

# DESIGN AND STUDY THE EFFECTIVENESS OF ENGINE CYLINDER FIN WITH VARIABLE GEOMETRY AND MATERIAL

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## Abstract

In automobiles, the engine cylinder is subjected to high temperature variations and thermal stresses .So as to cool the engine cylinder, fins are mounted on the engine cylinder to increase the rate of heat transfer. By doing thermal analysis on the engine cylinder fins you can know the rate of heat transfer inside the cylinder. The main objective of the project is to analyze the thermal behavior of cylinder fins by varying geometries, materials and thickness. In this project 2.5 mm and 3mm thickness of fins are considered for various fin geometries and they are designed using AUTO CAD 2016. Thermal analysis on the fins is done by using ANSYS WORKBENCH. In our project we have taken materials aluminum alloy 6063 and aluminum alloy 7068 instead of general material aluminum alloy 204. The geometries circular, rectangular and trapezoidal fins with Aluminum alloy 204, Aluminum alloys 6063 and 7068 of thickness 2.5mm &3mm are compared on the basis of total rate of heat flux & effectiveness. It is found that aluminum alloy 6063 of circular geometry with 2.5 mm thickness is having more rate of heat flux &effectiveness.

**Keywords:** Aluminum alloys 6063, Aluminum alloys 7068, Aluminum alloy 204, ANSYS WORKBENCH, AUTO CAD 2016.

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## 1. INTRODUCTION

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

$$Q = h A_s (T_s - T_{\infty})$$

Where  $h$ =convection heat transfer coefficient

$A_s$  =Heat transfer area of a surface

When the temperatures  $T_s$  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 ( $h_{gas} \ll h_{liquid}$ ) .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 aluminium, 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 preignition 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.

### 1.1 Classification of Fins

Based on the geometry of fins. Fins can be classified into three type .They are

1. Longitudinal fins
2. Annular fins
3. Pin- fin or spine fins

**Longitudinal fins:** It is a straight rectangular fin attached to a plane wall. It may be of uniform cross-sectional area, or its area may vary along its length to form a triangular, parabolic or trapezoidal shape.



Fig -1.1 longitudinal fin

**Annular fins:** An annular fin is a fin that is circumferentially attached to a cylinder and its cross-section varies with radius from center line of cylinder.



Fig -1.2 Annular Fin

**Spine or pin-fin:** A pin-fin or spine is an extended surface of circular cross-section whose diameter is much smaller than its length. The pin fins may also be uniform or non-uniform cross-section.



Fig -1.3 spine or pin-fin

## 1.2 Applications of Fins

- It is Mounted on engine cylinder to cool the engine
- It is also used in refrigeration system
- It is used in car radiators
- It is also used in electrical transformers and motors

## 2. FIN MATERIALS

Most commonly used material for manufacturing of fins is aluminum alloy. Now we are replacing present aluminum alloy with Aluminum alloy 6063 and Aluminum alloy 7068.

### Chemical Composition of Aluminum Alloy

Following Table is the composition for Aluminium alloy

Table -2.1 Chemical composition of AL Alloy

Element	Weight %
C	0.25
Mn	0.9
P	0.03
S	0.04
Si	0.15-0.30
Mo	0.45-0.60
Ni	0.05

### Chemical Composition Aluminum Alloy 6063

Following Table is the Chemical composition for Aluminium alloy 6063

Table -2.2 Chemical composition of AL alloy 6063

Element	Weight %
Aluminum	Balance
Chromium	0.1
Copper	0.1
Iron	0.35
Magnesium	0.45 - 0.9
Manganese	0.1
Silicon	0.2 - 0.6
Titanium	0.1
Zinc	0.1

### Chemical Composition of Aluminum Alloy 7068

Following Table is the chemical composition of Aluminium alloy 7.68

Table -2.3 Chemical composition of Aluminium 7068

Element	Weight %
Zinc	8.3
Magnesium	3
Copper	2.4
Iron	0.15
Zirconium	0.15
Silicon	0.12
Manganese	0.1
Titanium	0.1
Chromium	0.05
Aluminum	85.58

## Properties of Materials

Table -2.4 Properties of selected Materials

Aluminium alloy	204	6063	7068
Tensile Strength (Mpa)	331	330	710
Thermal conductivity (w/m-k)	120	200	190
Specific heat (J/g <sup>0</sup> C)	0.963	0.9	0.963
Density	2.8	2.7	2.8
Melting point ( <sup>0</sup> C)	529-649	616-654	476-635

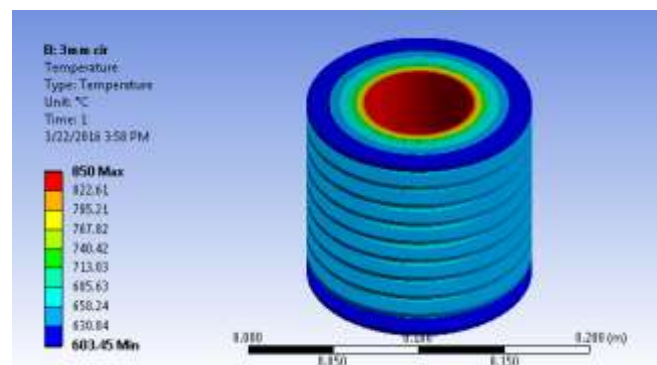
### 3. DIMENSIONS AND ANALYSIS OF FINS

Dimensions for fins and cylinder have been taken from the standard dimensions. We have made some changes to the standard dimensions according to our project. We have changed the thickness, length of the fins and pitch of fins. Following Table is the considered dimensions for design. All Dimensions are in mm.

