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Heat Transfer Analysis and Optimization of Engine Cylinder Fins by Varying Its Geometry and Material

G.V.Punna Rao
Associate Professor
Prakasam Engineering College.

ABSTRACT

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, the main aim of the project is to analyse the thermal properties such as Heat flux, Thermal gradient by varying geometry, material and thickness of cylinder fins.

Parametric models of cylinder fins have been developed to predict the transient thermal behaviour. The models are created by varying the geometry, rectangular shaped fins and also by varying thickness of the fins. In this project, we have taken rectangular fin of 2mm thickness, initially and reduce the thickness into 1.5mm and done analysis on the point "How the heat transfer changes by the reducing the thickness of the fin.

The 3D modelling software used is Pro/Engineer. The analysis is done using SOLID WORKS. Presently Material used for manufacturing cylinder fin body is Aluminium Alloy 2024 which has thermal conductivity of 140 W/mk. We are analysing the cylinder fins using this material and also using Aluminium Alloy 6061 which has thermal conductivity of 170 W/mk which have higher thermal conductivities.

Keywords: ***Cylinder Fins, Thermal analysis, Aluminum alloy, Heat Transfer***

INTRODUCTION

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. This is a very high temperature and may result into burning of oil film between the moving parts and may result it seizing or welding of same. In an internal combustion engine, the expansion of the high-temperature and -pressure gases produced by combustion This is a very high temperature and may result into burning of oil film between the moving parts and may result it seizing or welding of same. So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. To avoid overheating, and the consequent ill effects, the heat transferred to an engine component (after a certain level) must be removed as quickly as possible and be conveyed to the atmosphere. It will be proper to say the cooling system as a temperature regulation system. It should be remembered that abstraction of heat from the working medium by way of cooling the engine components is a direct thermodynamic loss.

Therefore, all heat engines require cooling to work. Cooling is also required because high temperature damage engine materials and lubricants. Internal-combustion engines burn up fuel hotter than the

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melting temperature of engine equipment, and hot adequate to set fire to lubricants. Engine cooling removes energy quick enough to keep temperatures low so the engine can survive.

Moreover, fins are also utilized in cooling of large heat flux electronic devices as well as in cooling of gas turbine blades. Fins are also used in thermal storage heat exchanger systems including phase change materials. To the best knowledge of the, fins as passive elements for enhancing heat transfer rates

It is seen that the quantity of heat given to the cylinder walls is considerable and if this heat is not removed from the cylinders it would result in the resignation of the charge. In addition, the lubricant would also burn away, thereby causing the seizing of the piston. Excess heating will also damage the cylinder material.

Keeping the above factors in view, it is observed that suitable means must be provided to dissipate the excess heat from the cylinder walls, so as to maintain the temperature below certain limits. However, cooling beyond optimum limits is not desirable.

An extended surface (also known as a combined conduction-convection system or a fin) is a solid within which heat transfer by conduction is assumed to be one dimensional, while heat is also transferred by convection from the surface in a direction transverse to that of conduction.

Heat transfer is classified into three types. The first is conduction, which is defined as transfer of heat occurring through intervening matter without bulk motion of the matter. A solid has one surface at a high temperature and one at a lower temperature.

DECREASES THE OVERALL EFFICIENCY DUE TO THE FOLLOWING REASONS:

1. Thermal efficiency is decreased due to more loss of heat to the cylinder walls.
2. The vaporization of fuel is less; this results in fall of combustion efficiency.
3. Low temperatures increase the viscosity of lubrication and hence more piston friction is encountered, thus decreasing the mechanical efficiency.

