Thermal Analysis of Engine Cylinder Fins By Varying Its Fin Geometry And Material

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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. The main aim of the project is to analyze the thermal properties such as Heat flux, Thermal gradient (temperature) by varying geometry, material and thickness of cylinder fins. The heat transfer performance of the engine cylinder fin is analyzed by the design of fin with using rectangular and circular extensions. These are compared with the fin without extensions and are found to increase the heat transfer rate. The basic principle behind this concept of providing extensions on the finned surfaces is to increase the surface area of the fin in contact with the fluid/coolant flowing around it thereby increasing the rate of heat transfer. The analysis is done using ANSYS. Using CFD analysis the heat transfer surface of the engine is modeled in SOLIDWORKS.18 and analyzed in ANSYS.16 software. We are analyzing the cylinder fins using this material and also using Aluminium alloy2014 and Beryllium copper alloy which have higher thermal conductivities.*

Keywords- Shape, Material and Geometry of the fin, Thermal analysis.

I. INTRODUCTION

Heat exchangers are widely used in various, transportation, industrial, or domestic applications such as thermal power plants, means of heating, transporting and air conditioning systems, electronic equipment and space vehicles. In all these applications improvement in the efficiency of the heat exchangers can lead to substantial cost, space and material savings. Hence considerable research work has been done in the past to seek effective ways to improve the efficiency of heat exchangers

The most effective heat transfer enhancement can be achieved by using fins as elements for the heat transfer surface area extension. In the past a large variety of fins have been applied for these purposes, leading a very compact heat exchangers with only gas or gas and liquid as the working media. Plate fin rotary regenerators and tube fin are widely encountered compact heat exchangers across the industry. Here the area of interest is the tube fin configuration. These are built as a combination of tubes with various cross sections with fins present both outside and inside the tubes. The common form of the tube cross-section is round or rectangular, but elliptical cross-sections are also encountered. Fins are generally attached by means of tight mechanical fit, adhesive bonding, soldering, brazing, and welding or by extrusion. Depending upon the form and direction of the fins, the tubes may be classified as individual tube with normal fins, individual tubes with longitudinal fins or tube arrays with plain, wavy or interrupted external of internal fins.

1.) MODES OF HEAT TRANSFER:

The modes of heat transfer can be divided into three segments.

Conduction
Convection
Radiation

i.) CONDUCTION:

Conduction refers to the transfer of heat between two bodies or two parts of the same body through molecules which are, more or less, stationary, as in the case of solids.

ii.) CONVECTION

When energy transfer takes place between a solid and fluid system in motion, the process is known as convection. If the fluid motion is impressed by compressor or pump, it is called Forced Convection. If fluid motion is caused due to density difference, it is called Natural Convection.

iii.) RADIATION:

Thermal radiation refers to the radiant energy emitted by bodies by virtue of their own temperatures, resulting from the thermal excitation of the molecules. Radiation is assumed to propagate in the form of electromagnetic waves.

The governing equation for Radiation heat transfer is:
PLANK'S LAW:

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{\frac{h\nu}{k_BT}}-1}, \text{ or } B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_BT}}-1}$$

Heat Transfer by Extended Surface:

Convection heat transfer is governed by the relation:

$$Q = h\,A\,(T_w - T_\infty)$$

2.) FIN PERFORMANCE:

i) FIN EFFECTIVENESS:

Fin effectiveness is defined as the ratio between heat transfer rate with fin and heat transfer rate without fin.

$$€_f = Q_o / hA\theta_o$$

While using a fin for increasing heat transfer rate we should consider that, the fin itself represents a conductive resistance to heat transfer from original surface. Therefore it is not necessary that by using fins the heat transfer rate increases. This factor is calculated by fin effectiveness

When $€_f < 2$, the use of such fins are not justified.

Fin effectiveness can be enhanced by,

1. Choice of material of high thermal conductivity. E.g. Aluminum, Copper
2. Increasing ratio of area to the perimeter of the fins. The use of thin closely placed fins is more suitable than thick fins.
3. Low values of heat transfer coefficient (h).

ii) FIN EFFICIENCY:

This is the ratio of the fin heat transfer rate to the heat transfer rate of the fin if the entire fin were at the base temperature.