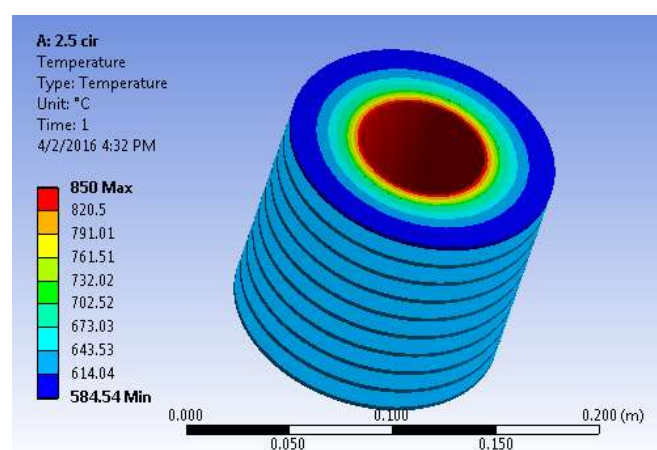
**Table -3.1** Selected Dimensions

Cylinder Inner Diameter	66
Cylinder Outer Diameter	78
Thickness of Fin	2.5
Length of Fin	27
Pitch of Fin	10
Length of Cylinder	120

#### 3.1. Result of Aluminum Alloy 204 Circular Fin Body with 3mm and 2.5mm Thickness



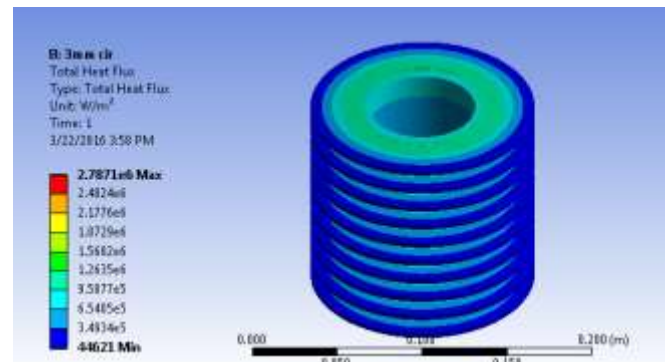
**Fig -3.1:** Temperature for Aluminum alloy 204 at 3mm thickness.



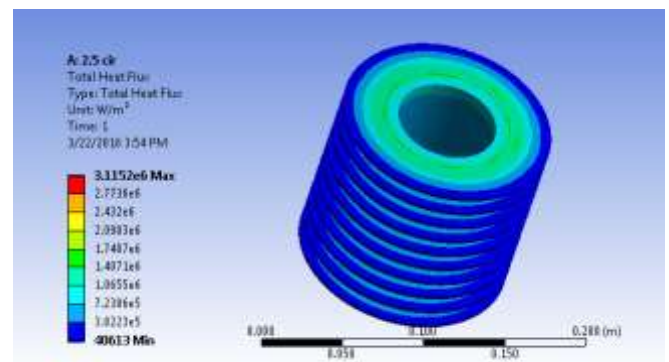
**Fig -3.2:** Temperature for aluminum alloy 204 at 2.5mm thickness

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 603.4°C by the flowing of air over the fin. Which is having a temperature gradient of 29°C. We have observed that the temperature change

within the fin of 2.5mm thickness is from 850°C to 584.54°C by the flowing of air over the fin. Which is having a temperature gradient of 29.5°C.



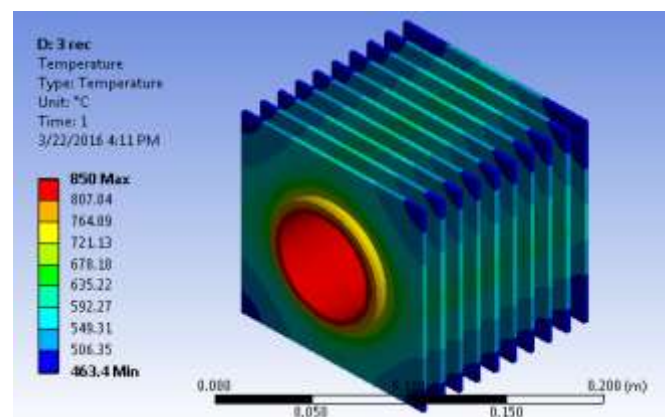
**Fig -3.3:** Total heat flux for Aluminum alloy 204 at 3mm thickness.



**Fig -3.4:** Total heat flux for Aluminum alloy 204 at 2.5 mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $2.7871 \times 10^6$  w/m<sup>2</sup> to 44621 w/m<sup>2</sup> by the flowing of air over the fin and the difference of total heat flux is 0.3047w/m<sup>2</sup>. We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $3.115 \times 10^6$  w/m<sup>2</sup> to 27086 w/m<sup>2</sup> by the flowing of air over the fin and the difference of total heat flux is 0.3416w/m<sup>2</sup>.

#### 3.2. Result of Aluminum Alloy 204 Rectangular Fin Body with 3mm and 2.5mm Thickness.



**Fig -3.5:** Temperature for Aluminum alloy 204 at 3mm thickness.

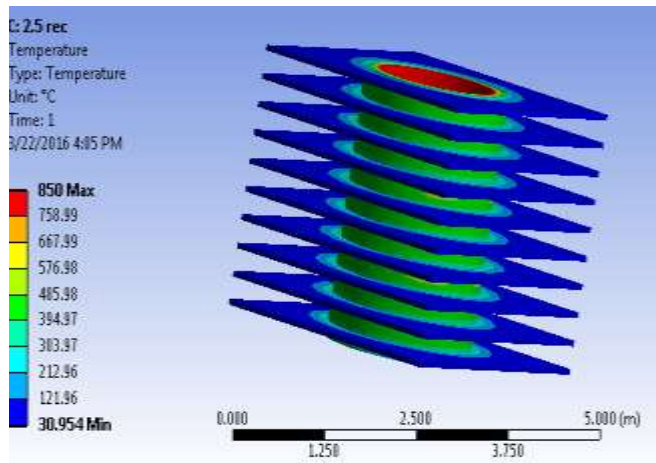


Fig -3.6: Temperature for aluminum alloy 204 at 2.5mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 463.4°C by the flowing of air over the fin. Which is having a temperature gradient of 42.96°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 30.950°C by the flowing of air over the fin. Which is having a temperature gradient of 91.01°C.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $3.2896 \times 10^6 \text{ w/m}^2$  to 62857  $\text{w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is 0.3047  $\text{w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $3.115 \times 10^6 \text{ w/m}^2$  to 27086  $\text{w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is 0.3416  $\text{w/m}^2$ .

### 3.3. Result of Aluminum Alloy 204 Trapezoidal Fin Body with 3mm and 2.5 mm Thickness

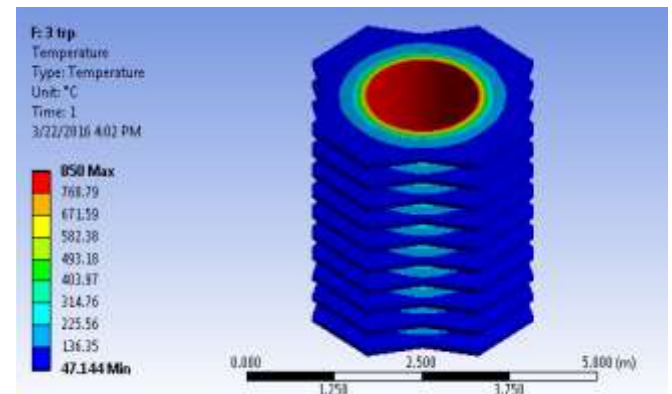


Fig -3.9: Temperature for Aluminum alloy 204 at 3mm thickness.