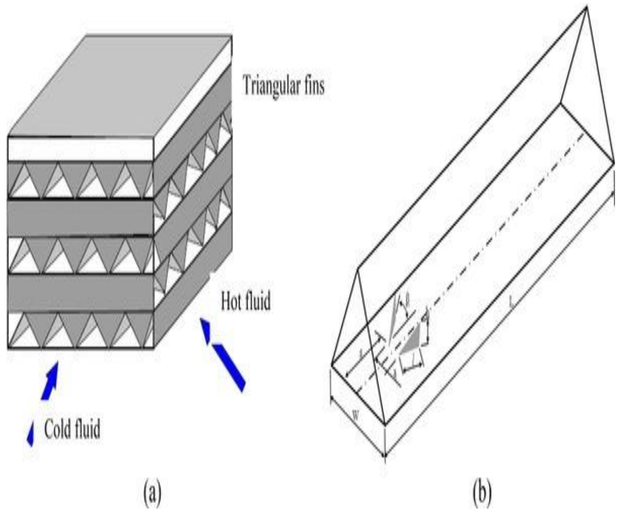
FIN PARAMETERS.

Sl.NO	Parameter	Forms
1.	Type of Fins	1. Rectangular
2.	Thickness of the fins	1. 2mm, and 2. 1.5 mm

1.5.2FINS HAVE THE FOLLOWING GEOMETRY

- Rectangle
- Elliptical
Triangular...etc

1.5.5 TRIANGULAR



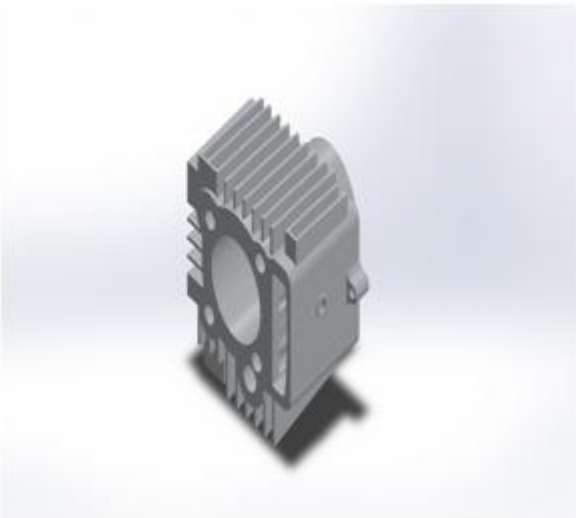
3.2 Soft wares used

Designing software; Pro/Engineer
Analysis software; Solid Works

MATERIALS USED FOR MANUFACTURING OF A FIN

Thermal Properties	Al alloy(2024)	Al alloy (6061)
Thermal conductivity	150 W/Mk	180 W/Mk
Specific heat	0.434J/go c	0.875J/go c
Density	2.69g/c	2.71g/c
Film coefficient	19W/mm2K	23W/mm2K
Bulk temperature	298K	298K
Temperature	500K	550K

