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Design Modification and Thermal Analysis of Engine Cylinder with Fins

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Abstract

The Engine Cylinder is one of the major automobile components which is subjected to high temperature. Fins are provided on the outer surface of the cylinder, so that an air – cooled bike engine release heat to the atmosphere through the mode of forced convection. Heat transfer rate depends upon the fin geometry, velocity of vehicle and ambient temperature. Insufficient removal of heat from engine will lead to lower engine efficiency and high thermal stresses. In this paper we make four Engine Cylinders with fins of rectangular shape and concave shape two – two each. Each shape is made, one with holes in it and another without holes and thermal analysis of the four cylinders is done. Modeling software used is Creo Parametric 2.0 To make design of fins and analysis is done using software Ansys. In Ansys Workbench Steady – State Thermal analysis is chosen from Analysis System Toolbox.

Keywords: *Fin Geometry; Engine Cylinder; Heat Transfer Rate; Creo 2.0; Ansys Workbench.*

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1. Introduction

1.1 Production of Heat in IC Engine

In Internal Combustion Engine Combustion take place inside engine cylinder which produces high amount of thermal energy up to 2500˚C and additional heat is also generated by friction between moving parts. The various parts of engine may get damaged and fluid film may evaporate because of this high unbearable temperature. So we should reduce this temperature up to required working condition to protect the engine. We can't reduce temperature as we want as it may affect the efficiency of engine. Only approximately 30 % of energy is converted into useful work and remaining 70 % must be removed to protect the engine or parts of engine.

1.2 Modes of Heat Transfer

There are three modes of heat transfer, they are:

1.2.1 Conduction: Conduction is the mode of heat transfer which generally occurs in solids due to temperature difference associated with molecular lattice vibrational energy transferred and also by free electron transfer.

1.2.2 Convection: Convection is a mode of heat transfer which generally occurs between a solid surface and the surrounding fluid due to temperature difference associated with macroscopic bulk motion of the fluid transporting thermal energy. According to fluid motion there are two types of convection.

i. **Forced Convection:** In case of forced convection heat transfer, the motion of the fluid is provided by an external agency like a fan or a blower.

ii. **Free Convection:** In case of free convection heat transfer, the motion of a fluid occurs naturally due to buoyancy forces arising out of density changes of fluid because of its temperature change.

1.2.3 Radiation: Radiation is the mode of heat transfer which does not required any material medium for its propagation and hence occur by electromagnetic wave propagation travelling with the speed of light.

1.3 Governing Laws of Heat Transfer

Governing Laws of Heat transfer are:

1. Fourier's Law of Conduction.

$$q_x \propto \frac{-dT}{dx}$$

$$q_x = -KA\frac{dT}{dx} \quad Watt$$

K = Thermal Conductivity of material

$\frac{dT}{dx}$ = Temperature Gradient

2. Newton's Law of cooling.

$$q_{convection} \propto (T_w - T_\infty)$$

$$q_{convection} = hA(T_w - T_\infty) \quad Watt$$

h = Convective heat transfer coefficient or film heat transfer coefficient

3. Stefan-Boltzman Law of Radiation.

$$E_b \propto T^4 \quad (T\ in\ kelvin)$$

$$E_b = \sigma T^4 \quad \frac{Joule}{Sec - m^2} = \frac{Watt}{m^2}$$

σ = Stefan-Boltzman Constant

σ = 5.67 * 10^{-8} Watt/m^2 K^4

A fin is a kind of heat exchanger that transfer the heat generated in or by mechanical or electronics device to the surrounding fluid. When heat transfer by this fin are not sufficient to cool the device, problems arises and cause damage to the devices.

Heat Transfer rate can be increased by increasing the different parameters, they are:

1. Surface Area of the Object.
2. Convection Heat Transfer Coefficient.

2. Literature Review

S. Mayakannan, V. Jeevabharathi, D. Suresh Kumar and N. Ashok Kumar [1] studied engine fins with several different shapes with material optimization heat removal method. They compare Cylinder with concave shape, half circular shape, trapezoidal shape, convex shape, square and triangular shape fins made up of four different material AL6061, AL200, CE17 and CE17M. After the analysis they conclude that Concave is the best cross section for the fin and AL200 produce the better thermal behaviour.