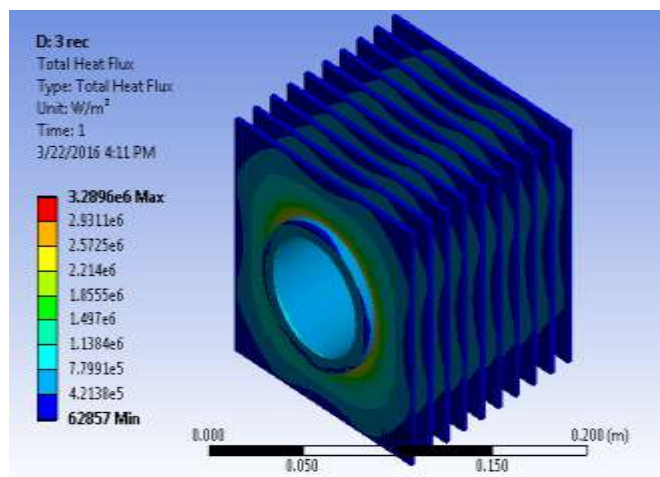


Fig -3.7: Total heat flux for Aluminum alloy 204 at 3mm thickness.

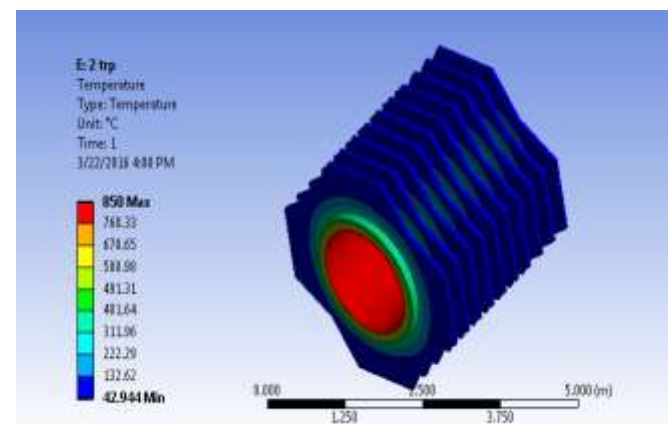


Fig -3.10: Temperature for aluminum alloy 204 at 2.5mm thickness.

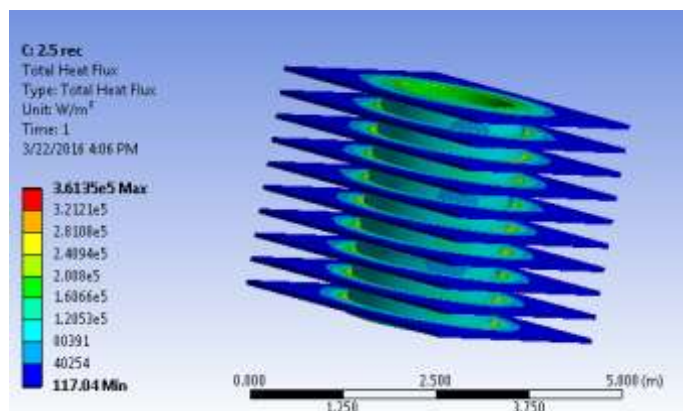


Fig -3.8: Total heat flux for Aluminum alloy 204 at 2.5 mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 47.14°C by the flowing of air over the fin. Which is having a temperature gradient of 89.21°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 42.944 °C by the flowing of air over the fin. Which is having a temperature gradient of 89.67°C.

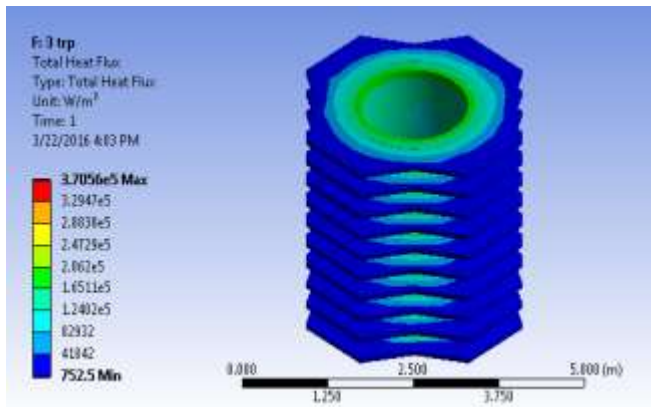


Fig -3.11: Total heat flux for Aluminum alloy 204 at 3mm thickness.

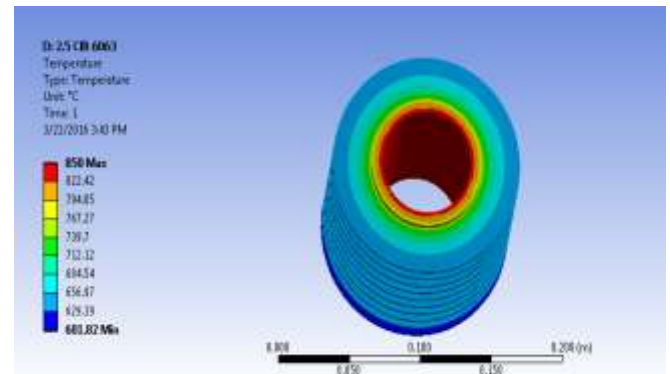


Fig -3.14: Temperature for aluminum alloy 6063 at 2.5mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 618.89°C by the flowing of air over the fin. Which is having a temperature gradient of 25.68°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 601.82 °C by the flowing of air over the fin. Which is having a temperature gradient of 27.58°C.