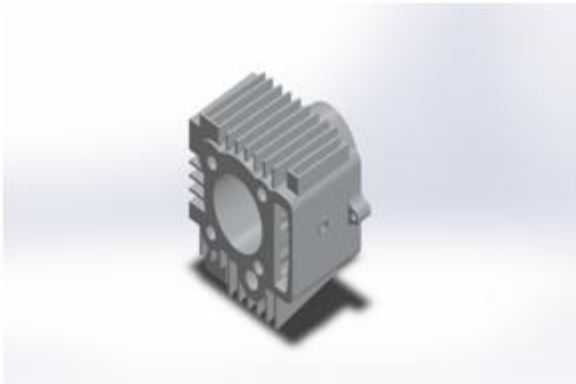
7.0 MODEL DESIGN IN PRO/E



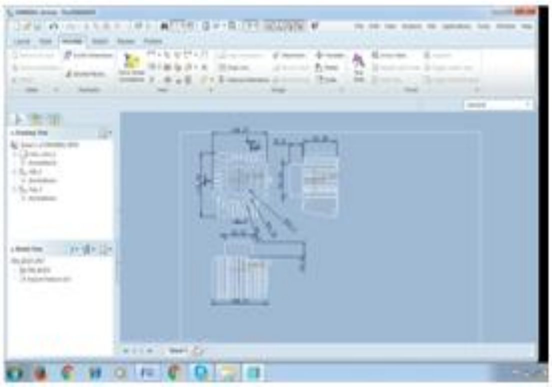
7.1 MODULES USED

- PART
- SOLID

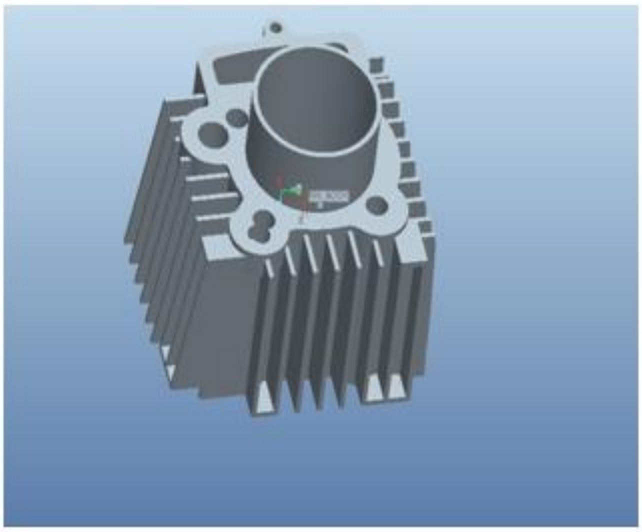
7.3 ORGINAL FIN BODY



7.4 DRAFTING IMAGE



7.6 MODIFIED FIN BODY



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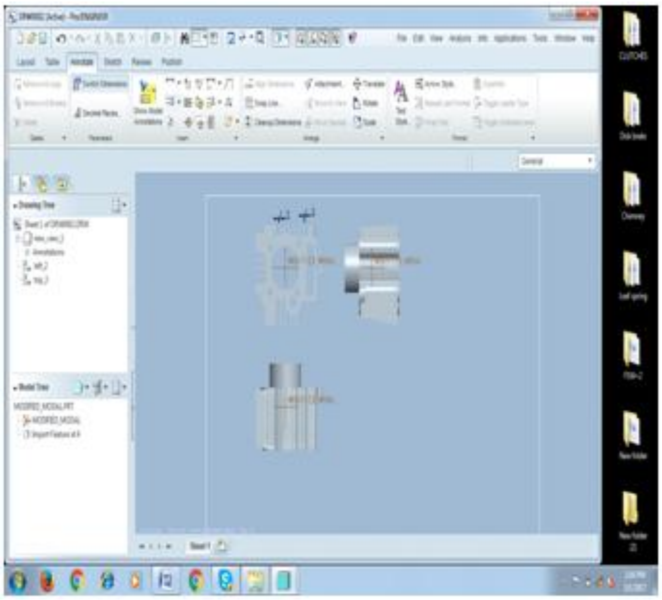
7.7 DRAFTING IMAGE



CALCULATION

Length of Cylinder=94mm =0.094m

Thickness of Cylinder=1.15mm

Cylinder Bore = 50.2mm

Perimeter of Cylinder(P) $=\pi D$ =157.708mm=0.157708m

Cross sectional area of Cylinder $A_c=\frac{\pi D2}{4}$ =29649 mm^2=0.029649m^2

K=conductivity of Aluminum=147w/mk

=0.147w/mmk

h=heat transfer coefficient =39.9w/m^2k=0.0399 w/mm^2k

$$m=\sqrt{\frac{hp}{kA_c}}=\sqrt{\frac{0.157708\times39.9}{0.147\times0.029649}}=12.01\ /m^2$$

$\Theta=T-T_a$=237k

Where T=temperature of cylinder head=550k

T_a=atmospheric temperature=313k

x=distance measured from base of cylinder =70.38mm=0.07038 m

$$\Theta=\Theta_o\times\left(\frac{h\cos hml+km\sin hml}{mk\cos hml+h\sin hml}\right)\times\sinh mx$$

