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Optimization of Thermal Analysis of Engine Cylinder Fins by Varying Geometry

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ABSTRACT

Heat transfer by convection between a surface and the fluid surrounding can be increased by attaching to the surface called fins. The heat conducted through solids, walls, or boundaries has to be continuously dissipated to the surroundings or environment to maintain the system in a steady state condition. The cylinder of the engine is one of the key components of the vehicle and is prone to maximum temperature variation and thermal stress. To cool the cylinder, the cylinder fin is designed to improve the heat transfer rate. Thermal analysis is done on the engine cylinder fins; it is very useful to understand the heat dissipation in the cylinder. The idea applied in this project is to increase the heat dissipation rate by using intangible working fluid, just air. It is understood that the heat dissipation rate is increased by changing the surface region; therefore, it is very challenging to design such a huge complicated engine. In this project, the analysis of the engine fin is carried out for different geometries such as Rectangular, Triangular, convex, and Tapered fin. A 3D model is created in SolidWorks and analysis is done using ANSYS Software in steady state condition. The material used for the fin body is Al6063. The result is compared to find the best geometry which gives the maximum heat flux.
Keywords : Thermal Analysis, Heat transfer, Fins, Varying Geometry, SolidWorks, ANSYS Software.

I. INTRODUCTION

The main design of a combustion engine has not changed for 100 years just the efficiency increases every time. Internal Combustion Engines means the combustion takes place internally inside the engine in the cylinder liner. The fire triangle for combustion consists of Oxygen, Fuel, and Heat. There are two types of the engine like 2- strokes generally used in petrol engines (for diesel it's only in large ships). In this system, the crankshaft rotates once and the piston moves twice in the cylinder space. They are cheap and create a lot of smoke and aren't that efficient 4 stoke. The other 4 Stroke Engines – are heavy and very efficient, here the piston moves 4 times in the cylinder liner and the crankshaft rotates twice. The exhaust air and the fuel are both passed through pipes into or from the cylinder in the 2-stroke engine, while the fuel is pumped or sprayed through a nozzle in 4 strokes and we have valves for both air and exhaust gas services. [1] In the engine cycle, we know that when the vehicle engine begins to fire, the internal Engine start to fire. Where fuel burns within the chamber of the piston as well as in the chamber of combustion. As we know, fuel combustion is almost 75% and heat would be lost in the atmosphere. Where only 30% of the heat generated is successfully transferred through the engine, according to the survey, but large quantities of heat from fins need to be transferred. Also, if we do not remove the heat from the engine, the engine portion will be impaired. Hence, we know that if we do not remove the heat it will damage the engine and it will be thermal engine damage. As we know that there are two kinds of dissipation required liquid-cooled engine as well as Air cooling engine, the water cooling has more complexity of the space in Engine. The air-cooled engine needs a smaller vehicle while the liquid-cooled for a larger vehicle. We know that if high heat dissipation is needed, fins are an essential part of the engine. If high heat dissipation is required then an accurate design of fins is necessary.

Fin which has several things such as geometry, size, shape, etc. In the current scenario, the research that may affect the different geometry seems to have examined the size of the reduction in the fins. [2] As we know, the engine has internal combustion where the oxidizer has provided the fuel, such as air from the combustion chamber. Hence from the internal combustion chamber which has a high temperature and the combustion has been produced. It seems to force the engine directly from the part where the turbine blade or nozzle is mounted. As we know that internal combustion models are cooled from the closed circuit, it seems that it produces mechanical energy. [3] It also has the liquid coolant while from the channel from the engine block as we know that coolant absorbs the heat, from the heat exchanger from the radiator, and the coolant release the heat into the air.

The air moves through the liquid-coolant circuit and water cools the coolant circuit, which is called cooled air. From the air-cooled engine created by the heat directly released into the air, the fins were covered by the cylinder, as we covered the fins cylinder in all the combustion engines. As we know that the fuel of the combustion is nearly 75 % where the heat will be lost in the atmosphere. Where according to the survey only 30% of the heat will generate successfully to pass through the fin of the engine but a large quantity of the fuel has been required as well. If we do not remove the engine heat, the engine component will be harmed. Therefore, we know that the engine will be affected by thermal engine damage if we do not remove the heat. [4]

II. PROPOSED METHODOLOGY

The major components for the automobile engines are subjected to wear thermal stress. It has a combustion process of the temperature that is high. Further, the heat has been transferred to increase the internal combustion of the engine. Further, the output has come to be mechanical power. It gives the thermal energy which has been converted from the chemical energy of the fuel. Assume the engine cylinder that has first heat conducted and dissipated through the extended surfaces. As further it is seen that the air-cooled engine has the low energy of the heat. It has been transferred that has a low rate of heat, which is the major problem. To avoid all these things that changing the geometry has been modified the fins of the engine. For this purpose, it has been taken various geometry such as rectangular type, triangular type, convex type, and trapezoidal type on which it has gone through simulation. It has analyzed two-wheeler bikes in a steady-state manner for different geometry. Fin is modeled with the help of fin data collected for the super splendor bike. Then the finite element analysis is performed for different geometry.

III. Mathematical model of fin

1.1. Rectangular Fin profile

The rectangular fin is shown in Figure 1. The length of the fin is L, the thickness of the fin is 2δ, and the width of the fin is W. Assuming that the heat flow is unidirectional and along the length and the heat transfer coefficient (h) of the fin surface is constant.