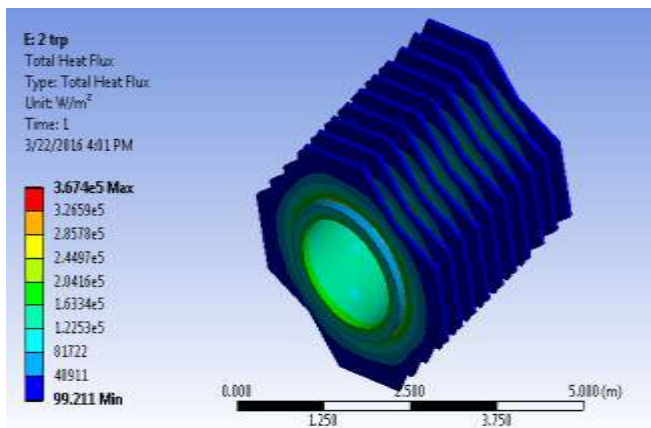


Fig -3.12: Total heat flux for Aluminum alloy 204 at 2.5 mm thickness.

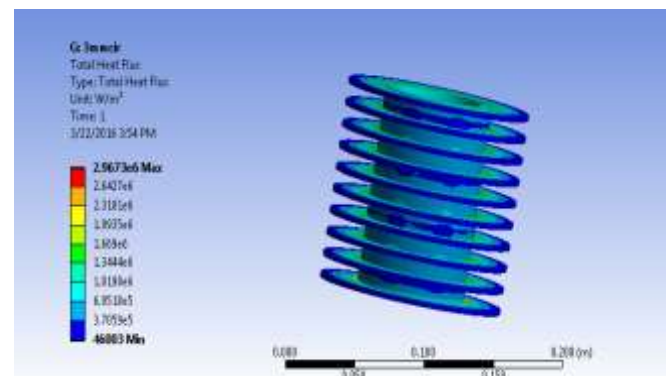


Fig - 3.15: Total heat flux for Aluminum alloy 6063 at 3mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $3.7056 \times 10^6 \text{ w/m}^2$  to  $752.5 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4109 \text{ w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $3.674 \times 10^6 \text{ w/m}^2$  to  $99.211 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4081 \text{ w/m}^2$ .

### 3.4. Result of Aluminum alloy 6063 Circular Fin Body with 3mm and 2.5mm Thickness

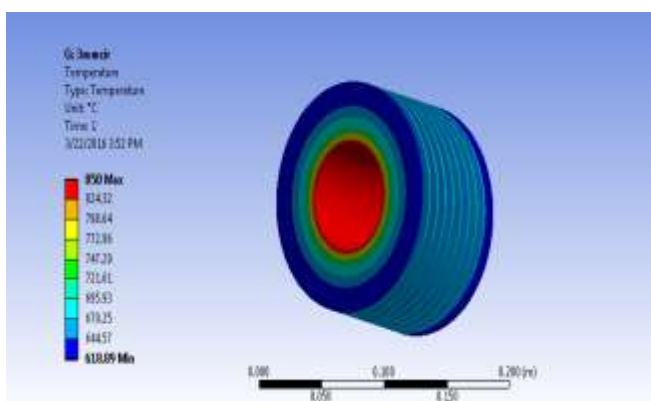


Fig -3.13: Temperature for Aluminum alloy 6063 at 3mm thickness .

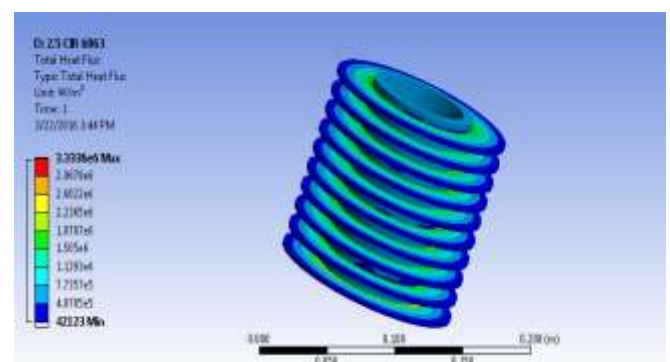


Fig -3.16: Total heat flux for Aluminum alloy 6063 at 2.5 mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $2.9673 \times 10^6 \text{ w/m}^2$  to  $46003 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.3246 \text{ w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $3.3336 \times 10^6 \text{ w/m}^2$  to  $42123 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.3657 \text{ w/m}^2$ .

### 3.5. Result of Aluminum alloy 6063 Rectangular Fin Body with 3mm and 2.5mm Thickness

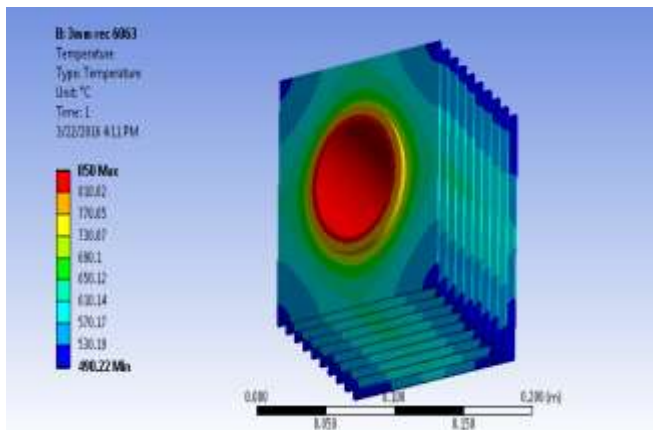


Fig -3.17: Temperature for Aluminum alloy 6063 at 3mm thickness

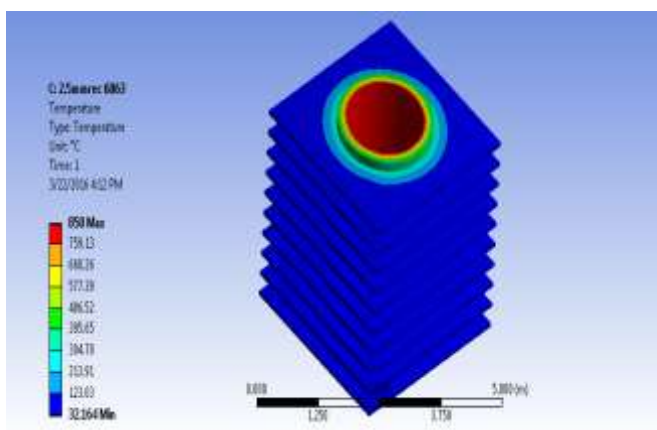


Fig -3.18: Temperature for aluminum alloy 6063 at 2.5mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 490.22°C by the flowing of air over the fin. Which is having a temperature gradient of 39.98°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 32.164°C by the flowing of air over the fin. Which is having a temperature gradient of 90.87°C.

