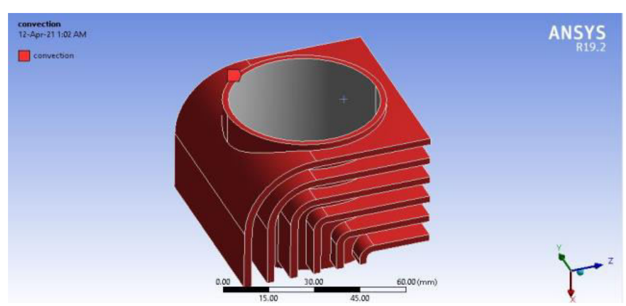
	Al-6061	Al-2024	Al-5059
Total temperature maximum (*C)	301.07	301.72	301.95
Total temperature minimum (*C)	295.08	293.48	292.91
Heat flux (w/mm^2)	0.034696	0.034557	0.034508

Forced convection results









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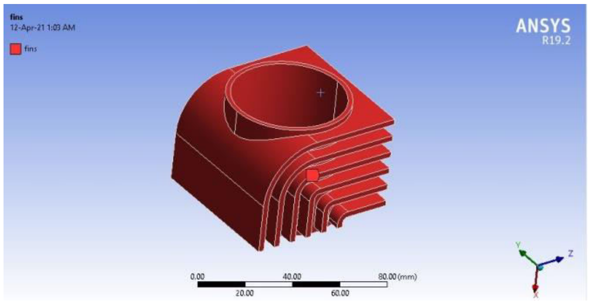

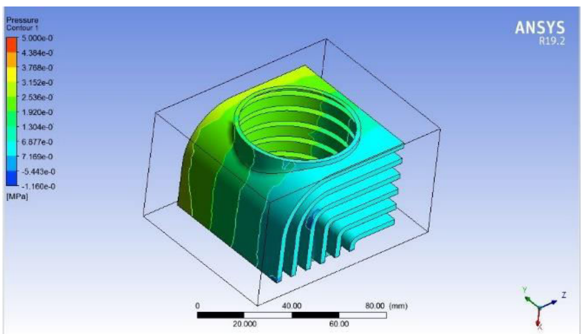

CONCLUSION

The main aim of the project is to increase the heat transfer through cooling fins, to meet this aim here curved cylinder fins designed by using cad tool solid works, in this process this curved fins cylinder optimized with different types of fin thickness and their gap between fins and also number of fins, and to analyses these models here 3 materials were chosen (al-6061, al-2024, al-5059), by using Ansys workbench here calculated each material/model maximum bearing capacity by applying static loads. And after using forced convection in Ansys fluent calculated each material/model heat transfer rate values,

From static analysis results it is clearly shown that each design can with stand up to 10Mpa of pressure on it and these values are consider based on safety factor values, here multiple pressure values applied on each design/material until minimum safety factor value to reach 1.5, among all materials al-2024 has high yield strength value, it means by using this material our object can with stand more pressure on it, by knowing only static analysis results it is not possible to choose an optimum material or model, to get more accurate results here thermal and fluent boundary conditions were applied.

From thermal analysis results heat flux values are high for curved fins with 2.25mm thickness with 7.75mm gap in between,

Finally forced convection boundary conditions were applied with the help of fluent module and calculated pressure, from all these results curved fins with 2.25mm thickness with 7.75mm fins are having high surface heat transfer coefficient values for each material, and also it has performing better in static conditions also,

Finally thesis can curved fins with 2.25mm thickness with 7.75mm gap in between with al-2024 material, and this material can withstand high pressure values and it can increases the durability of the object and also increases the object performance

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