237=

$$\Theta_o\times\left(\frac{39.9\times\cos(39.9\times12.01\times0.094)+147\times12.01\sin(hml)}{12.01\times147\times\cos(hml)+39.9\times\sin(hml}\right)\times$$

$\sin(39.9\times12.01\times0.07038)$

Θ_o=426.401 k

8.1 Heat lost by cylinder

$$Q=KA_c m\Theta_o\left(\frac{h\cos hml+km\sin hml}{mk\cos hml+h\sin hml}\right)$$

Q=0.147× 0.029649 × 12.01 × 426.401 × (1.0014) = 22.352 $\frac{W}{m2}$

Cylinder thickness = 2.02mm

Cylinder area =0.03606 m^2

T_iInside temperature = 550K

T_o Outside temperature =313K

ΔT = 273K

d = 50.2 mm

Al 6061

K=0.170w/mmk

H=1300J/Kgk

P=0.0000027kg/mm^3

Al 7475

K=0.147

H=880

P=0.000002810

U=0.0399

Heat flow q = UAΔT

= 0.0399×36006×237

= 340483.53w

Heat Flux h = q/a =340483.53/19207= 1.22733w/mm^2

8.2 ALUMINUM ALLOY 6082

Film coefficient = U = 0.0399 w/ mmk

8.2.1 Heat flux

Heat flow q = UAΔT

= 0.0399×2492.8847×237

= 23573.4655w

Heat Flux h = q/a =23573.4655/0.03606 = 9.4563w/mm^2

8.3 THICKNESS OF CYLINDER HEAD

Length of cylinderhead l=31.06mm

Width of Cylinder=1.15mm

Perimeter of Cylinder=157.708mm

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Cross-sectional Area od Cylinder head=31.06x50.2 mm = 1559.212mm^2

K=0.147 , h=0.0399

$$m=\sqrt{\frac{hp}{kA_c}} = m = \sqrt{\frac{hp0.0399x157.708}{0.147x1559.212}} = 165.703$$

Θ=T-T$_a$=237k

l=31.06

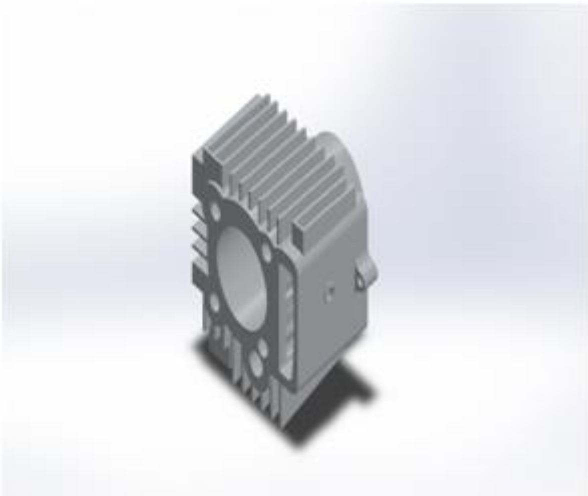
$$\Theta=\Theta_o\times\left(\frac{hcos\,hml+kmsin\,hml}{mkcos\,hml+hsin\,hml}\right)\times sinhmx$$

$$237=\Theta_o\times\left(\frac{39.9cos(39.9x0.16569x0.03106)+147x0.16569\,sin\,hml}{0.16569x147xcos\,hml+39.9sin\,hml}\right)\times sin(39.9x.16569x0.03106)$$

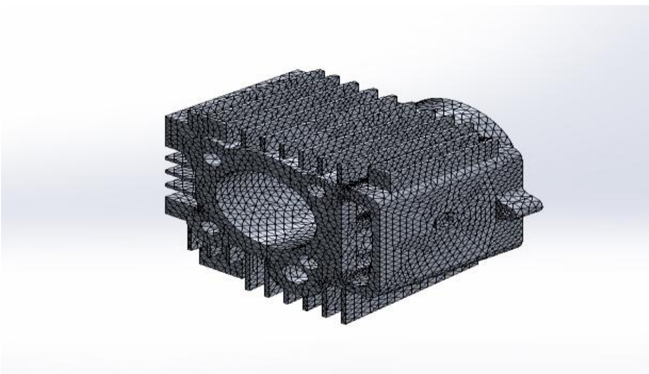
$$237=\Theta_o\times\left(\frac{39.987}{24.499}\right)\times 3.5831x10^{-3} = -46.48/-39.07\ X\ (0.4273)$$