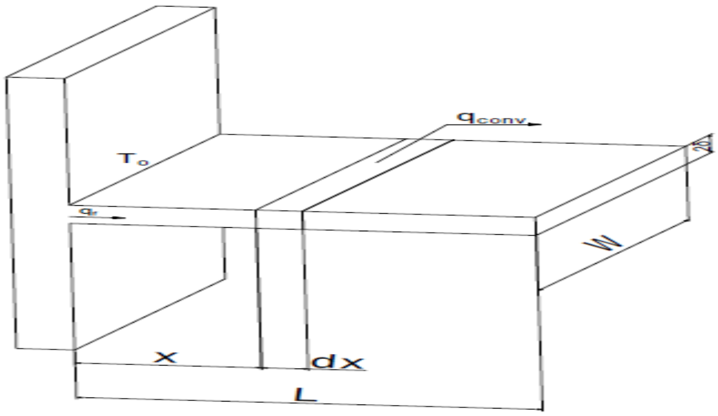


Figure 1: Rectangular fin profile. [14]

Now, consider the case of heat dissipation from a fin losing heat at the tip. The equation for the heat flow rate is given by.

$$Q_{fin} = KA_C m\theta_0 \frac{h \cosh mL + km \sinh mL}{km \cosh ml + h \sinh mL}$$

Where,
K = thermal conductivity, W/mK
A_c = cross-section area of fin, m^2
m = fin parameter, $\left(\sqrt{hp/kA_c}\right)$
P = perimeter of the fin, (2W+4δ), m
θ_0 = temperature difference, K
h = heat transfer coefficient, W/m^2 K.

1.2. Triangular Fin profile

The triangular fin is shown in Figure 2. The length of the fin is L, the thickness of the fin is 2δ, and the width of the fin is W. Assuming that the heat flow is unidirectional and along the length and the heat transfer coefficient (h) of the fin surface is constant.

Heat lost by triangular fin,

$$Q_{fin} = 2W\theta_0 \sqrt{(hk\delta)} \left[\frac{I_1(2B\sqrt{L})}{I_0(2B\sqrt{L})}\right]$$

Where,

θ_0 = temperature difference, K

K = thermal conductivity, W/mK

B = fin parameter, $\left(\sqrt{hL/_{k\delta}}\right)$

I_1 = Bessel function of the first kind

I_0 = Bessel function of the first kind

h = heat transfer coefficient, W/m^{2}K. [14]

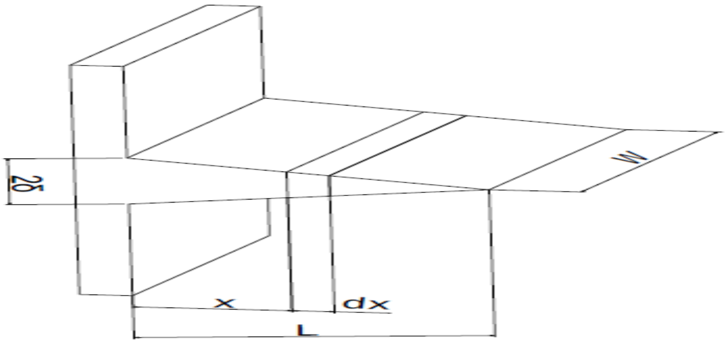


Figure 2: Triangular fin profile. [14]

1.3. Convex fin profile

For longitudinal fins with the convex parabolic profile is shown in figure 3.

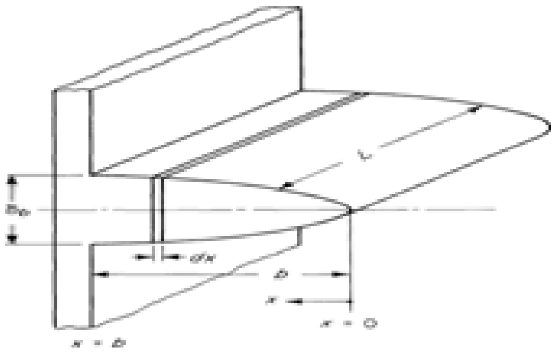


Figure 3: Convex fin profile. [15]

Heat transfer through the base of the fin is given by,

$$q_{fin} = k\delta_b L m\theta_b \frac{I_{2/3}\left(\frac{4}{3}mb\right)}{I_{-1/3}\left(\frac{4}{3}mb\right)}$$

Where,

m = $\sqrt{2h/k\delta}$

I = Bessel function. [15]

2. Working Principle

The working principle of the IC Engine when combustion takes place in the engine can generate heat where 40 % of the heat has gone through the cylinders as well as fins. The heat has been dissipated during the heat has been extracted as by the engine which has the following shapes:

- Rectangular
- Triangular
- Tapered
- Convex

It has the combustion of the process. It has heat energy which can be wasted through the heat which has been surrounding. The fin has been increasing the surface of the area. It has the heat flux has increased the fins. The main principle has the force for the convection. It has been analyzed by the vehicle for running the given conditions. The flowing air has been moved through the air conditioner that has been imposed through the isometric flow.

IV. Analysis Procedure

The steps involved in the analysis of the procedure:

