Design and thermal analysis on engine cylinder fins by modifying its material and geometry

A Sathishkumar*, MD KathirKaman, S Ponsankar, C Balasuthagar
Department of Mechanical Engineering, SRM University, Kattankulathur, Tamilnadu, India
***Corresponding author: E-Mail: sathishvinothkumar@gmail.com**

ABSTRACT

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, material and angle of cylinder fins using Ansys work bench and the models are created by changing the geometry like rectangular, circular, angular and curved shaped fins. Transient thermal analysis shows the deviation of temperature over time and the precise thermal simulation is very useful to identify the design parameters for improved life. The observations from the present investigation work, Aluminium Alloy 2014 showing 17 % higher temperature distribution compared to Aluminium Alloy 204. All the materials are showing linear distribution of temperature alongside the length of fins. Also, the circular fins increase the efficiency of the engine by reducing the weight of the engine.

Keywords: Engine, Fins, Geometry, Material, Heat dissipation.

1. INTRODUCTION

The internal combustion engine is an engine in which the combustion of a fuel takes place in a combustion chamber. Here, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to component of the engine, such as piston, turbine blades, or a nozzle. This force transfers the component over a distance, generating useful mechanical energy. Air cooled engines are replaced by water cooled engines which are more efficient, but all two wheelers uses Air cooled engines, because Air-cooled engines are lighter weight and lesser space requirement. The heat produced during combustion in IC engine should be retained at higher level to increase thermal efficiency, but to prevent the thermal damage some heat should remove from the engine.

In Internal engine combustion engines, combustion of air – fuel mixture takes place inside engine cylinder and hot gases are produced. The temperature of gases will be around 2300 – 500°C.The high temperature may result into burning of oil film between moving parts and may result into seizing or welding. Hence, this temperature must be reduced to increase the efficiency of the engine.It has been observed from the literature that the heat dissipative effects of the fins used in engine by changing geometry and material have not been reported. The present investigation work aims to investigate heat dissipative effect of fins made up of Aluminium 6061, Aluminium 2014 and Aluminium Alloy C443and also, modifying its geometry.

2. DESIGN AND MODELLING

The present study is to design the engine cylinder with fins for a 150cc engine by changing the geometry such as rectangular, circular & curve shaped (parabolic) and angular fins. Table 1 show that different materials and geometry chosen for present study and material properties are given in the Table 2.

Table.1.Different materials and geometry chosen for analysis

Type of Fins	Material of the fin
Rectangular	Aluminium Alloy 6061
Circular	Aluminium Alloy 204
Angular	Aluminium Alloy 2014
Curved	Aluminium Alloy C443

Table.2.Material properties thermal conductivity

Materials	Thermal Conductivity (W/mK)	Heat transfer co-efficient (W/m^2k)	Density (g/cc)	Melting Point (K)
Aluminium 6061	167	25	2.7	855
Aluminium 204	156	25	2.75	820
Aluminium 2014	160	25	2.8	780
Aluminium C443	146	25	2.69	847

Figure 1 to 4 illustrates the design of all four geometries and it is designed using SOLIDWORKS 2016. The cylinder diameter of 50 mm and height of 53 mm have been chosen for the present analysis. The fin thickness is 2.5 mm and gab between fins is 7.5 mm. Figure – 5 to 8 shows the engine cylinder is designed with different fin geometries.