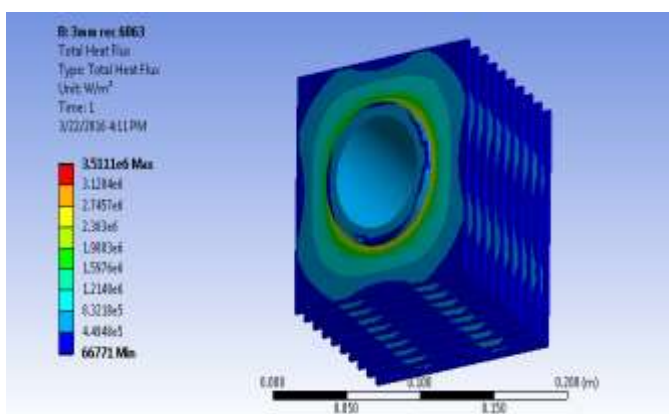


Fig -3.19: Total heat flux for Aluminum alloy 6063 at 2.5 mm thickness.

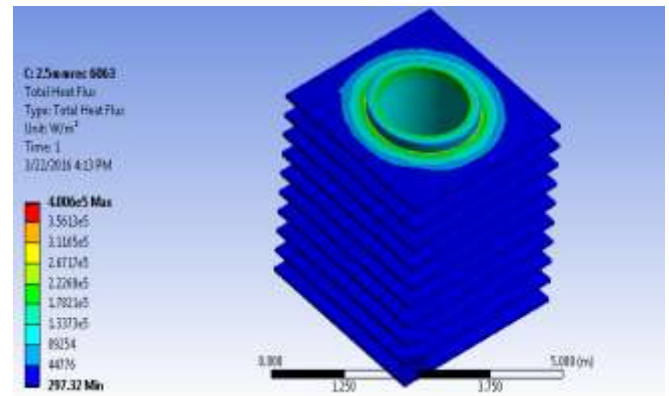


Fig -3.20: Total heat flux for Aluminum alloy 6063 at 3 mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $3.5111 \times 10^5 \text{ w/m}^2$  to  $66771 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.3827 \text{ w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $4.006 \times 10^5 \text{ w/m}^2$  to  $297.32 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4447 \text{ w/m}^2$ .

### 3.6. Result of Aluminum 6063 Trapezoidal Fin Body with 3mm and 2.5 mm Thickness

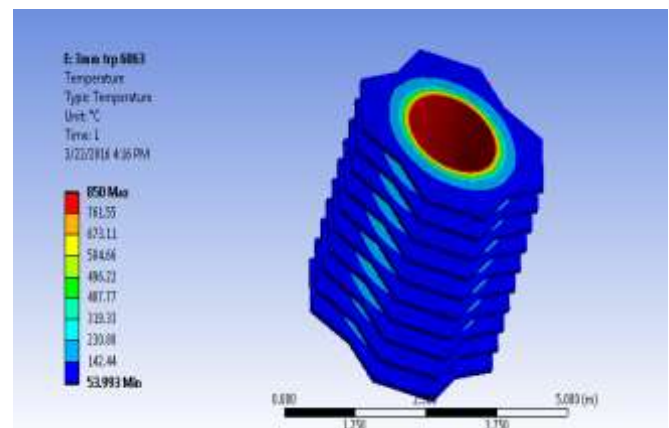


Fig -3.21: Temperature for Aluminum alloy 6063 at 3mm thickness.

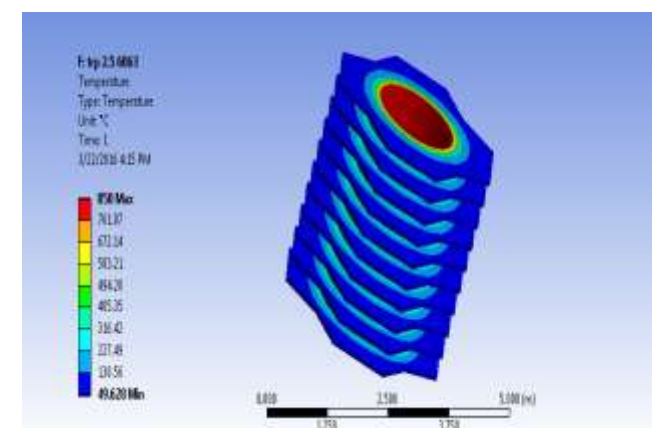


Fig -3.22: Temperature for Aluminum alloy 6063 at 2.5mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 53.993°C by the flowing of air over the fin. Which is having a temperature gradient of 88.45°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 49.628°C by the flowing of air over the fin which is having a temperature gradient of 88.93°C.

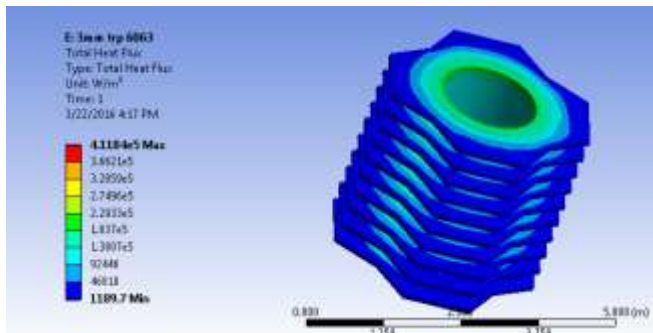


Fig -3.23: Total heat flux for Aluminum alloy 6063 at 3mm thickness.

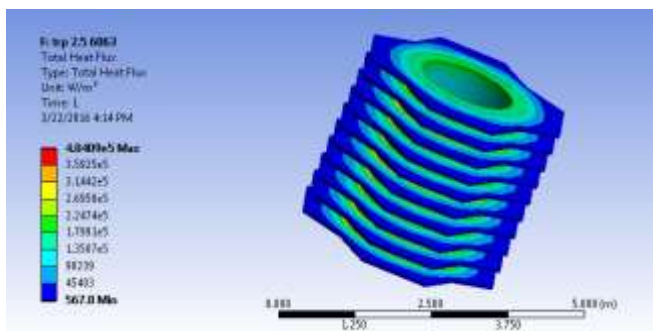


Fig -3.24: Total heat flux for Aluminum alloy 6063 at 2.5 mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $4.1184 \times 10^5 \text{ w/m}^2$  to  $1189.7 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4563 \text{ w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $4.040 \times 10^5 \text{ w/m}^2$  to  $567.8 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4484 \text{ w/m}^2$ .