1. Modeling
2. Thermal Analysis

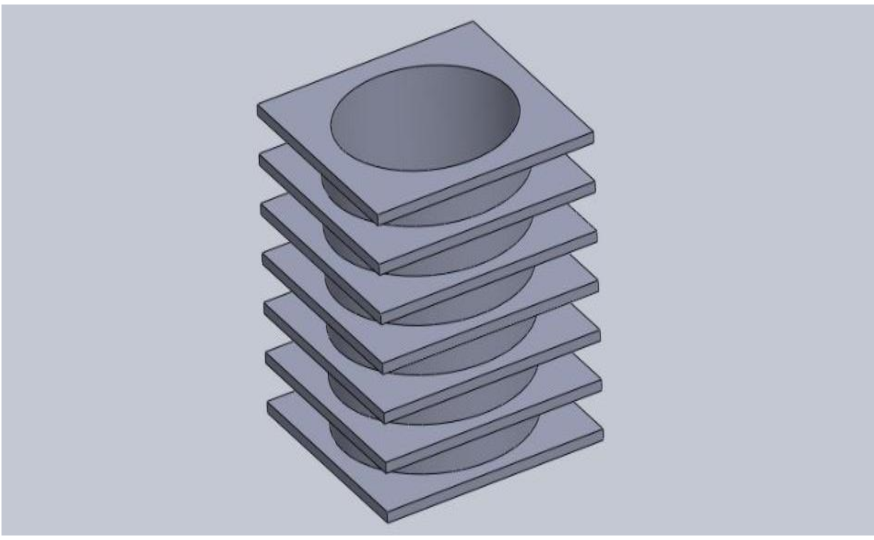


Figure 4: Rectangular fin

- Model is created by solid works. Geometry is imported in the form of IGES/STEP
- from the solid works in the ANSYS Workbench.
- Generate mesh: Orthogonal Quality matrix and tetrahedral meshing are used as the inner surface of the cylinder is curved.
- Build analysis by providing boundary conditions.
- Control and monitor the solver to achieve a solution.
- Visualize results and create reports.

- The comparison of the result.
- Temperature for the distribution.
- Total for the heat flux.

Table 1: Design for the Specification [22]

Cylinder Parts	Dimension
Bore	52.4mm
Stroke	57.8mm
Thickness of fin	2mm
Pitch	9mm
Cylinder wall thickr	3mm
Length of fin	68.4mm

V. RESULTS AND DISCUSSION

Completion of the process optimal outcome of solving process has culminated in the post-processor outcome. It has been seen from the result portion that the current one is a new design that has established the temperature of the total heat flux that has been measured. The comparison of each design is shown in this section. The design process focuses primarily on temperature and total heat flux. Thus, the results section of the various forms of fin geometry design shows the difference in temperature and heat flux according to the design. In each type of design, comprehension is often carried out to achieve an effective and efficient design for the optimum heat dissipation in the engine. The comparison results calculated the increase of the heat flux and temperature range in the new design.

Table 2: Al6063 Martial Property [17]

Property	Value
Density (Kg/m^3)	2770
Coefficient of thermal expansion(1/^{0}C)	2.3*10^{-5}
Specific heat (J/Kg/^{0}C)	875
Thermal conductivity (Watt/m/^{0}C)	170

6.1 Tapered Fin

The tapered section has been shown that the total no. of nodes is 176802 which also has the total elements is 99230.