$$\eta_f = \frac{q_f}{hA_f\theta_b}$$

II. IDENTIFY, RESEARCH AND COLLECT IDEA

1. "Masao YOSHIDA, Soichi ISHIHARA, Kohei NAKASHIMA: Air-Cooling Effects of Fins on a Motorcycle Engine" The author had developed the experimental cylinder for an air-cooled engine and the effects of the number of fins, fin pitch and wind velocities on cylinder cooling were investigated.
2. "Pratima S. Patil, S.N. Belsare, Dr. S. L. Borse Analysis of internal combustion engine heat transfer rate to improve engine efficiency, specific power & combustion performance prediction" This paper focuses on substantial difference of heat flux exists for various places in the cylinder of an engine.
3. G.Raju, Dr. BhramaraPanitapu, S. C. V. Ramana Murty Naidu. "Optimal Design of an I C engine cylinder fin array using a binary coded genetic algorithm".This study also includes the effect of spacing between fins on various parameters like total surface area, heat transfer coefficient and total heat transfer
4. MagarajanU. ,Thundilkarrupa Raj R. , Elango T. " Numerical study on heat transfer I C Engine cooling by extended fins using CFD" In this study, heat release of an IC engine cylinder cooling fins with six numbers of fins having pitch of 10 mm and 20 mm are calculated numerically using commercially available CFD tool Ansys Fluent. The experiment results shows that the value of heat release by the ethylene glycol through cylinder fins of pitch 10mm and 20mm are about 28.5W and 33.90 W.
5. Mr. N. Phani Raja Rao, Mr. T. Vishnu Vardhan. "Thermal Analysis Of Engine Cylinder Fins By Varying Its Geometry And Material." The principle implemented in the project to increase the heat dissipation rate by using the invisible working fluid nothing but air. The main aim of the project is to varying geometry, material. The results shows, by using circular fin with material Aluminium Alloy 6061 is better since heat transfer rate, Efficiency and Effectiveness of the fin is more. By using circular fins the weight of the fin body reduces compare to existing engine cylinder fins.
6. N.Nagarani and K. Mayilsamy, Experimental heat transfer analysis on annular circular and elliptical fins."This other had analyzed the heat transfer rate and efficiency for circular and elliptical annular fins for different environmental conditions. Elliptical fin efficiency is more than circular fin.

III. WRITE DOWN YOUR STUDIES AND FINDINGS

Objectives of the project

The following are the main objectives of the present work:

1.) To design cylinder with fins for a I.C. engine by varying the geometry such as rectangular, circular and thickness of the fins.

2.) To identify suitable alloy for the fabrication based on results obtained from finite element analysis.

Sl. No.	Parameters	Forms
1.)	Types of fins	i) Rectangular ii) Circular
2.)	Thickness of the fins	i) 1.5mm ii) 2.75mm
3.)	Materials Used for fins	i) Aluminum 2014 ii) Beryllium copper

METHODOLOGY

Design

The current analysis and Design is done for the Engine Cylinder head to find the Effectiveness of the Fin thickness in the and the Material to improve the cooling Effect using the natural convection the project is done for the 2 different models with rectangular and the Circular for the Thickness of 1.5mm and 2.75mm to determine the effect of thickness and to optimize the material to improve effectiveness so the Aluminium 2014 and beryllium copper is used.

Rectangular Fin Model

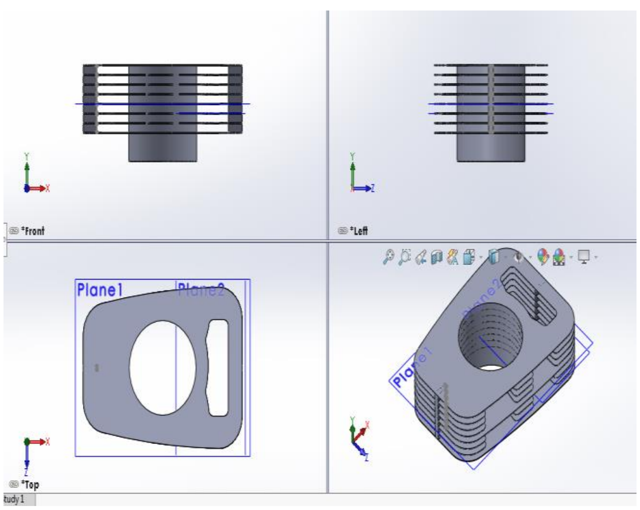


Fig 1 Design of the Rectangular Fin Model

Circular Fin Model

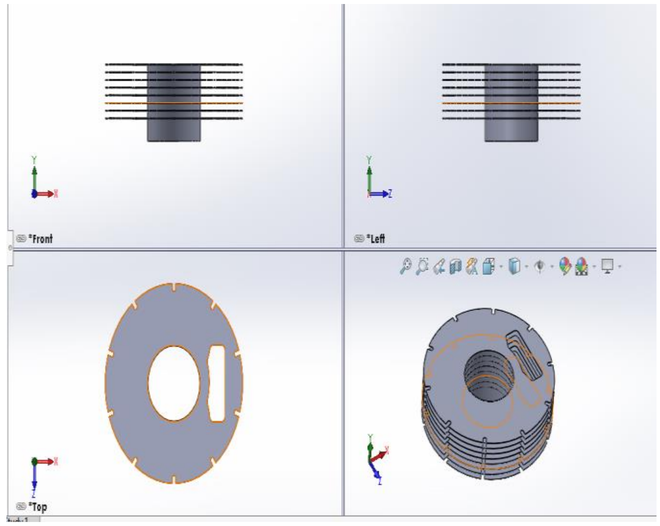


Fig 2 Design of the Circular Fin Model

ANALYSIS:

The Analysis of the project is carried out in the ansys software. Ansys is a multi physics software which allows us to perform various types of performance tests which includes, dynamics, static structural, harmonic response, response spectrum, steady state, transient

We are using Ansys 16.0 version to analyze our model.