$237=\Theta_o\times(-0.508)$

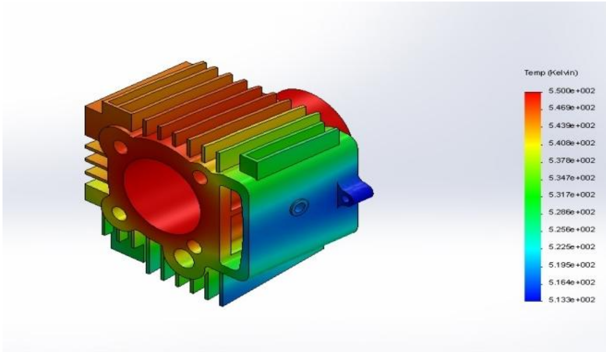
Θ_o = 237/0.608 = 466.458k



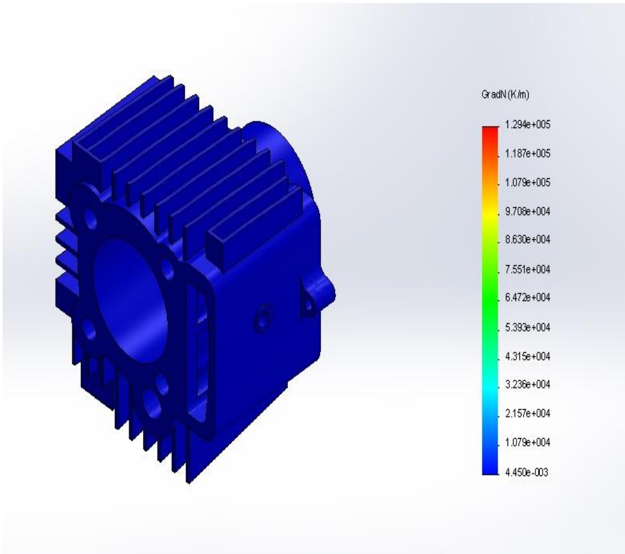
Meshed model



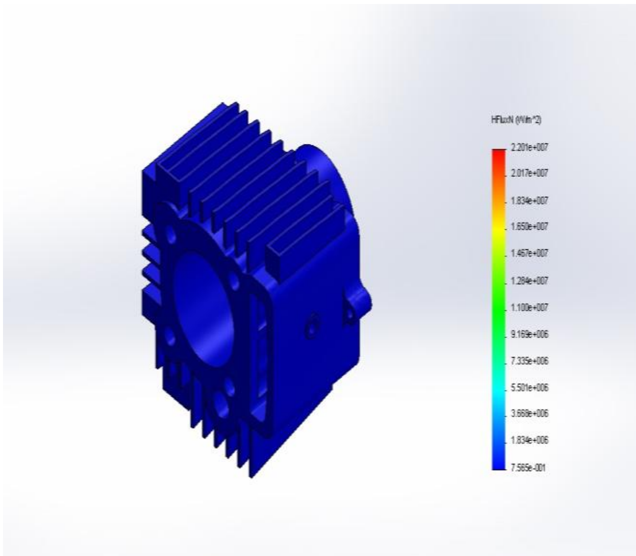
Temperature: 550 K