Table 3: Tapered fin

Nodes	Elements
176802	99230

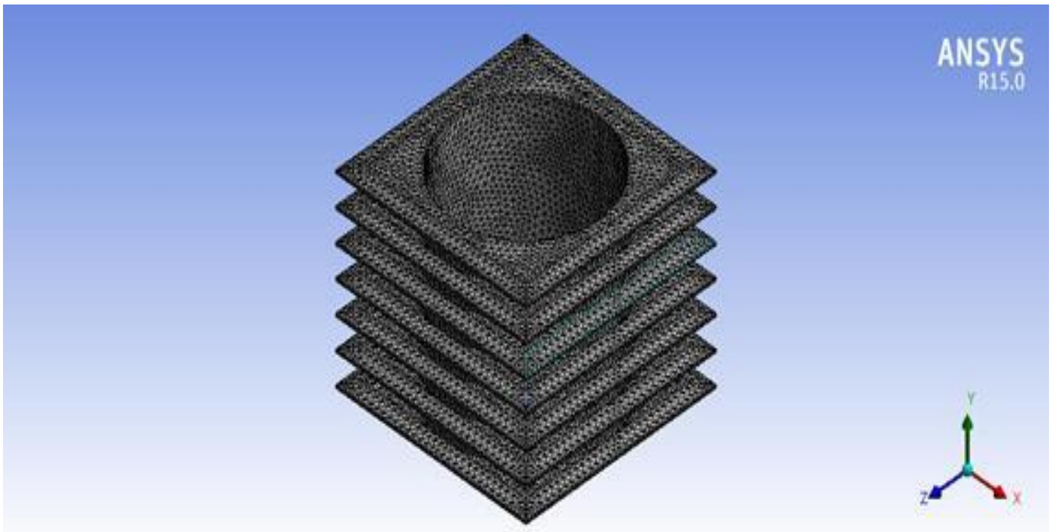


Figure 5: Mesh in tapered fin

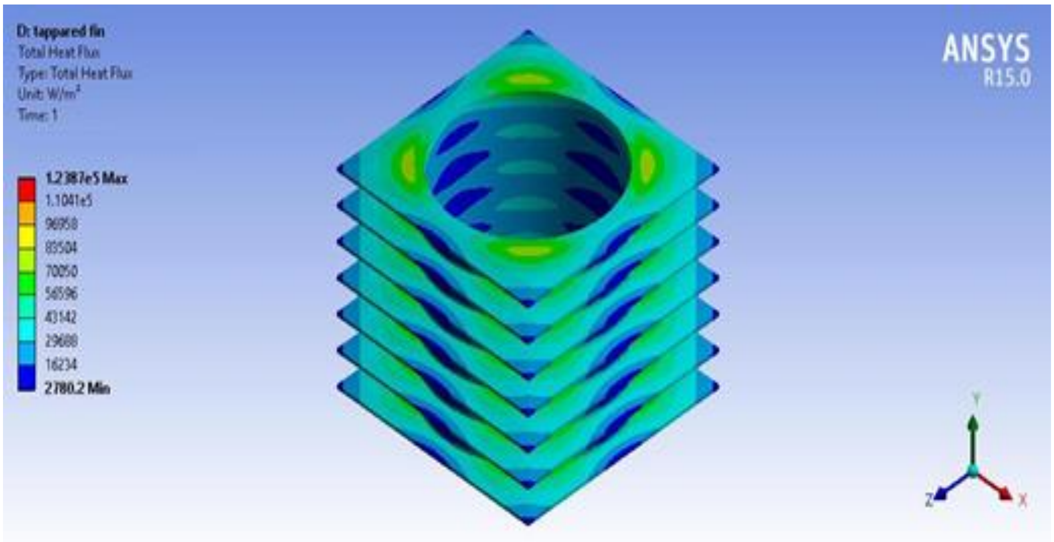


Figure 6: Total Heat Flux in tapered fin

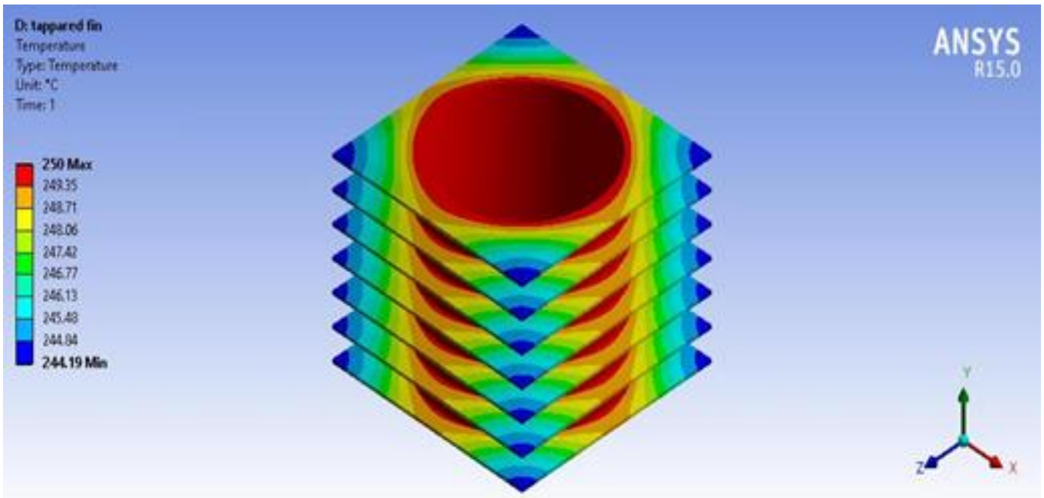


Figure 7: Temperature in tapered fin

Above figures 5, 6, 7 show the mess of the tapered fin geometry design, total heat flux, and temperature respectively.

Table 4: Temperature and Total Heat Flux in Tapered.

Value	Temperature (°C)	Total Heat flux (W/m^2)
Maximum	250. °C	1.2387*10^5
Minimum	244.19	2780.2

In above table 4, it describes the tapered fins which have the maximum and minimum temperature as well as total heat flux which has in the table.

6.2 Convex Fin

The convex section which has been shown in table 5 has the total no. of nodes 195929 which also has the total no. of elements is 110792.