NOTE: “ANSYS only supports universal file formats like STEP, IGES, PARASOLID, PARASOLID BINARY.”

IMPORTED GEOMETRY TO ANSYS DESIGN MODELER

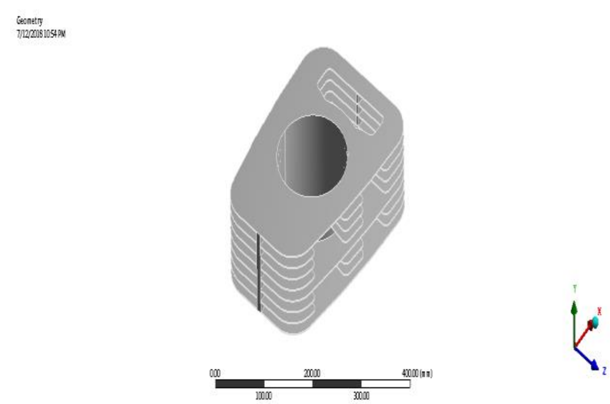


Fig 3 Imported Step File of Rectangular Fin to Design Modeler in Ansys Workbench

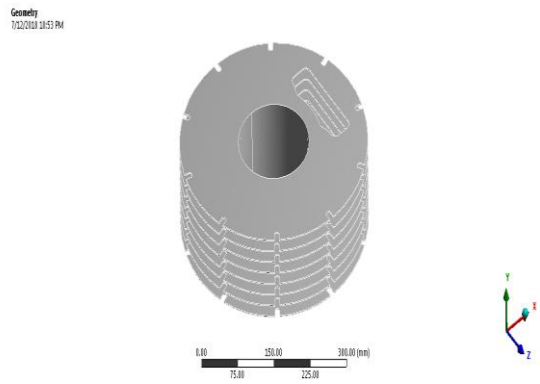


Fig 4 Imported Step File of Circular Fin To Design Modeler in Ansys Workbench

After importing of the geometry the discretization process must be done using meshing solver.

MESHED MODEL:

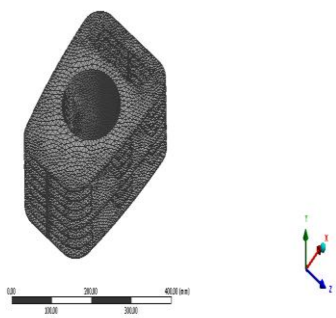


Fig 5 Discretized model of the Rectangular Fin model in Ansys Mesh

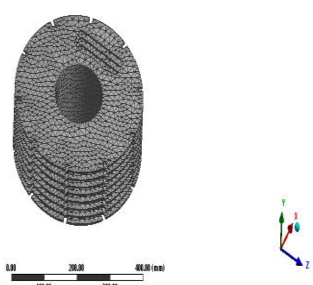


Fig 6 Discretized model of the Circular Fin model in Ansys Mesh.

ANALYSIS OF THE GEOMETRY:

Analysis of the model Is carried out in both steady state and transient state thermal analysis with same boundary conditions.

Analysis of the Model with Aluminum:

Steady state process

Steady state thermal process is an analysis system which effectively calculates the heat transfer rate at a given time it uses in built algorithms meshes and boundary conditions to solve a given problem.

Boundary Conditions

Boundary conditions are the input parameters we consider to solve a problem therefore the inputs we given affect the output result.

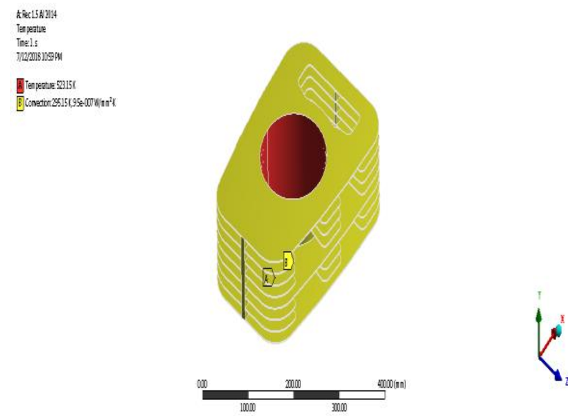


Fig 7 Boundary conditions For the Rectangular Fin Model.