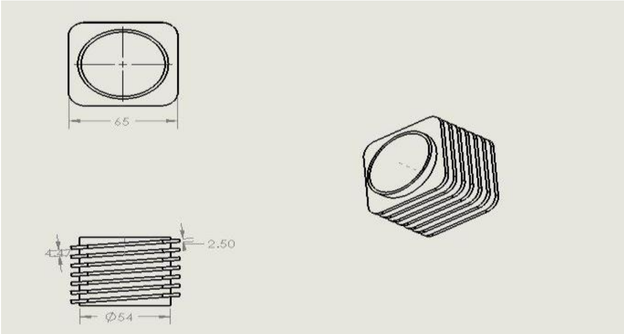

Figure.1.Engine cylinder with angular fins

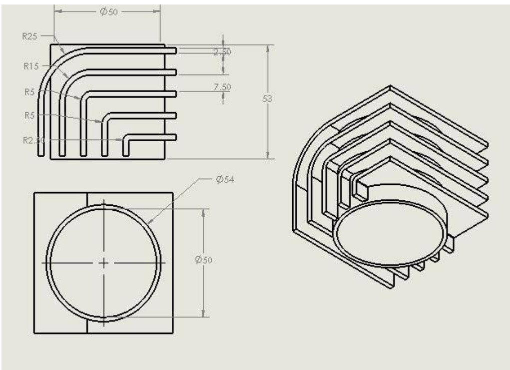

Figure.2.Engine cylinder with curved fins

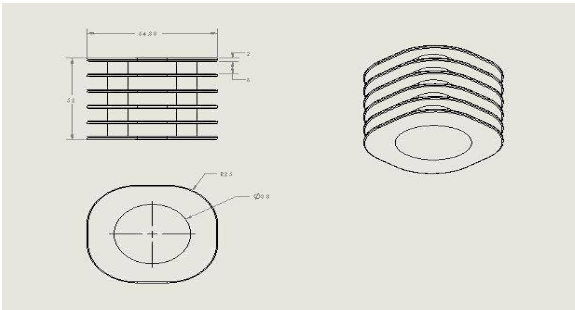

Figure.3.Engine cylinder with circular fins

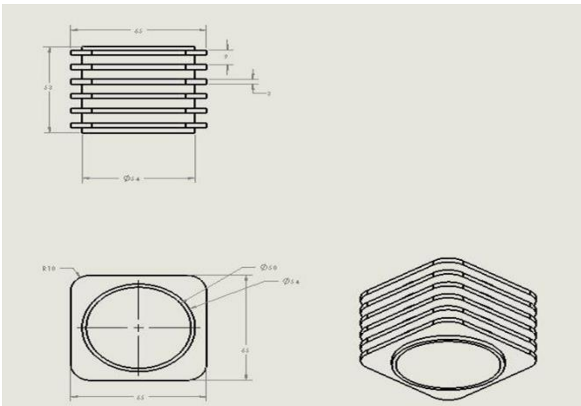

Figure.4.Engine cylinder with rectangular fins

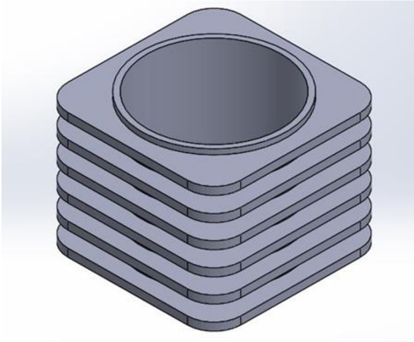

Figure.5.Cylinder fin with rectangular geometry

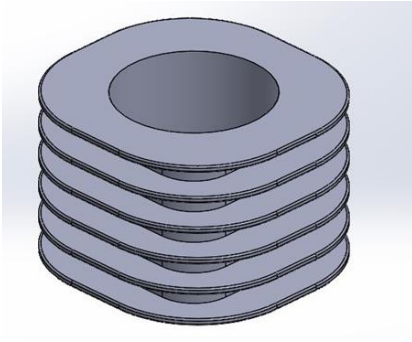

Figure.6.Cylinder fin with circular geometry

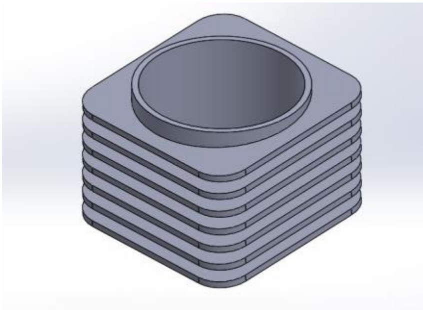

Figure.7.Cylinder fin with angular geometry

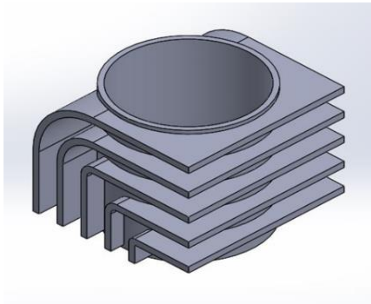

Figure.8.Cylinder fin with curved geometry

Finite Element Analysis (FEA): Finite Element Analysis uses a system of points called nodes and they make a grid called a mesh. Thismesh is programmed to cover the material and structural properties which define how the structure will react to loading conditions. Nodes are allocated at a certain density all over the material depending on the anticipated stress levels of a particular area. Created geometries were meshed carefully using FLUENT in Ansys workbench. Thermal analysis was carried out to determine the temperature and other thermal quantities and the boundary conditions were given as follows.

Model : k-ε
Inlet velocity : 30 (m/s)
Inlet temperature : 1100°C
Outer temperature : Ambient temperature (pressure outlet)

3. RESULT AND DISCUSSION