Table 5: Convex fin

Nodes	Elements
195929	110792

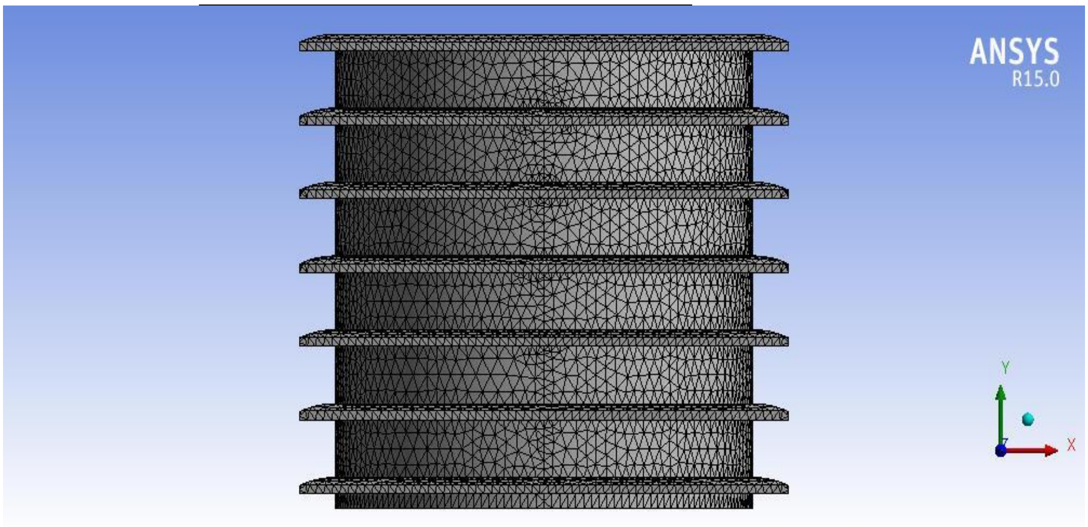


Figure 8: Mesh in convex fin

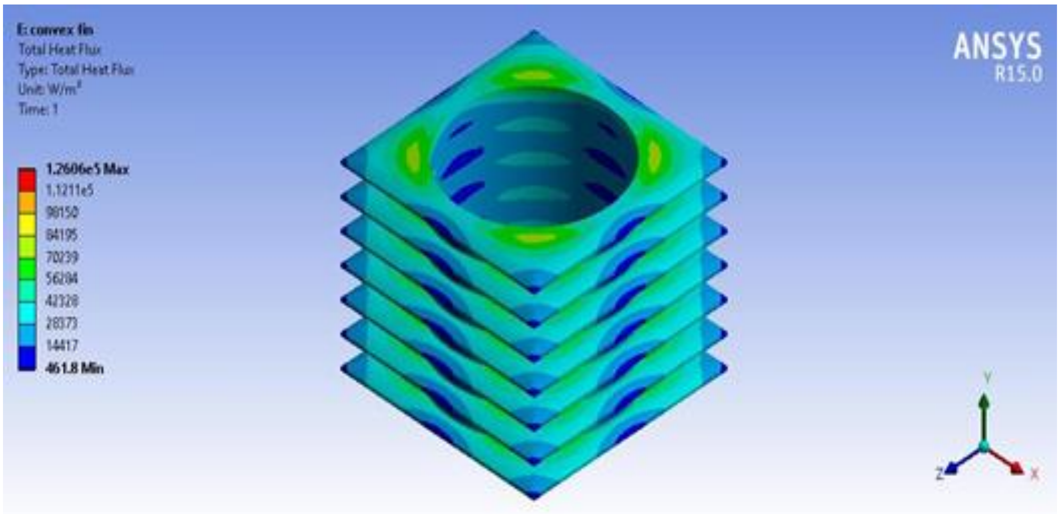
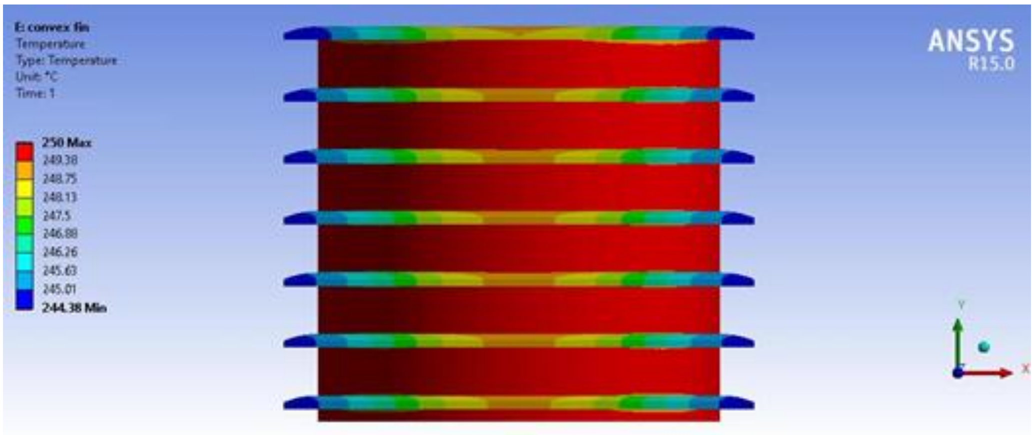
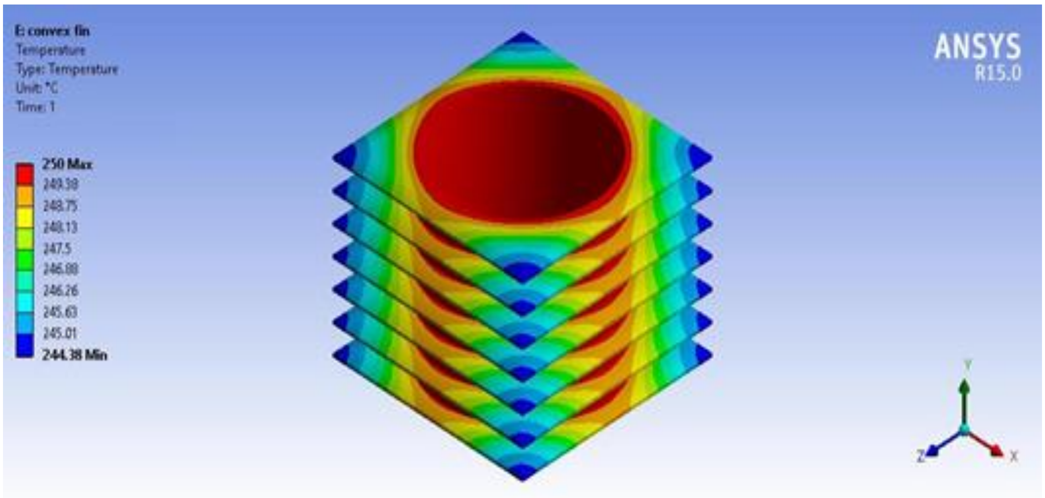


Figure 9: Total Heat Flux in convex fin



(a)



(b)

Figure 10: (a) & (b) Temperature in convex fin

Above figures 8, 9, 10(a) & (b) show the mess of the tapered fin geometry design, total heat flux, and temperature respectively.

Table 6: Temperature and Total Heat Flux in Convex fin

Value	Temperature (°C)	Total Heat flux (W/m^2)
Maximum	250.	$1.2606*10^5$
Minimum	244.38	461.8

In above table 6, it is described the convex fins which have the maximum and minimum temperature as well as total heat flux which has in the table.

6.3 Rectangular Fin

The rectangular section has been shown that the total no. of nodes is 180529 which also has the total no. of elements is 102932.