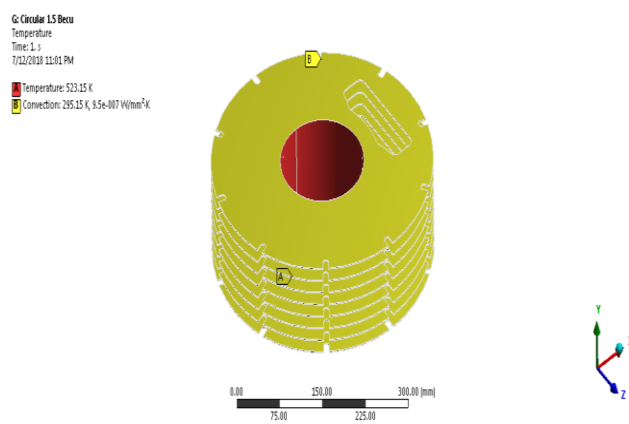


Fig 8 Boundary conditions For the Circular Fin Model.

IV.THERMAL ANALYSIS OF FIN MODELS

Thermal analysis can be either linear or nonlinear. Temperature dependent material properties or temperature dependent convection coefficients or radiation effects can result in nonlinear analyses that require an iterative procedure to achieve accurate solutions. The thermal properties of most materials do vary with temperature, so the analysis usually is nonlinear.

Case 1

Analysis of Rectangular Fin Cylinder Heat with 1.5mm Thickness

i) Aluminium 2014

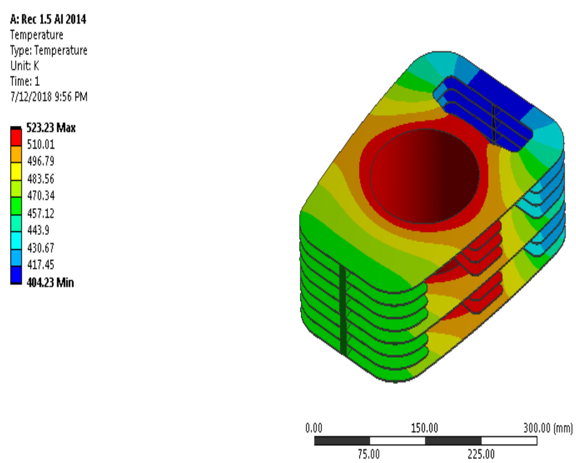


Figure 9 Temperature Distribution of the Rectangular Fin engine head with 1.5 mm thickness

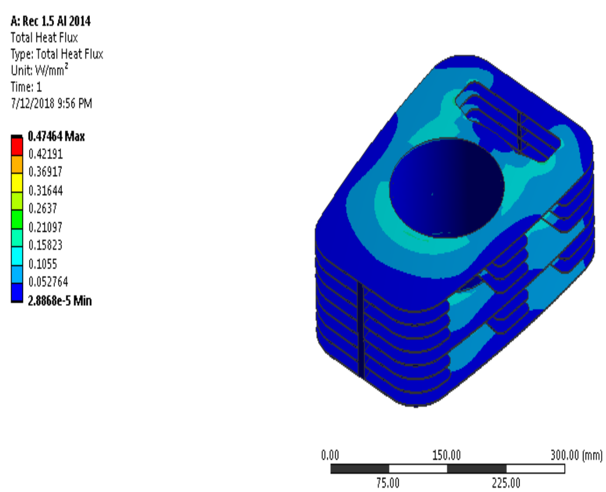


Figure 10 Heat flux Distribution of the Rectangular Fin engine head with 1.5 mm thickness

i) Beryllium Copper.

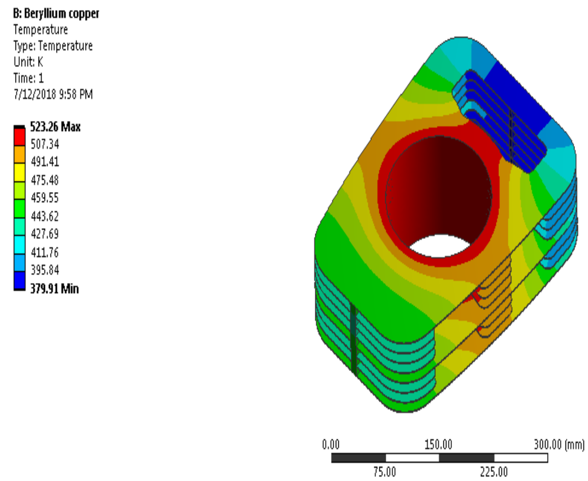


Figure 11 Temperature Distribution of the Rectangular Fin engine head with 1.5 mm thickness