Transient heat transfer Analysis: Transient heat transfer analysis determinesthe temperature and other thermal quantities which vary over time. The deviation of temperature distribution over time is of prime interest in many applications such as with cooling of electronic components or a quenching analysis for heat treatment. Also, the temperature variation results in thermal stresses that can cause failure. In such cases the temperatures from a transient heat transfer analysis are used as input to a structural analysis for thermal stress evaluation. Heat transfer application such as heat treatment problem, electronic package design, engine blocks, nozzles, pressure vessels, fluid-structure interaction problems, and so on involving transient heat transfer analysis. In all type of applications, transient heat transfer analysis can be either linear or non-linear. Material properties such as thermal conductivity, specific heat or temperature depending convective coefficients or radiation effects can result in non-linear analyses that require an iterative procedure to achieve accurate solutions. Temperature distributions of modified engine fins with unlike metal alloys are shown in Figure.

Temperature distributions of modified engine fins with aluminium alloy 6061:

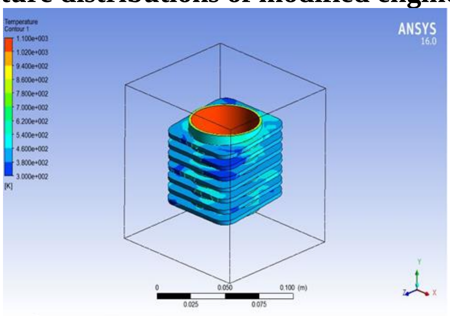

Figure.9.Temperature flow around rectangular fin

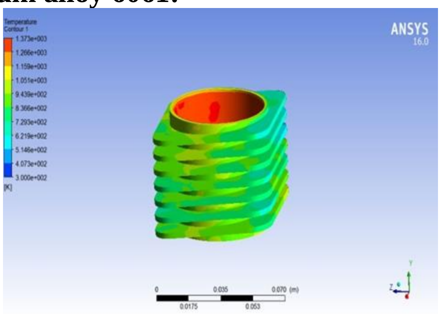

Figure.10.Temperature flow around angular fin

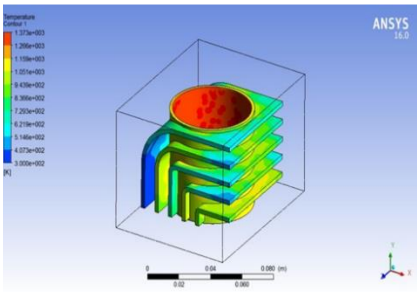

Figure.11.Temperature flow around curved fins

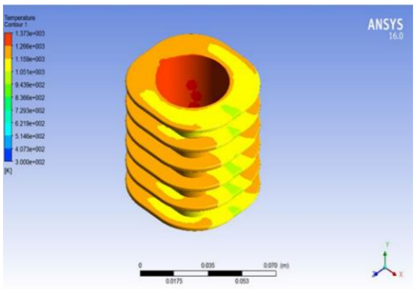

Figure.12.Temperature flow around circular fins

It is observed from the Figure 9 to 12, the circular fins showing good temperature distribution along the fin length. Also, the angular fins are showing good distribution of heat compared to that of rectangular and curved fins.