Table 7: Rectangular fin

Nodes	Elements
180529	102932

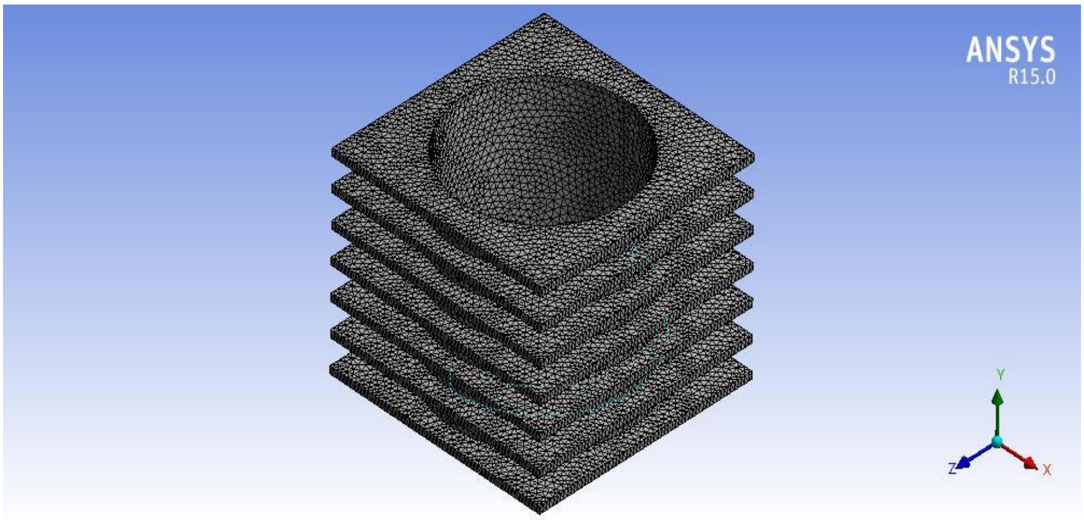


Figure 11: Mesh of rectangle fin

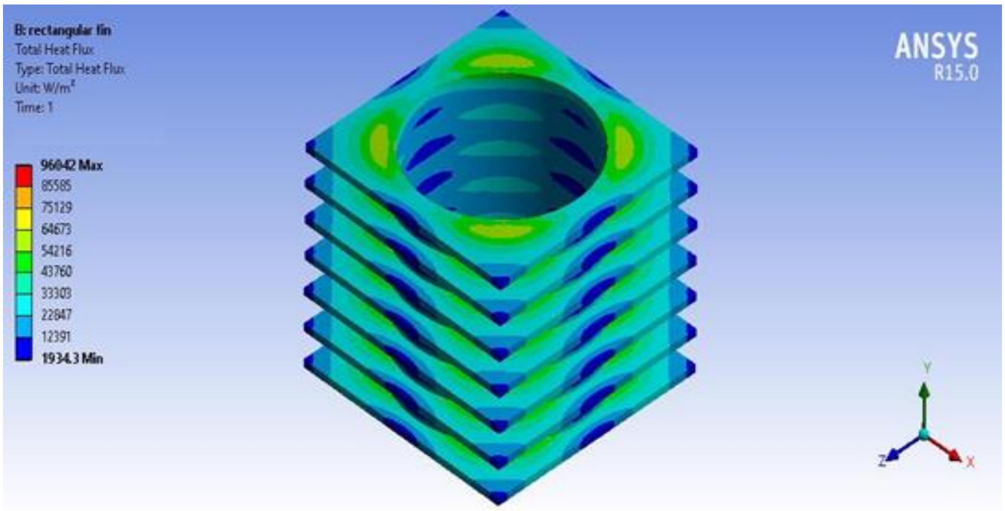


Figure 12: Total Heat flux in rectangular fin

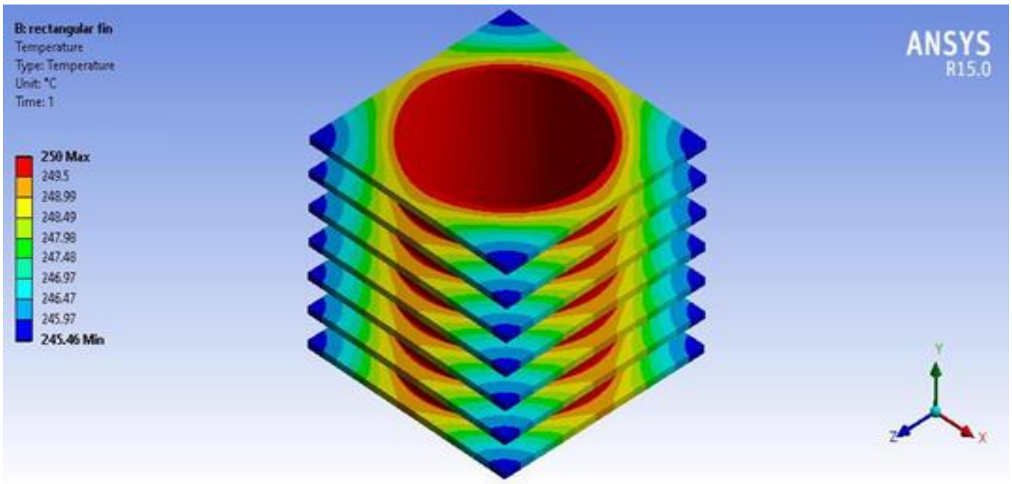


Figure 13: Temperature in Rectangular fin

Above figures 11, 12, 13 show the mess in the rectangular fin geometry design, total heat flux, and temperature respectively.

Table 8: Temperature and Total Heat Flux in Rectangular fin

Value	Temperature (°C)	Total Heat flux (W/m^2)
Maximum	250.	96042
Minimum	245.46	1934.3

In the above table 8, it is described the Rectangular fins which have the maximum and minimum temperature as well as total flux which has in the table.

6.4 Triangular Fin

The Triangular fin section has been shown that the total no. of nodes is 167384 which also has the total no. of elements is 94183.