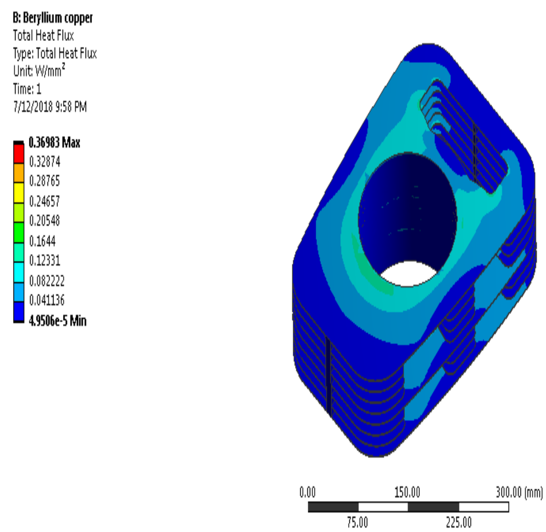
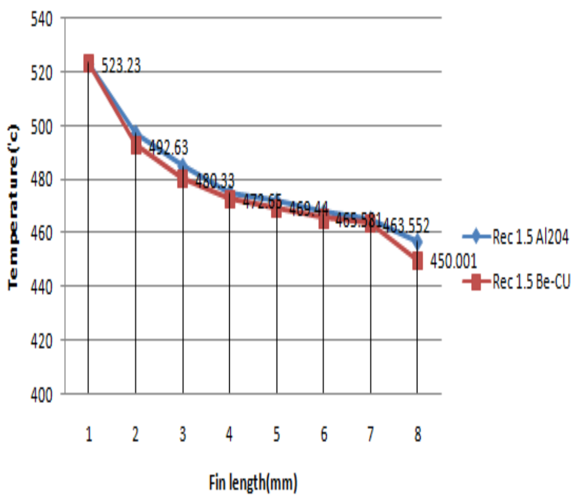
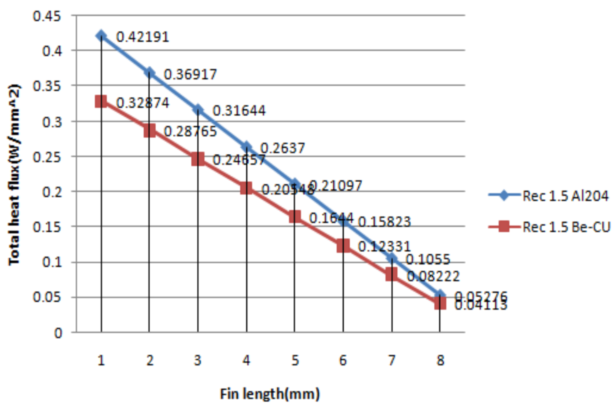


Figure 12Heat flux Distribution of the Rectangular Fin engine head with 1.5 mm thickness

Graphical representation for temperature and heat flux in rectangular fin for thickness 1.5mm:



Plot 1 Temperature distribution between AL2014 & Beryllium copper through fin of 1.5mm thickness.



Plot 2 Total heat flux variation between AL2014 & Beryllium copper through fin of 1.5mm thickness

Case 2

Analysis of Rectangular Fin Cylinder Heat with 2.75mm Thickness

i) Aluminium2014

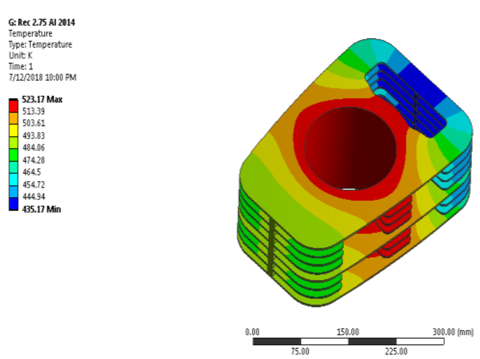


Figure 13 Temperature Distribution of the Rectangular Fin engine head with 2.75 mm thickness

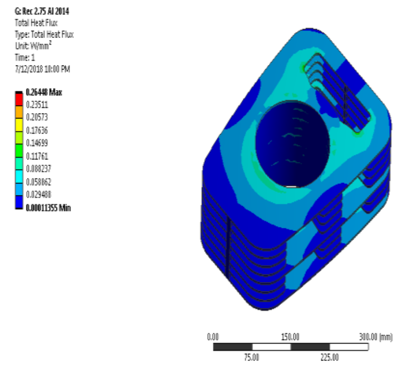


Figure 14 Heat flux Distribution of the Rectangular Fin engine head with 2.75 mm thickness

ii) Beryllium Copper

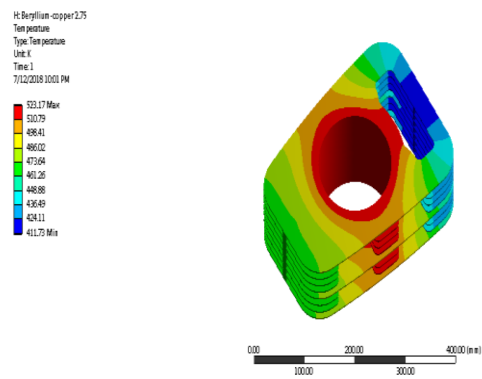


Figure 15 Temperature Distribution of the Rectangular Fin engine head with 2.75 mm thickness.