Temperature distributions of modified of engine fins with aluminium alloy 2014:

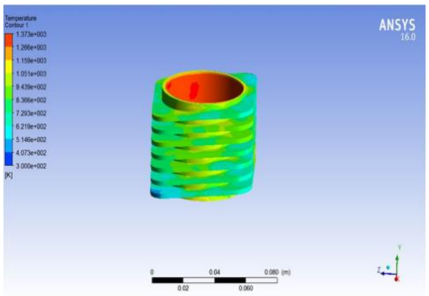

Figure.13.Temperature flow around Angular fins

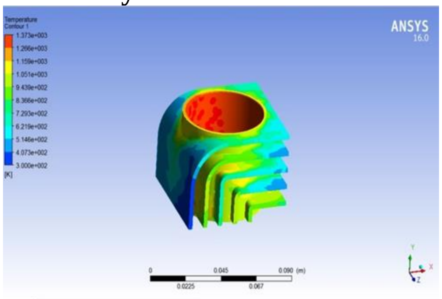

Figure.14.Temperature flow around curved fins

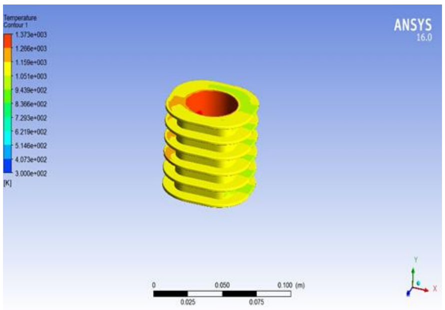

Figure.15.Temperature flow around circular fins

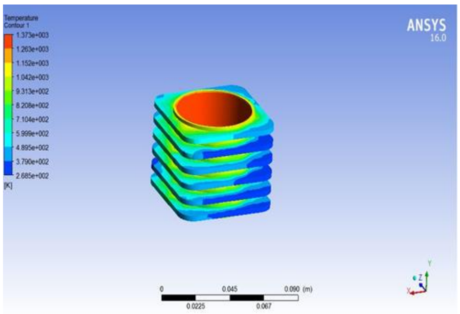

Figure.16.Temperature flow around rectangular fins

It is observed from the Figure 13 to 16, the circular fins showing good temperature variation along the fin length. Also, the angular fins are showing good distribution of heat compared to that of rectangular and curved fins.

Temperature distributions of modified of engine fins with aluminium alloy a204:

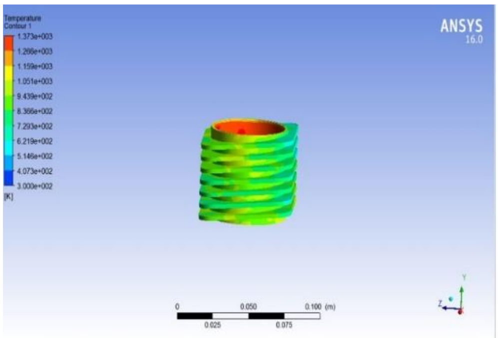

Figure.17.Temperature flow around curved fins

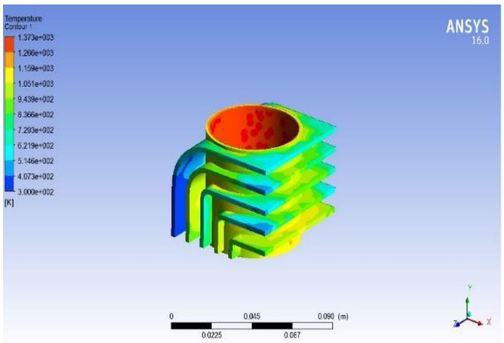

Figure.18.Temperature flow around angular fins

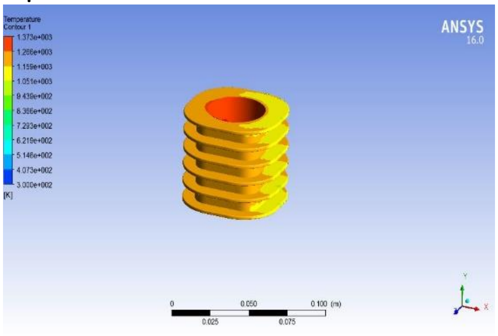

Figure.19.Temperature flow around circular fins

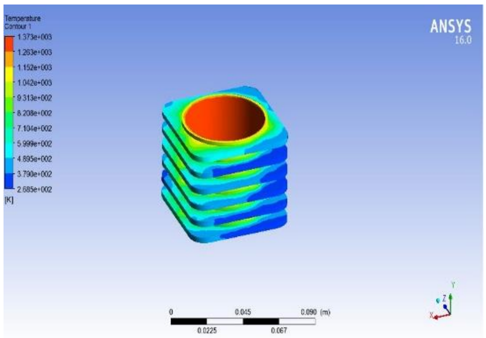

Figure.20.Temperature flow around rectangular fins

Figure17 to 20 illustrates the transient temperature distribution of engine fins with different geometries. It is noted that the circular fins are showing good temperature distribution along the length of the fins.

Temperature distributions of modified of engine fins with magnesium alloy C443:

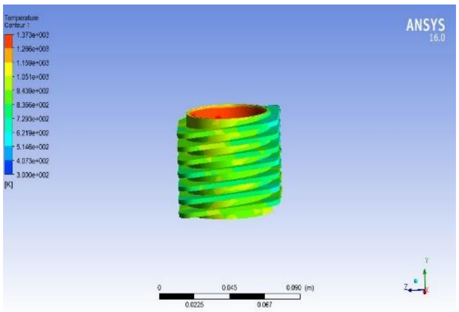

Figure.21.Temperature flow around angular fins

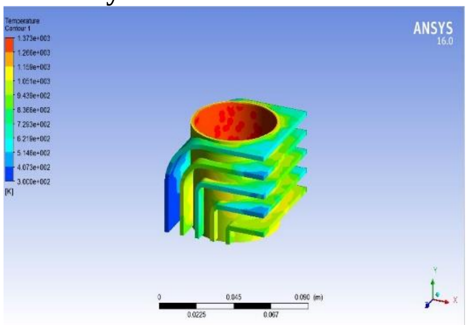

Figure.22.Temperature flow around curved f

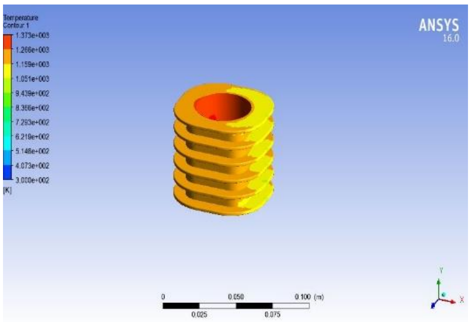

Figure.23.Temperature flow around circular fins

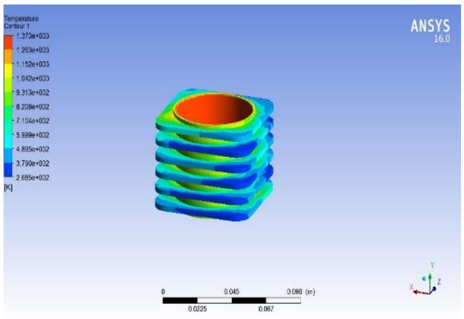

Figure.24.Temperature flow around rectangular fins

It has been observed from the Figure 21to 22, the temperature is spread throughout the area in the circular fins therefore better heat transfer rate is obtained from the circular fins.

Temperature distribution through the circular fins for different alloys: It is observed from the transient temperature analysis the circular fins showing good temperature distribution along the fin length. Figure 5illustrates the temperature distribution of circular fins with different alloys. It is seen from the figure the Aluminium Alloy 2014 showing 17 % higher temperature distribution compared to that of Aluminium Alloy 204. All the materials are showing linear distribution of temperature along the length of fins. Also, the circular fins increases the efficiency of the engine by reducing the weight of the engine.