Table 9: Triangular Fin

Nodes	Elements
167384	94183

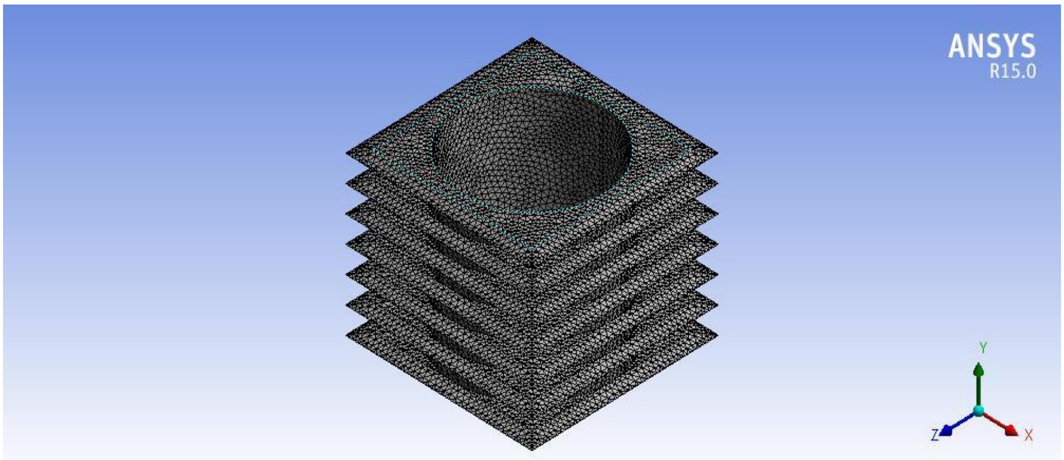


Figure 14: Mesh in Triangular fin

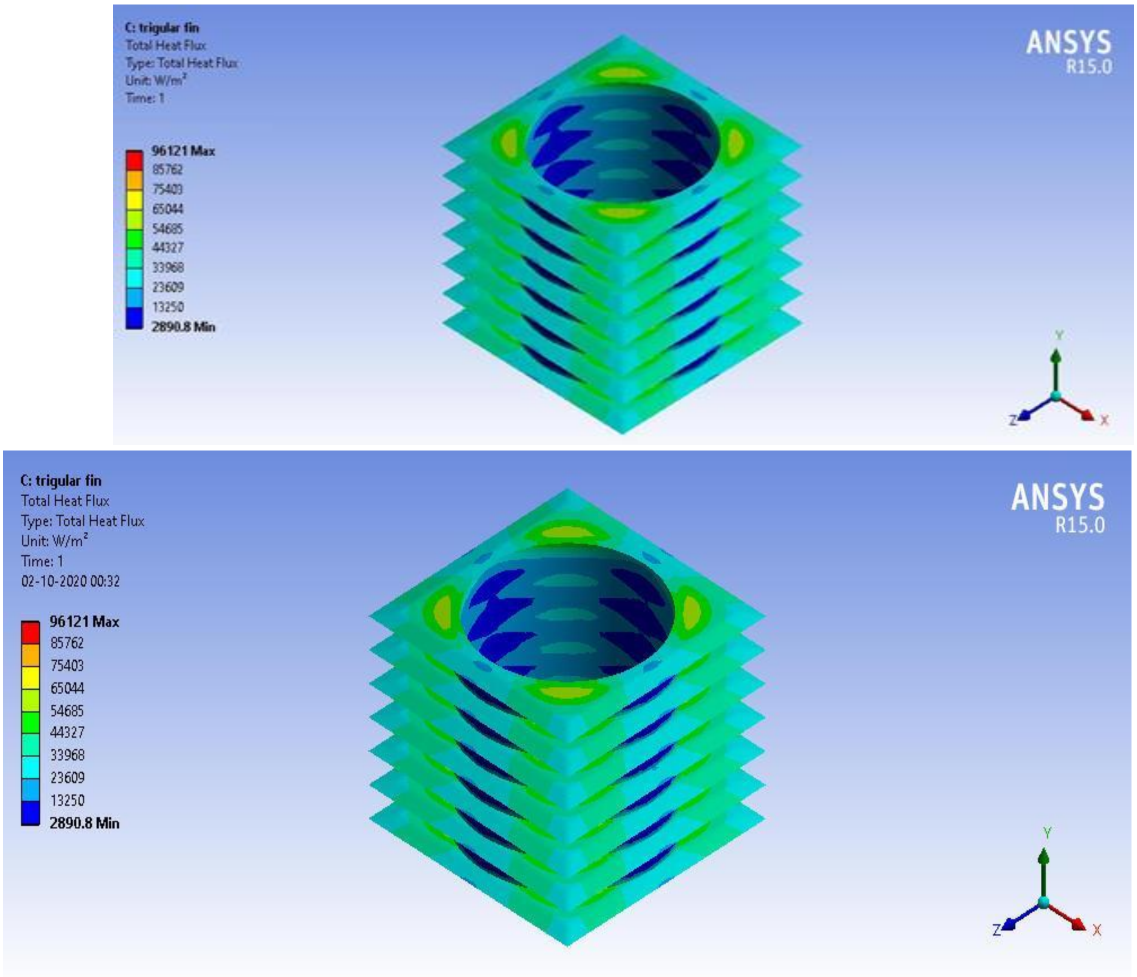


Figure 15: Total Heat flux in Triangular fin

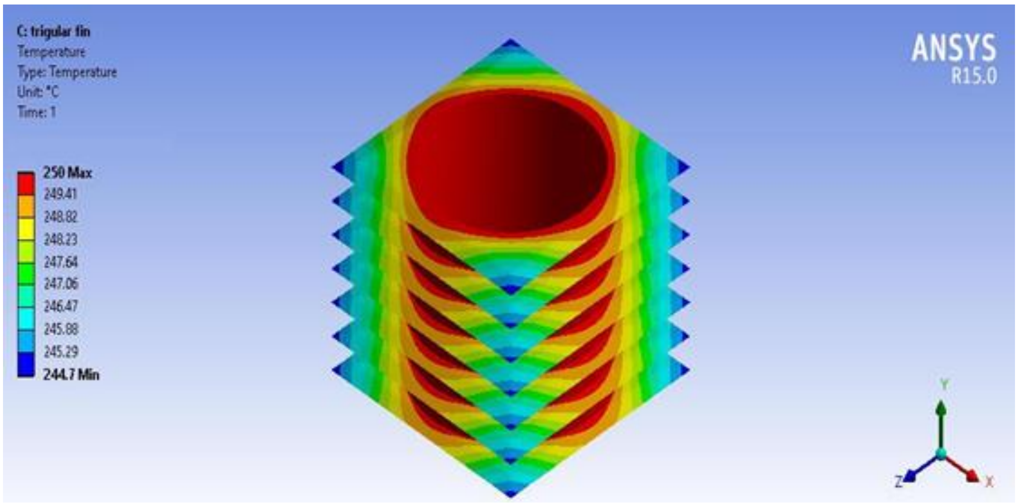


Figure 16: Temperature in Triangular fin

Above figures 14, 15, 16 show the mess in the rectangular fin geometry design, total heat flux, and temperature respectively.