### 3.7. Result of Aluminum 7068 Circular Fin Body with 3mm and 2.5mm Thickness

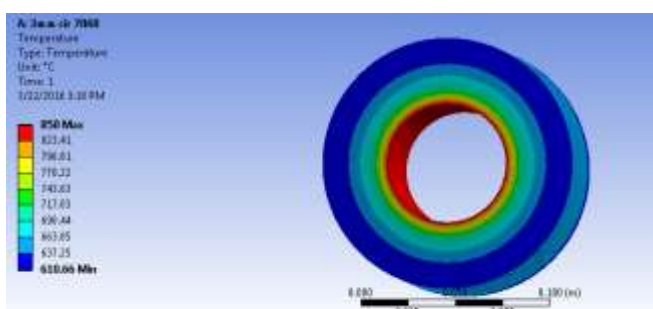


Fig -3.25: Temperature for Aluminum alloy 7068 at 3mm thickness.

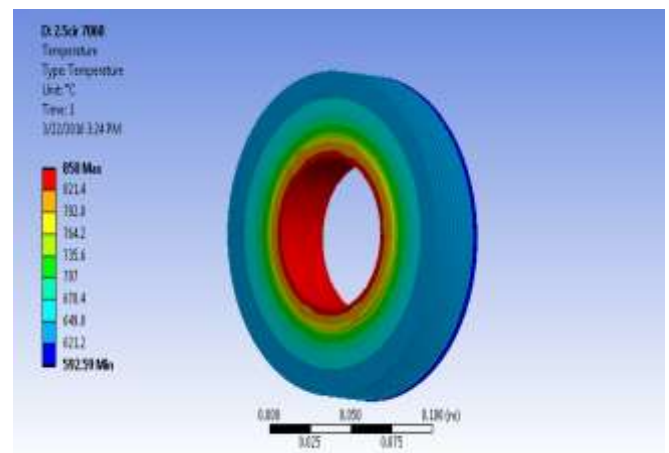


Fig -3.26: Temperature for aluminum alloy 7068 at 2.5mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 610.66°C by the flowing of air over the fin. Which is having a temperature gradient of 26.59°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 592.56°C by the flowing of air over the fin which is having a temperature gradient of 28.6°C.

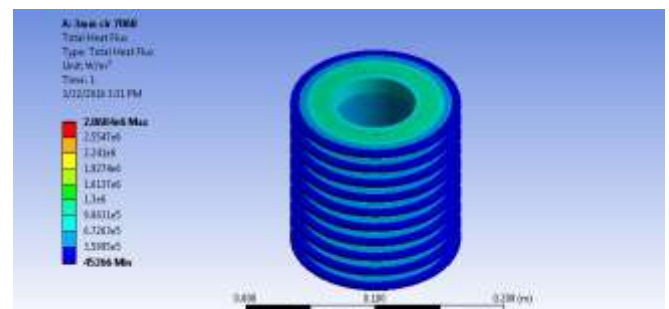


Fig -3.27: Total heat flux for Aluminum alloy 7068 at 3mm thickness.

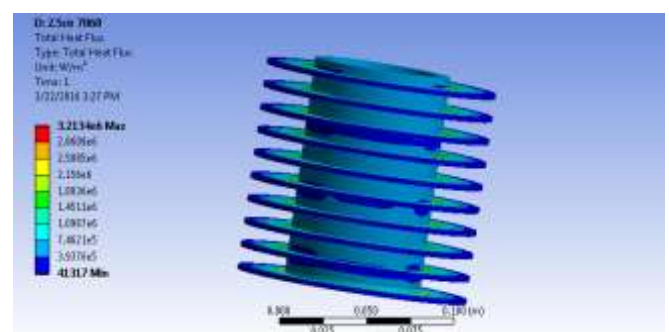


Fig -3.28: Total heat flux for Aluminum alloy 7068 at 2.5 mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $2.8684 \times 10^6 \text{ w/m}^2$  to  $45266 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.3137 \text{ w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $3.213 \times 10^6 \text{ w/m}^2$  to  $41317 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.3525 \text{ w/m}^2$ .

### 3.8. Result of Aluminum 7068 Rectangular Fin Body with 3mm and 2.5 mm Thickness

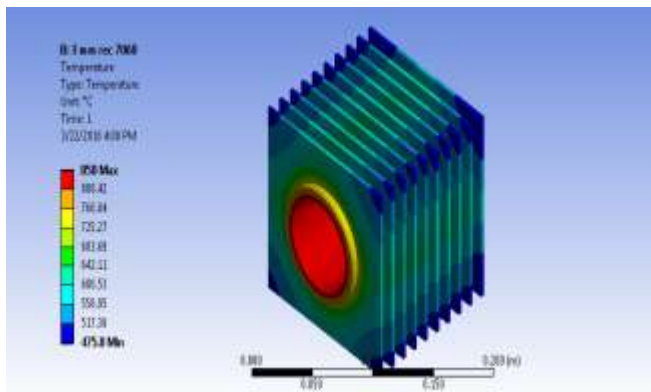


Fig -3.29: Temperature for Aluminum alloy 7068 at 3mm thickness.

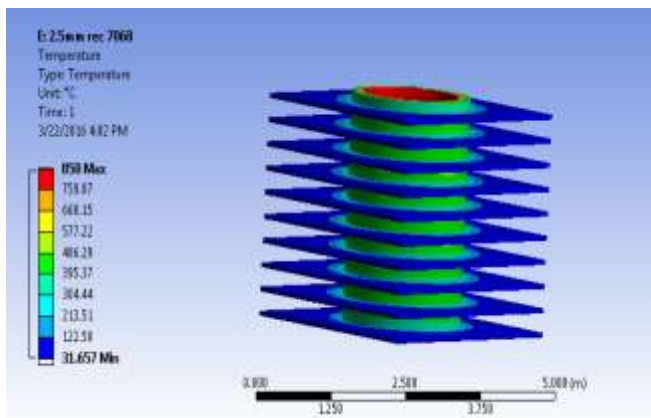


Fig -3.30: Temperature for aluminum alloy 7068 at 2.5mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 31.657°C by the flowing of air over the fin. Which is having a temperature gradient of 41.58°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 31.567°C by the flowing of air over the fin. Which is having a temperature gradient of 90.93°C.