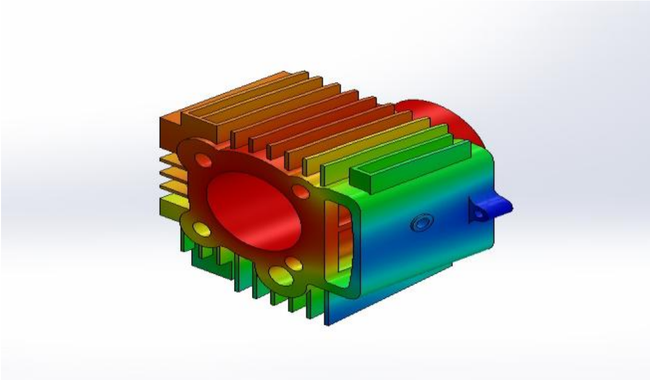
Temperature Gradient: 129443 k/m



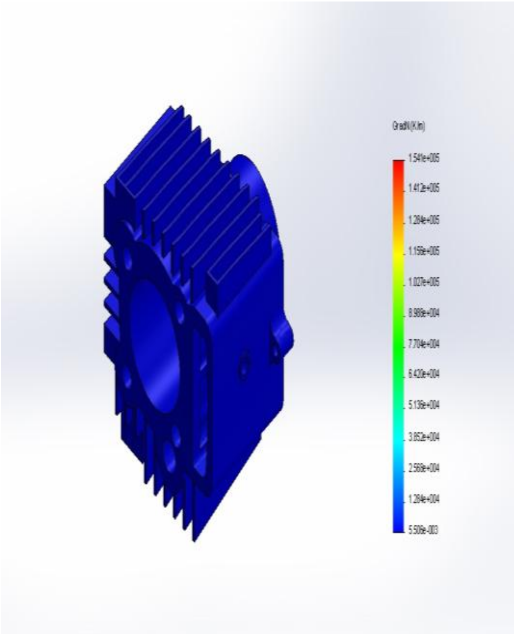
Temperature flux: 2.20054e^{+7} W/m^2



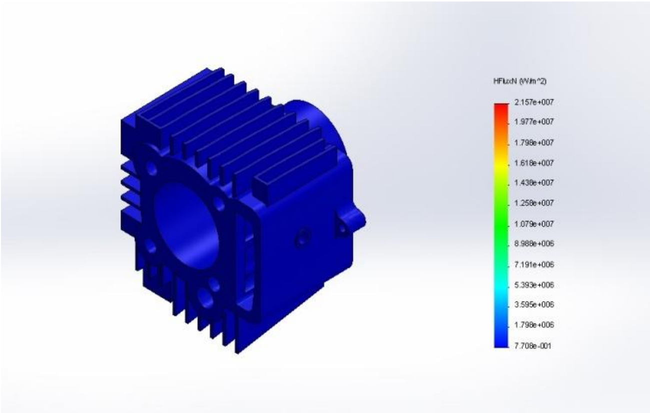
11.1 Material: Al 2024 Alloy
Temperature: 550 K