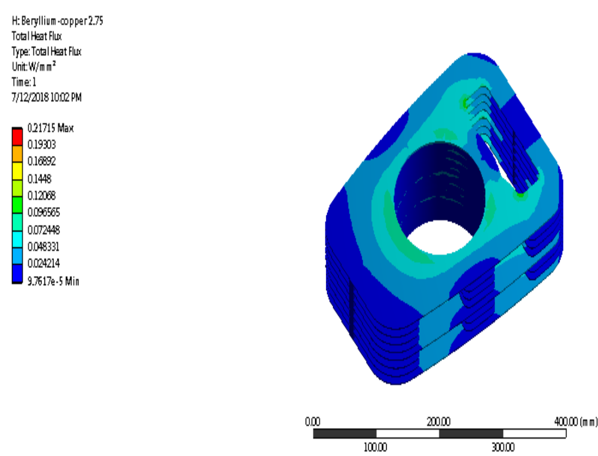
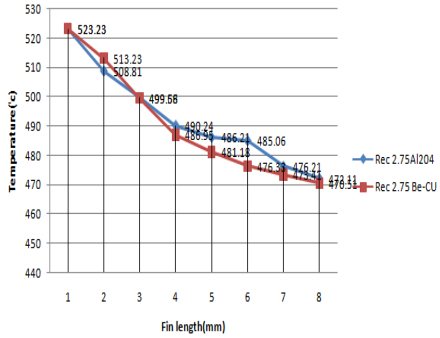
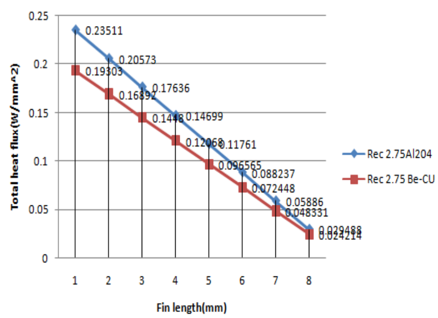


Figure 16 Heat flux Distribution of the Rectangular Fin engine head with 2.75 mm thickness

Graphical representation for temperature and heat flux in rectangular fin for thickness 2.75mm:



Plot 3 Temperature distribution between AL2014 & Beryllium copper through fin of 2.75mm thickness.



Plot 4 Total heat flux variation between AL2014 & Beryllium copper through fin of 2.75mm thickness.

Case 3

Analysis of Circular Fin Cylinder Head with 1.5 mm Thickness.

i) Aluminium2014

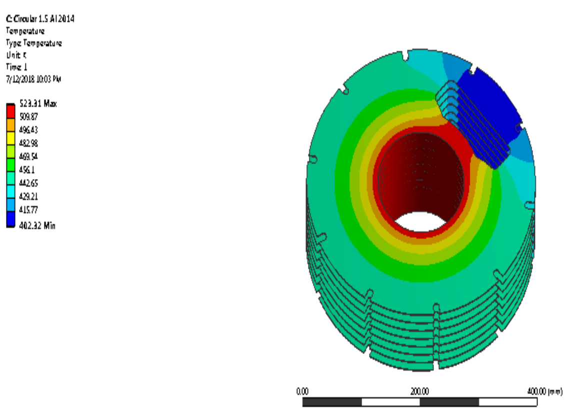


Figure 17 Temperature Distribution of the Circular Fin engine head with 1.5 mm thickness.

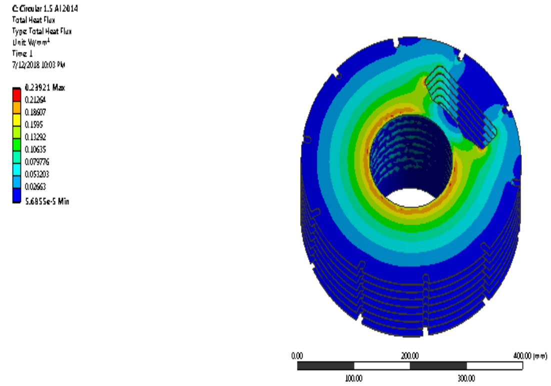


Figure 18 Heat flux Distribution of the Rectangular Fin engine head with 1.5 mm thickness

ii) Beryllium Copper.

Graphical representation for temperature and heat flux in circular fin for thickness 1.5mm:

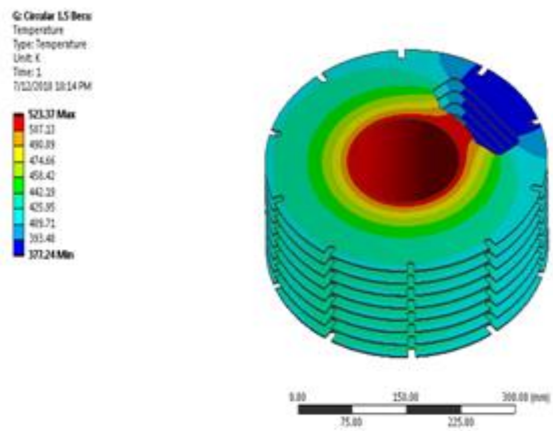


Figure 19 Temperature Distribution of the Circular Fin engine head with 1.5 mm thickness.