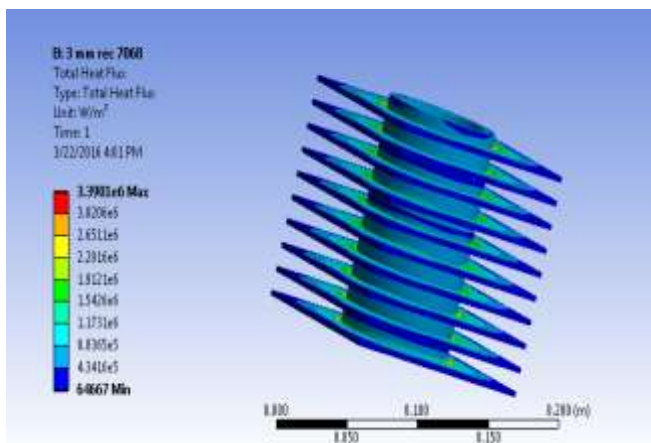


Fig -3.31: Total heat flux for Aluminum alloy 7068 at 3mm thickness.

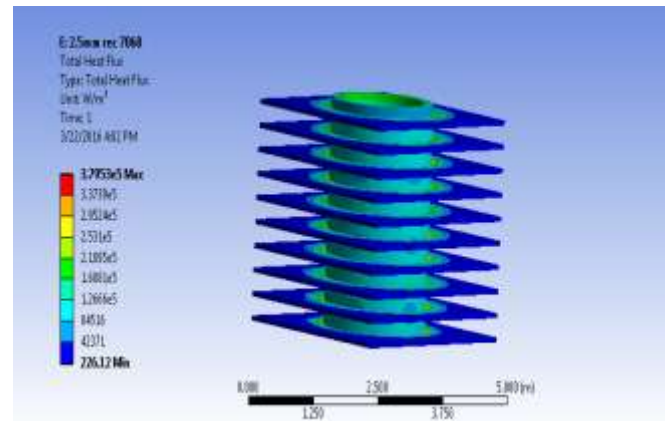


Fig -3.32: Total heat flux for Aluminum alloy 7068 at 2.5 mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $3.795 \times 10^5 \text{ w/m}^2$  to  $226.12 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.3695 \text{ w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $3.795 \times 10^5 \text{ w/m}^2$  to  $226.12 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4214 \text{ w/m}^2$ .

### 3.9. Result of Aluminum 7068 Trapezoidal Fin Body with 3mm and 2.5mm Thickness

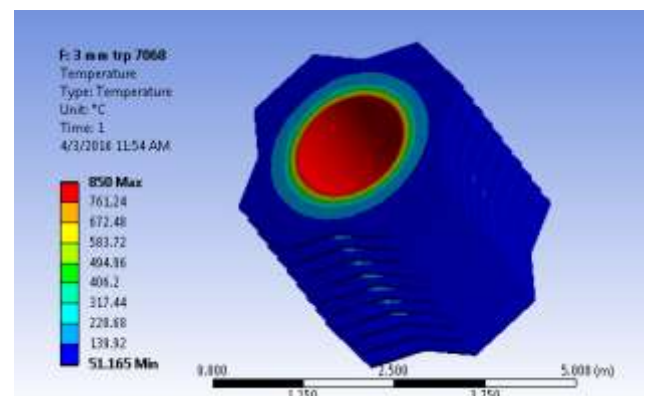


Fig -3.33: Temperature for Aluminum alloy 7068 at 3mm thickness

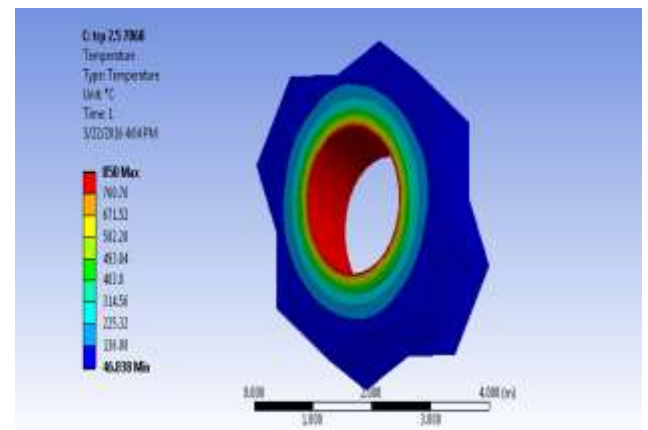


Fig -3.34: Temperature for aluminum alloy 7068 at 2.5mm thickness.

We have observed that the temperature change within the fin of 3mm thickness is from 850°C to 51.615°C by the flowing of air over the fin. Which is having a temperature gradient of 88.76°C. We have observed that the temperature change within the fin of 2.5mm thickness is from 850°C to 46.838°C by the flowing of air over the fin which is having a temperature gradient of 89.24°C.

$$\epsilon = \frac{q_{Fin}}{q_{No\ Fin}}$$

Where,  $\epsilon$  = Effectiveness of fin  
 $q_{Fin}$  = Heat flux with fin  
 $q_{No\ fin}$  = Heat flux without fin

Some observations with use of fins are:

- An effectiveness  $\epsilon_{fin}=1$ , indicates that the addition of fins to the surface does not affect the heat transfer rate at all.
- An effectiveness  $\epsilon_{fin} < 1$ , indicates that the fin actually act as insulation and decreasing the heat transfer rate from the surface. It may occur, if fin of low thermal conductivity material is used.
- An effectiveness  $\epsilon_{fin} > 1$ , indicates that fins are increasing the heat transfer rate from the surface.
- However, the use of fins cannot be justified unless  $\epsilon_{fin}$  is more than 5.

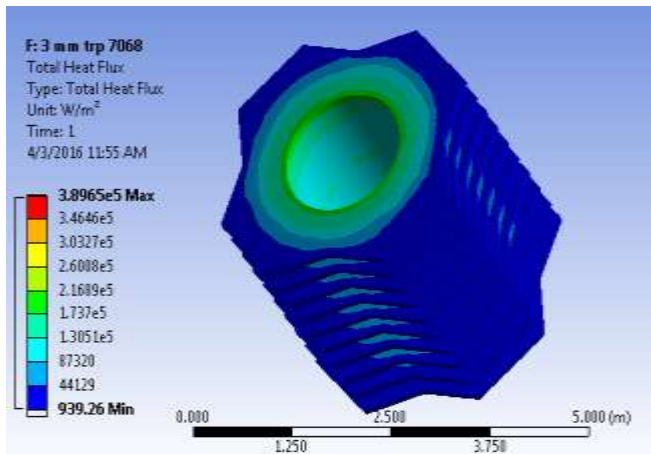


Fig 3.35: Total heat flux for Aluminum alloy 7068 at 3mm thickness.