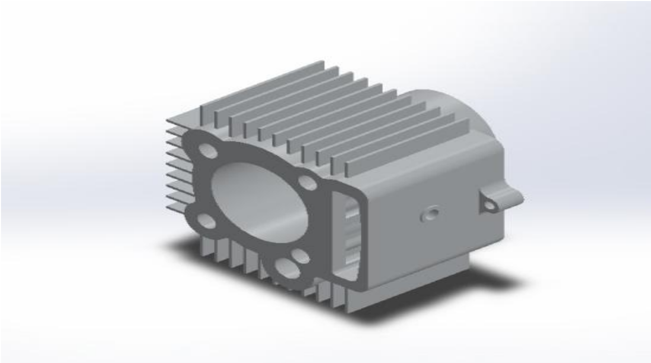
Temperature Gradient: 154084 k/m



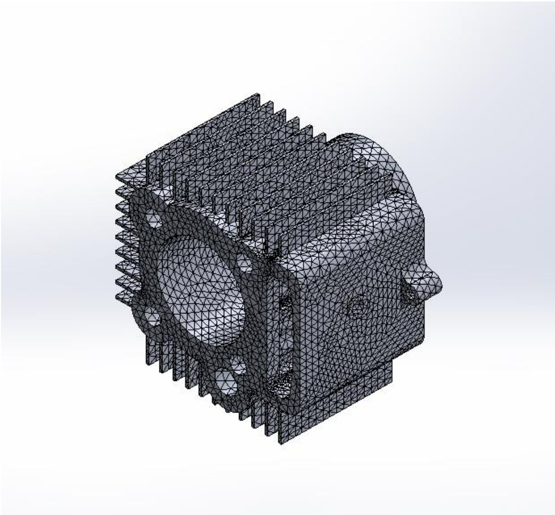
Temperature flux: $2.15717e^{+7}W/m^2$



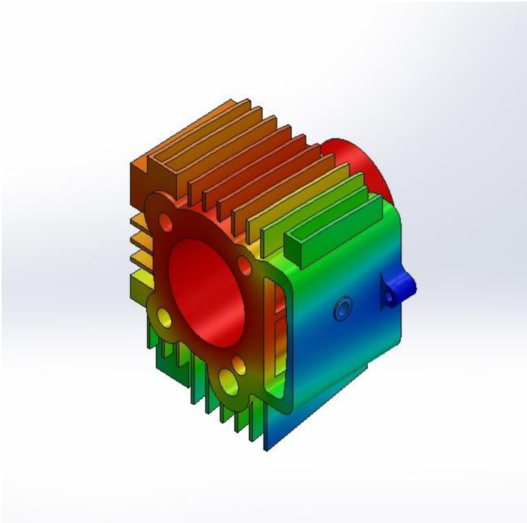
11.3 MODIFIED FIN BODY ANALYSIS
Material: Al 6061 alloy
Imported model



Meshed model



Temperature: 550 K



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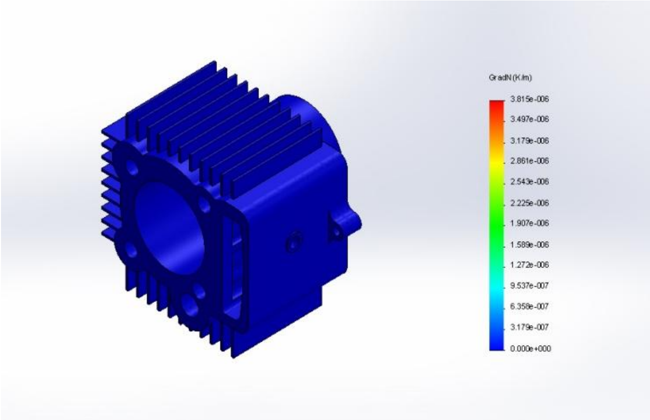
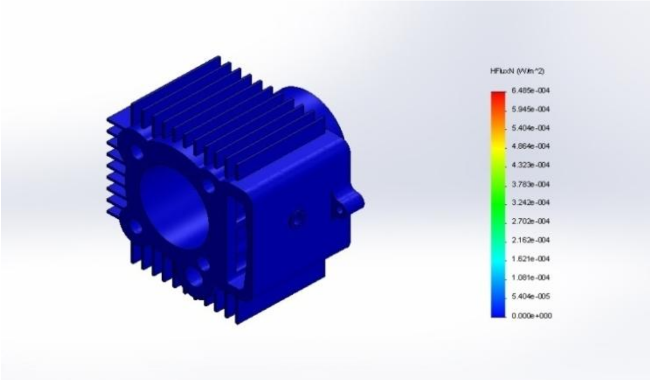
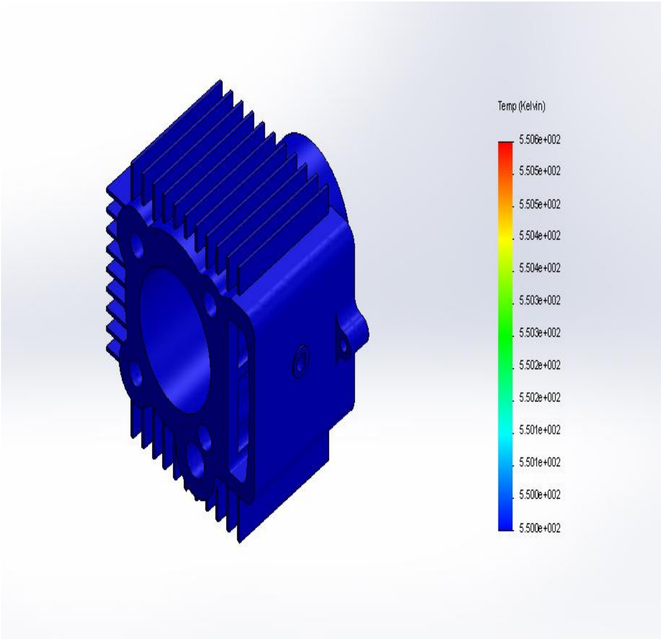
Temperature Gradient: 3.8147e^{-6} k/m