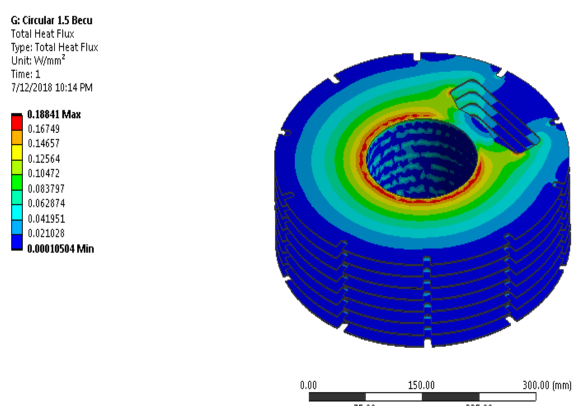
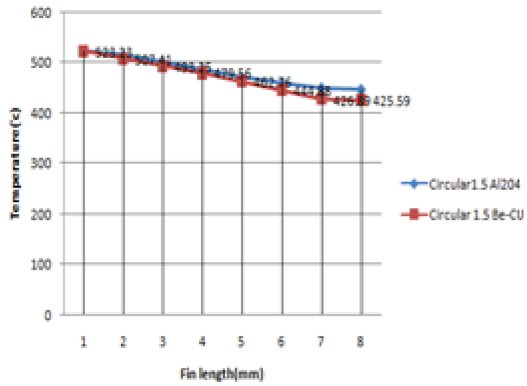
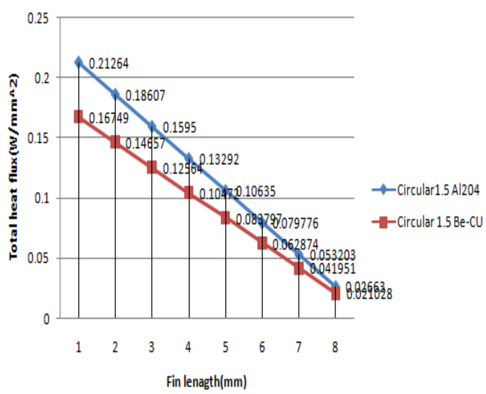


Figure 20 Heat Flux of the Circular Fin engine head with 1.5 mm thickness.



Plot 5 Temperature distribution between AL2014 & Beryllium copper through fin of 1.5mm thickness.



Plot 6 Total heat flux variation between AL2014 & Beryllium copper through fin of 1.5mm thickness

Case 4

Analysis of Circular Fin Cylinder Head with 2.75 mm Thickness.

i) Aluminum2014

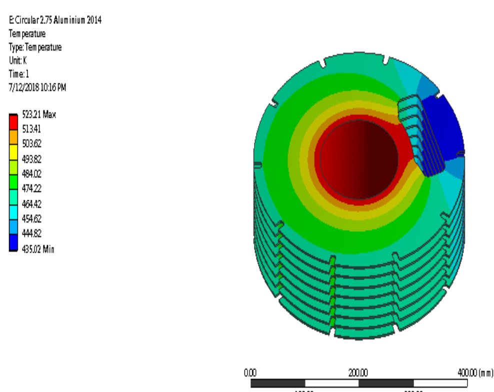


Figure 21 Temperature Distribution of the Circular Fin engine head with 2.75 mm thickness.

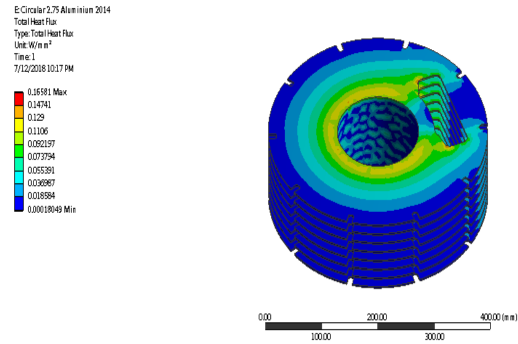


Figure 22 Heat Flux of the Circular Fin engine head with 2.75 mm thickness.

iii) Beryllium copper

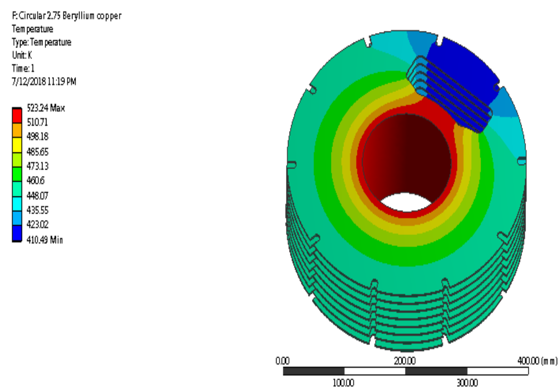


Figure 23Temperature Distribution of the Circular Fin engine head with 2.75 mm thickness.