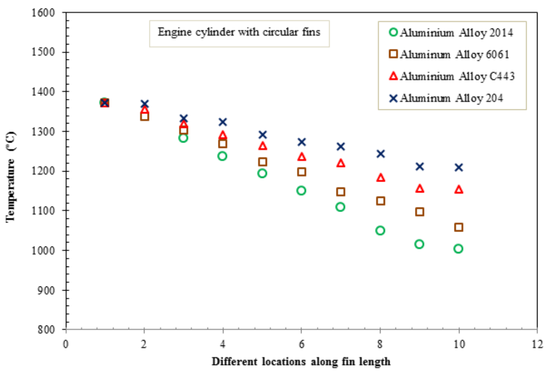

Figure.25.Distribution of temperature in circular fins for different materials

4. CONCLUSION

In this present research we have designed cylinder fin body used in 100cc motorcycle. We have replaced the engine fins with different materials such as Aluminium 6061, A2014, C443. The various geometries of fins used are angular, curved and circular instead of rectangular fins. The observations from the present research work are, Aluminium Alloy 2014 showing 17 % higher temperature distribution compared to that of Aluminium Alloy 204 due to its material composition and higher thermal conductivity. All the materials are showing linear distribution of temperature along the length of fins and the circular fins increase the efficiency of the engine by reducing the weight of the engine. Also, observed that the engine with curved fins is shown better efficiency due to its less weight.

REFERENCES

Harish P, Ramakrishna Reddy B, Optimization of Engine Cylinder Fins of Varying Geometry and Material". International Journal of Innovative Research in Advanced Engineering, 1(2), 2014.

Biermann AE and B Pinkel, Heat Transfer from finned metal cylinders in an air stream, NACA Report No.488, 1934.

Sanders JC, Cooling test of an air-cooled engine cylinder with copper fins on the barrel, NACA Report E-103, 1942.

Denpong Soodphakdee, Masud Behniaet, A Comparison of Fin Geometries for Heatsinks in Laminar Forced Convection Part 1 - Round, Elliptical, and Plate Fins in Staggered and In-Line Configurations, The International Journal of Microcircuits and Electronic Packaging, 24(1), 2001.

Fernando Illan and M Alarcon, Optimization of Annular Cylindrical and Spherical Fins in an Internal Combustion Engine under Realistic Conditions, Journal of Thermal Science and Engineering Applications 2, 2002.

Bassam A and Hijleh KA, Enhanced Forced Convection Heat Transfer from a Cylinder Using Permeable Fins, ASME Journal of Heat Transfer, 125, 2003.

Yoshida Masao, Air-Cooling Effects of Fins on a Motorcycle Engine, Nippon Kikai GakkaiRonbunshu B Hen (Transactions of the Japan Society of Mechanical Engineers Part B) (Japan), 17(9), 2005, 2324-2330.

Han-Taw C, Jui-Che C, Investigation of naturalconvection heat transfer coefficient on a vertical square fin of finned-tube heat exchangers, International Journal of Heat and Mass Transfer, 49(17-18), 2006, 3034-3044.

Mohammadi A, Analysis of local convective heat transfer in a spark ignition engine, International Communications in Heat and Mass Transfer, 35, 2008.

Kumbhar DG, Finite Element Analysis and Experimental Study of Convective Heat Transfer Augmentation from Horizontal Rectangular Fin by Triangular Perforations, Proc. of the International Conference on Advances in Mechanical Engineering, 2009.

Nagarani. N, Mayilsamy K, Experimental heat transfer analysis on annular circular and elliptical fins, International Journal of Engineering Science and Technology, 2(7), 2010, 2839-2845.

Pise AT, Awasarmo UV, Investigation of Enhancement of Natural Convection Heat Transfer from Engine Cylinder with Permeable Fins, International Journal of Mechanical Engineering & Technology, 1(1), 2010, 238-247.

Agarwa P, Heat Transfer Simulation by CFD from Fins of an Air Cooled Motorcycle Engine under Varying Climatic Conditions, Proceedings of the World Congress on Engineering, 2011.