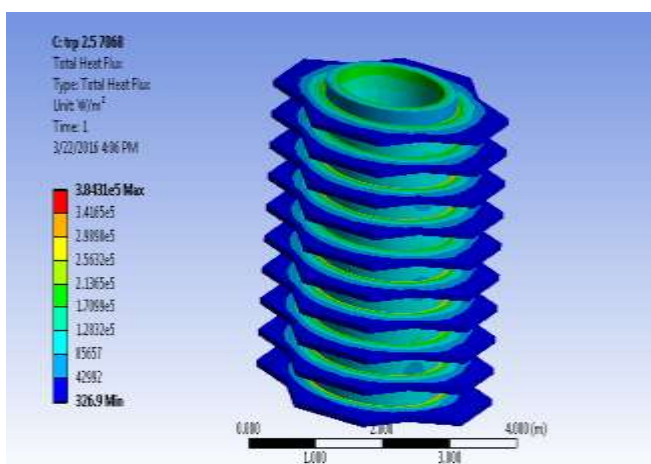


Fig -3.36: Total heat flux for Aluminum alloy 7068 at 2.5 mm thickness.

We have observed that the total heat flux change within the fin of 3mm thickness is from  $3.8965 \times 10^5 \text{ w/m}^2$  to  $936.25 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4319 \text{ w/m}^2$ . We have observed that the total heat flux change within the fin of 2.5mm thickness is from  $38.43 \times 10^5 \text{ w/m}^2$  to  $326.9 \text{ w/m}^2$  by the flowing of air over the fin and the difference of total heat flux is  $0.4266 \text{ w/m}^2$ .

#### 4. EFFECTIVENESS OF FIN

The performance of the fin is judged on the basis of the enhancement in heat transfer relative to the no-fin case. The performance of fin is expressed in terms of the fin effectiveness is defined as the ratio of the heat transfer rate from the fin of base area to the heat transfer rate from the surface of area i.e. It is equal to the base area of fin.

#### 4.1. Effectiveness of Al Alloy Circular Fin having Thickness 2.5 mm

- Heat flux of cylinder is  $q = 1.428 \times 10^5$
- Heat flux of finned cylinder is  $q = 2.88226 \times 10^6$
- Effectiveness  $\epsilon = \frac{q_{Fin}}{q_{No\ Fin}} = \frac{2.88226 \times 10^6}{1.428 \times 10^5} = 19.766$

#### 4.2 Effectiveness of Al Alloy7068 Circular Fin having Thickness 2.5mm

- Heat flux of cylinder is  $q = 1.428 \times 10^5$
- Heat flux of finned cylinder is  $q = 2.8998 \times 10^6$
- Effectiveness  $\epsilon = \frac{q_{Fin}}{q_{No\ Fin}} = \frac{2.8998 \times 10^6}{1.428 \times 10^5} = 20.30$

#### 4.3 Effectiveness of Al Alloy 6063 Circular Fin Having Thickness 2.5 mm

- Heat flux of cylinder is  $q = 1.428 \times 10^5$
- Heat flux of finned cylinder is  $q = 2.9938 \times 10^6$
- Effectiveness  $\epsilon = \frac{q_{Fin}}{q_{No\ Fin}} = \frac{2.9938 \times 10^6}{1.428 \times 10^5} = 21$

4.4 Comparison of Effectiveness:

Table -4.1 Comparison of Effectiveness

Fin material	Fin shape	Effectiveness of fin	
		2.5 mm thickness	3 mm thickness
Al alloy	Circular	19.766	17.88
	Rectangular	2.23	18.6
	Trapezoidal	2.083	1.64
Al 6063	Circular	20.964	18.83
	Rectangular	2.44	19.74
	Trapezoidal	2.26	1.79
Al 7068	Circular	20.30	18.27
	Rectangular	2.335	19.15
	Trapezoidal	2.163	1.71

Effectiveness for selected materials at 2.5mm thickness

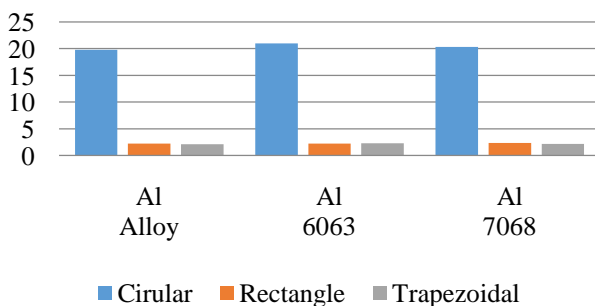


Fig -4.1: Effectiveness of selected Materials at 2.5mm Thickness

Effectiveness for Selected Materials at 3mm Thickness

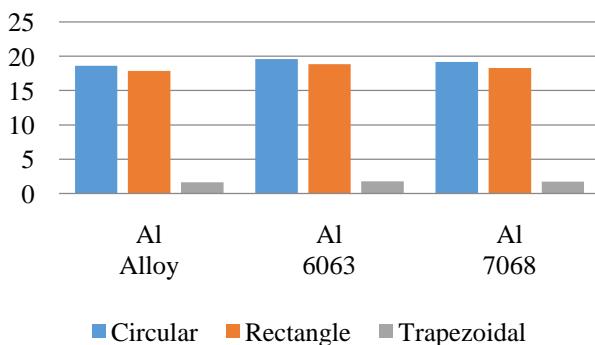


Fig -4.2: Effectiveness of Selected Material at 3mm Thickness

5. CONCLUSION

In this project we have compared the materials aluminum alloy 6063 and aluminum alloy 7068 with general material aluminum alloy 204 with varying thickness of engine cylinder fins. The fin geometries are modeled by using AUTOCAD2016 and then thermal analysis is done on ANSYS workbench. By observing thermal analysis results, we can clearly conclude that fin material aluminum alloy 6063 of circular geometry with 2.5mm thickness is most

effective in terms of rate of heat flux & effectiveness. By using circular fins with aluminum alloy 6063, the weight of the fin body is also reduces compared with the existing material of fin body.

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