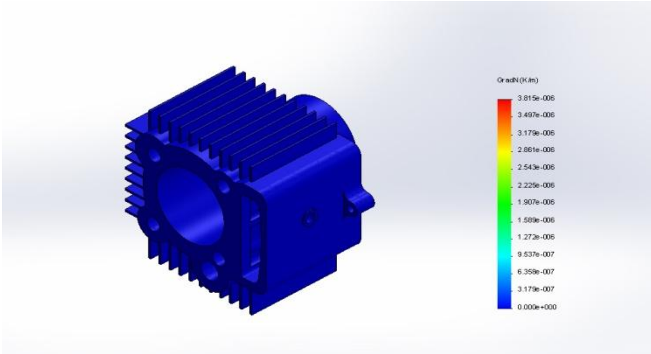
Temperature flux: 0.000648499W/m^2



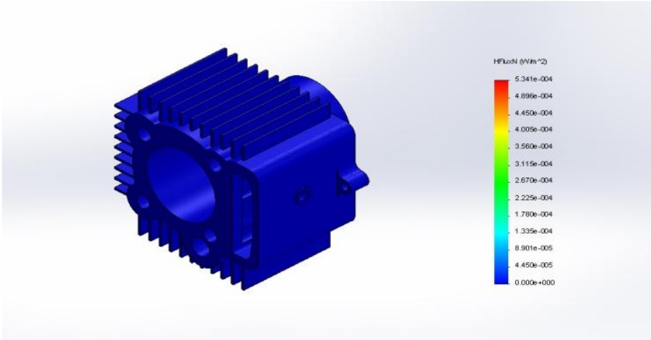
11.3.1 Material: Al 2024 Alloy
Temperature: 550 K



Temperature Gradient: 3.8147e^{-6} k/m



Temperature flux: 0.000534058W/m^2



RESULTS TABLE

MATERIAL	THICKNESS (mm)	TEMPERATURE (k)	THERMAL GRADIENT (k/m)	THERMAL FLUX W/m²
AL Alloy 2024	2	550	1.5408e^{-6}	0.000215717
AL Alloy 6061	2	550	1.2944e^{-6}	0.000220054
AL Alloy 2024	1.5	550	1.5447e^{-6}	0.000534058
AL Alloy 6061	1.5	550	**3.8147e^{-6}**	**0.000648499**

CONCLUSION

- In this project we have designed the fin body of Hero Honda as per the parameter varying reverse engineering process
- We are decreasing the fin thickness from 2mm to 1.5mm.
- In this we are optimize the materials present used material is AL2024 and replacing materials are aluminium 60601 and grey cast iron.
- We are doing model analysis using solid works software and designing in PRO/E software.

- Finally, we are comparing all the results for original and modified fin body. The material is AL 6061.
- In aluminium 6061 the heat flux value is more when compared to aluminium and grey cast iron.
- Finally, we conclude that aluminium 6061 is used for manufacturing of engine cylinder fin is safer and efficient

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