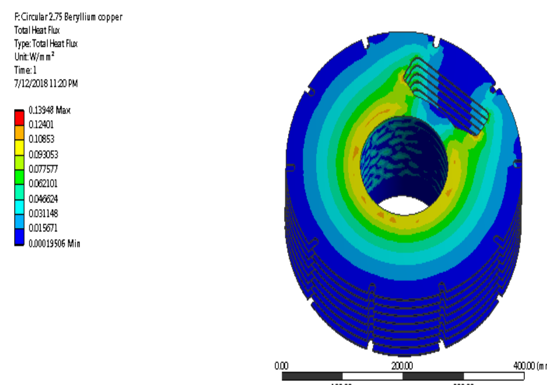
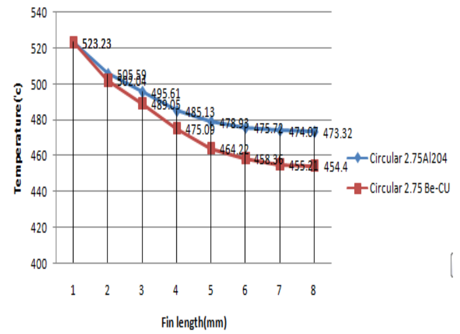
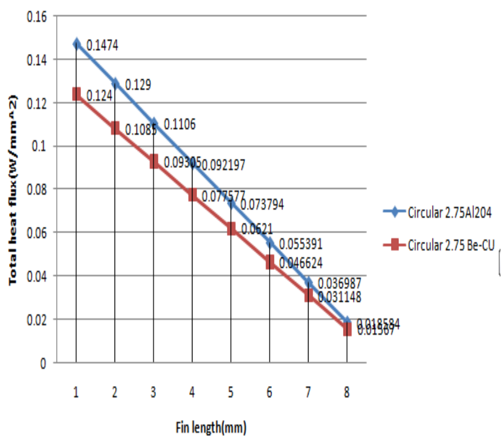


Figure 24Heat Flux of the Circular Fin engine head with 2.75 mm thickness.

Graphical representation for temperature and heat flux in circular fin for thickness 2.75mm:

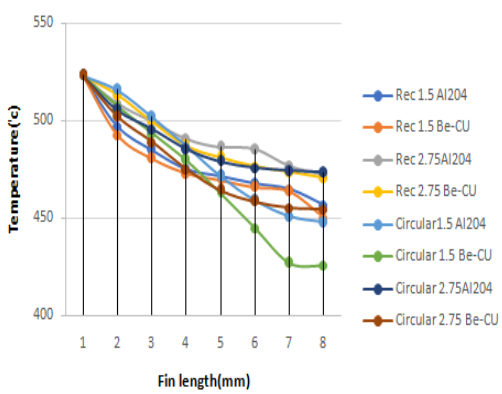


Plot 7 Temperature distribution between AL2014 & Beryllium copper through fin of 2.75mm thickness.

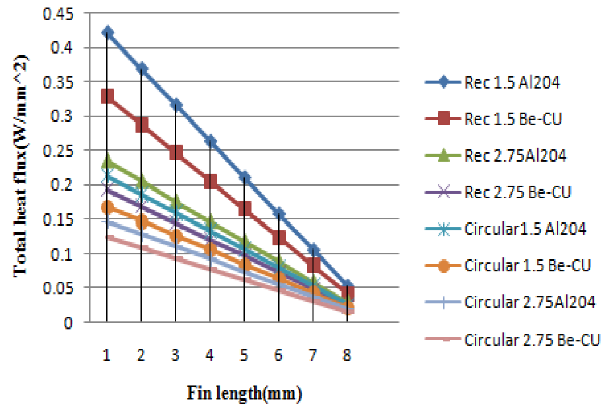


Plot 8 Total heat flux variation between AL2014 & Beryllium copper through fin of 2.75mm thickness.

Comparison graphs between rectangular and circular shaped fins:



Plot 9 Comparison plot between materials Al204 & Be-Cu with thicknesses 1.5mm & 2.75mm along Temperature (in °c) and fin length (in mm).



Plot 10 Comparison plot between materials Al204 & Be-Cu with thicknesses 1.5mm & 2.75mm along Total heat flux (in W/mm^2) and fin length (in mm).

V. CONCLUSION

In present work, a cylinder fin body is modeled and transient thermal analysis is done by using Solidworks and ANSYS. These fins are used for air cooling systems for two wheelers. By reducing the thickness and also by changing the shape of the fin to circular shaped, the weight of the fin body reduces thereby increasing the heat transfer rate and efficiency of the fin.

Out of all the Analysis the design with Fins of 1.5mm Thickness and the circular pattern is good and convects heat efficiently with beryllium copper. There is a significant improvement in the heat dissipation or convection in the below cases

	Rectangular Fins		
	1.5mm		2.75mm
Be-Cu	379.91		411.73
	523.26		523.17
Al2014	404.23		435.17
	523.23		523.17
	Circular Fins		
	1.5mm		2.75mm
Be-Cu	377.24		410.09
	523.37		523.24
Al2014	402.32		435.02
	523.31		523.21

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