Siyaram Shah and Rohit Soni [2] did CFD Transient Thermal Analysis of Cylinder fins by using different materials like Aluminium Alloy, Aluminium Alloy 6061 and Al metal matrix composition alloys (Al-MMC). They use ANSYS software for analysis. They did temperature, total heat flux and directional heat flux analysis for these three materials and they conclude that the fin which is made up of Aluminium Alloy 6061 dissipates more heat and attain maximum heat flux as compare to other materials they used.

N. Srinivasa Rao, G.V. Subhash, K. Ashok Kumar and B.N. Malleswara Rao [3] design and study the effectiveness of engine cylinder fins with variable geometry and material. In this paper the cylinder fins are made up of three materials Aluminium Alloy 204, Aluminium Alloy 6063 and Aluminium Alloy 7068. Each material is used to make fins with different shape body. Different shapes of fin body are circular fin body, rectangular fin body and trapezoidal fin body. For design of fins they used AutoCAD 2016. Thermal Analysis is done in ANSYS software and after analysis the concluded that Aluminium Alloy 6063 of circular geometry is most effective in terms of effectiveness and heat transfer rate.

Thammala Praveen and Dr. P. Sampath Rao [4] analyse thermal properties by varying Geometry, Material and Thickness of Cylinder Fins. In their paper they use a cylinder fin body for a 150cc motorcycle. Software used was Pro/Engineering and ANSYS. They use different material to make fins like Aluminium Alloy 7075, Aluminium Alloy 204, Beryllium and Magnesium. Each material is used in two different shapes of fins like rectangular and Circular. After the thermal Analysis they conclude that thermal flux is more for Beryllium and heat transfer rate can be improve by modifying the shape of the fins.

Deepak Tekhre and Jagdeesh Saini [5] they make IC engine fins with two different materials and make holes on it of different size and number. They use materials are Aluminium 6063 and Aluminium Nitride. They used two state to do analysis steady state and transient state. Four models of each material were made with no hole, 2mm hole, 6mm hole and 10mm hole. Analysis is done in ANSYS software. After the analysis they conclude that on increasing the diameter of hole the dissipated heat also gets increased and Aluminium Nitride is a better option than Aluminium Alloy 6063. Fin with holes diameter 10 mm show the best result.

3. Material Selection

Aluminium Alloy 6061 is selected for fins material and base material of fins of various configurations. The Values of Physical, Thermal and Mechanical properties of Aluminium Alloy 6061 are given in table below.

Table 3. Properties of Aluminium Alloy 6061

Physical Properties	
Density (ρ)	2700 Kg/m^3
Thermal Properties	
Specific Heat (c)	897 J/Kg-K
Thermal Conductivity (K)	167 W/m-K
Melting Temperature (T_m)	585℃
Mechanical Properties	
Young’s Modulus (E)	68.9 GPa
Tensile Strength (σ_t)	124 – 290 MPa
Poisson’s ration (v)	0.33

4. Conclusion

We make four engine cylinders with fins of rectangular shape and concave shape two–two each. Each shape is made, one with hole in it and another without hole.

Four Cylinders with Fins are as follow:

1. Cylinder with Rectangular shape Fins.
2. Cylinder with Concave shape Fins.
3. Cylinder with Rectangular shape Fins with Holes.
4. Cylinder with Concave shape Fins with Holes.

   Geometrical Dimensions of Cylindrical blocks and Fins are:

   Standard dimensions are selected for Fins and Cylinders. Some changes have been made to the dimensions according to our Thesis. Following is the considered dimensions for design:

   Cylinder Inner Diameter: 50mm

   Cylinder Outer Diameter: 53 mm

   Height of Cylinder block: 53 mm

   Thickness of Fin: 2.5 mm

Gap between Fins: 7.5 mm

Number of Fins: 5

Number of Holes: 5

Diameter of each Hole: 5 mm

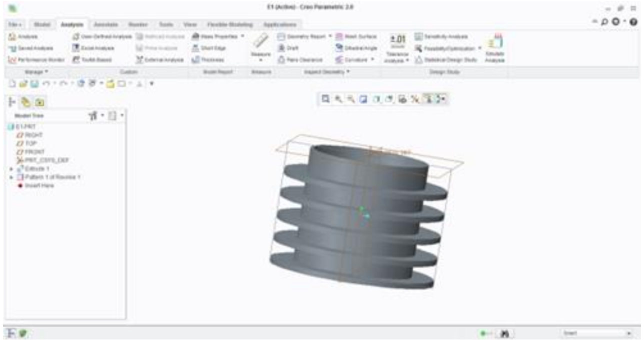

Figure 1. Design of cylinder with rectangular shape fins

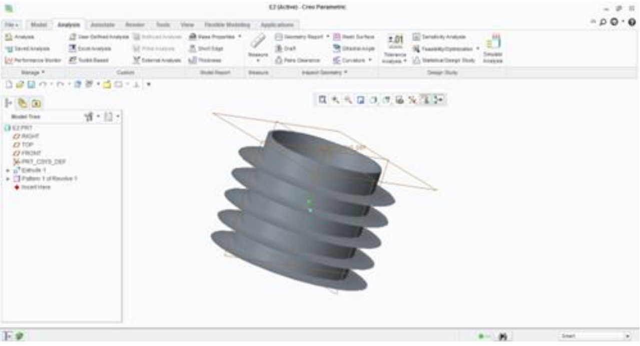

Figure 2: Design of cylinder with concave shape fins

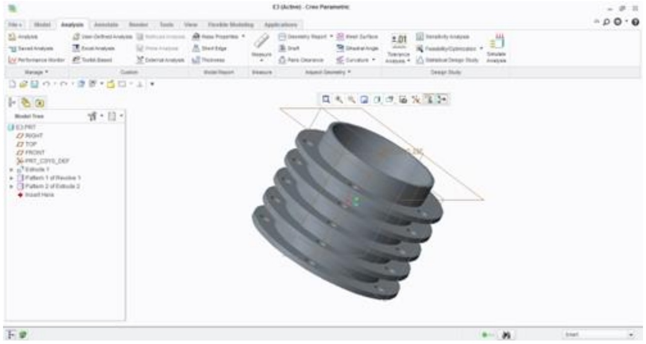

Figure 3: Design of cylinder with rectangular shape fins with holes

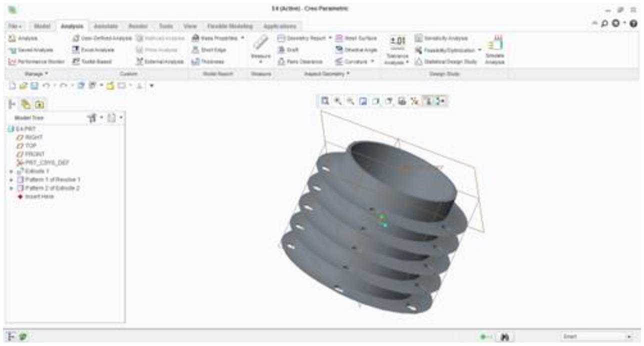

Figure 4: Design of cylinder with concave shape fins with holes

5. Analysis

After creating 3D models of four Cylinders with different fins in CREO Parametric 2.0, the next process is to analysis the design. We did this analysis in ANSYS by importing the Step-File (.stp). First, we define the material in Engineering Data by importing the properties of Aluminium Alloy 6061. Then we select Steady-State Thermal from Analysis System Toolbox. Then we define the cylinder temperature as 900˚C, ambient temperature as 30˚C and convection coefficient of heat transfer as 40 W/m^{2}°C. Then the solution is generated.

The Solution generated for Engine Cylinder with different Fins are:

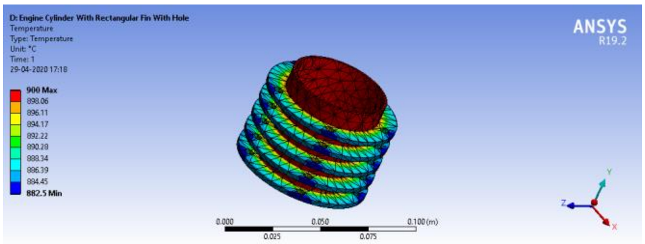

Figure 5. Temperature distribution of cylinder with rectangular shape fins with holes