Table 10: Temperature and total heat flux in Triangular Fins

Value	Temperature (°C)	Total Heat flux (W/m^2)
Maximum	250.	96121
Minimum	244.7	2890.8

Above table 10, it is described the triangular fins which have the maximum and minimum temperature as well as total flux which has in the table.

Table 11: Comparison of All types of Fins

Type of Fin	Temperature (°C)		Total Heat flux (KW/m^2)
	MAX	MIN	MAX
Tapered	250	244.19	123.87
Convex	250	244.38	126.06
Rectangular	250	245.46	96.042
Triangular	250	244.7	96.121

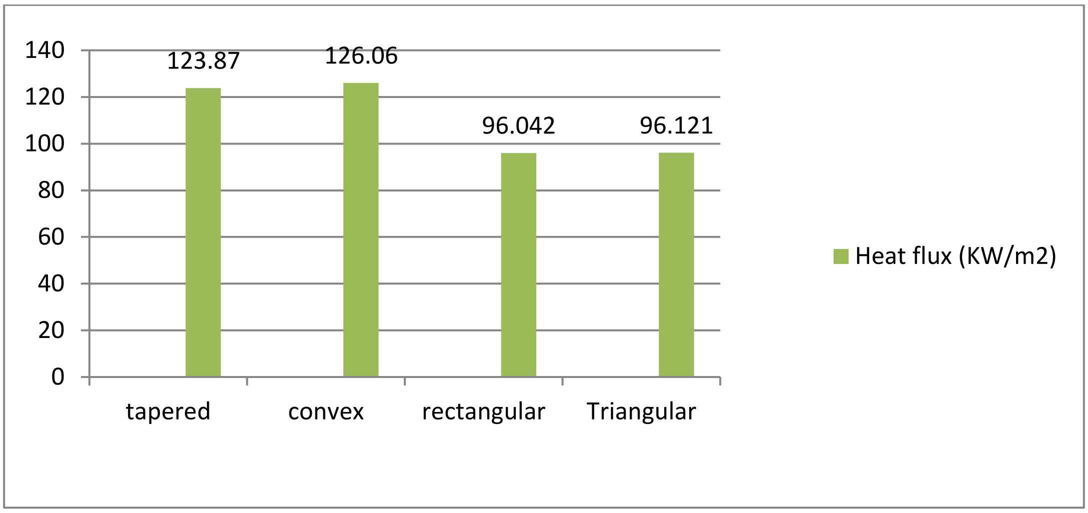


Figure 17: Compression of heat flux for different geometry

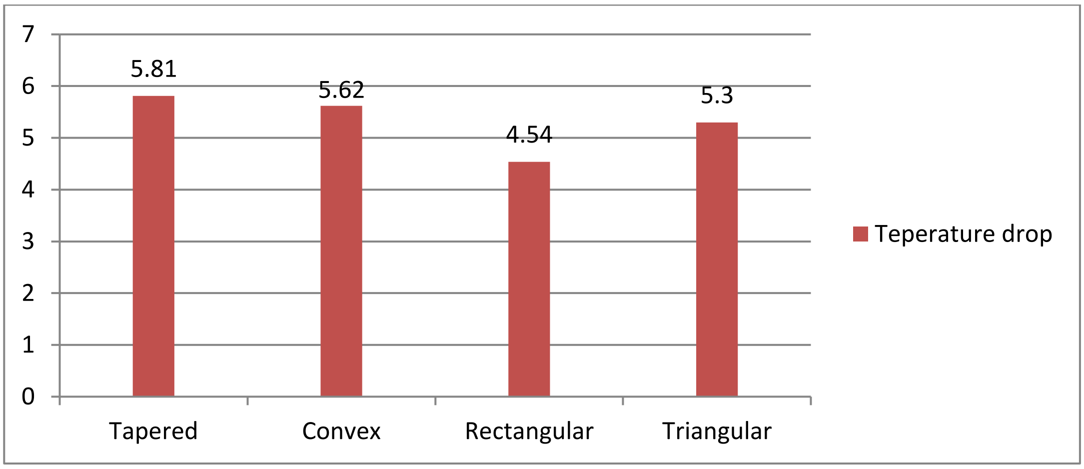


Figure 18: Compression of temperature drop for different geometry

The result section of comparison and from the above graphical representation shows that different geometry gives the value of maximum heat flux and temperature range. From the above two graphs, it is shown that the maximum heat flux in the convex fin is followed by tapered, rectangular, triangular. The drop is highest for tapered fin as compared to the other geometry rectangular, convex, and triangular.

VI. Conclusion

A cylinder fin body of two-wheelers is modeled in parametric 3D modeling Software solid works. Steady-state thermal analysis was performed using Ansys Software. The geometry used is rectangular, triangular, tapered, and convex. The material used for the fin body is Al6063. From the analysis, by observing the results it has been seen that the heat flux is Maximum in convex fin followed by tapered, triangular and rectangular fin. It is also seen that the maximum temperature reduction in tapered fin followed by convex, triangular and rectangular fin. It can also be concluded that the variation in geometry can increase and decrease the heat flux and temperature reduction. From the graph of the heat flux and temperature drop, it is found that variation in Maximum heat flux is more significant and varies to a higher numerical value as compared to the temperature drop, which is highest for convex fin.

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