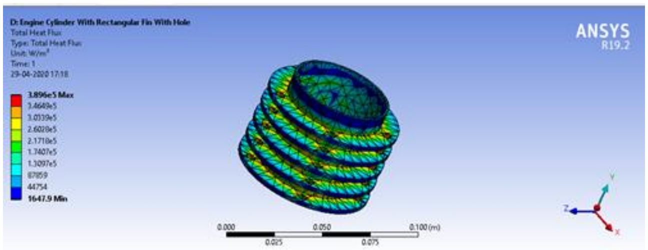

Figure 6. Heat flux of cylinder with rectangular shape fins with holes

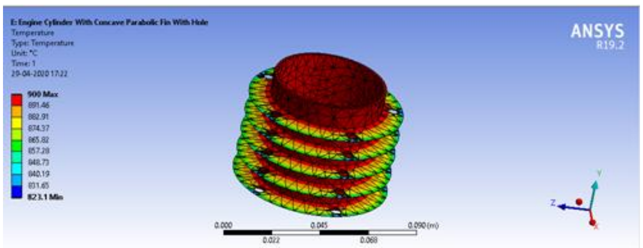

Figure 7. Temperature distribution of cylinder with concave shape fins with holes

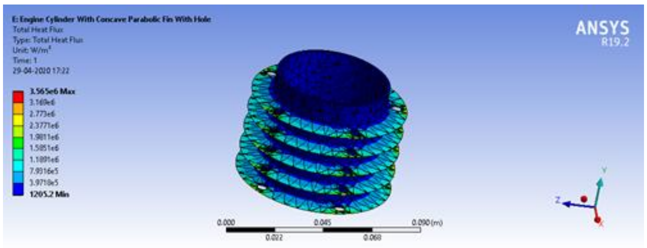

Figure 8. Heat flux of cylinder with concave shape fins with holes

6. Results

Material imported is Aluminium Alloy 6061. The analysis is done by keeping the cylinder temperature at 900˚C, ambient temperature at 30˚C and convection coefficient of heat transfer as 40 W/m^{2}˚C. Result so obtained are given below

6.1 Temperature Difference for Engine Cylinder with different fins

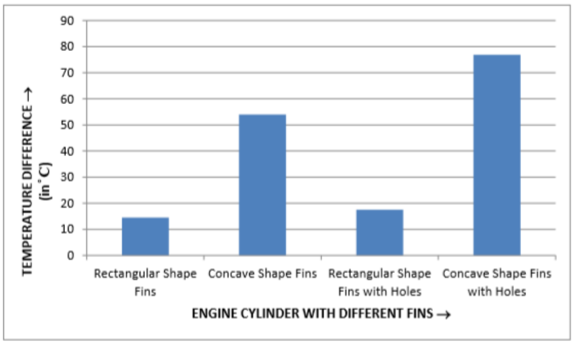

Figure 9. Graph of variation of temperature drop with varying engine cylinder fins

Table 2. Temperature difference for engine cylinder with different fins

Engine Cylinder With	**Ambient Temp (T_a)**	**Base Temp (T_b)**	**Fin Tip Temp (T_t)**	**Temp Difference (T_b - T_t)**
Rectangular Shape Fins	30	900	885.51	14.49
Concave Shape Fins	30	900	846.08	53.92
Rectangular Shape Fins with Holes	30	900	882.5	17.5
Concave Shape Fins with Holes	30	900	823.1	76.9

6.2 Total Heat Flux for Engine Cylinder with different fins

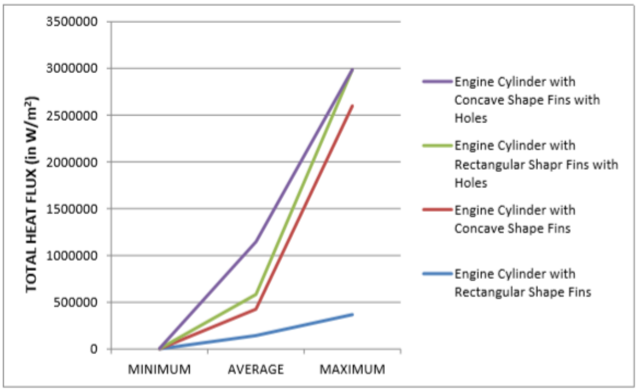

Figure 10. Graph of total heat flux for engine cylinder with different fins

Table 3. Total heat flux for engine cylinder with different fins

Engine Cylinder With	Maximum	Minimum	Average
Rectangular Shape Fins	3.6893e+005	1618.3	1.4365e+005
Concave Shape Fins	2.2309e+006	1222.3	2.8292e+005
Rectangular Shape Fins with Holes	3.896e+005	1647.9	1.5713e+005
Concave Shape Fins with Holes	3.565e+006	1205.2	5.6336e+005

7. Conclusion

- The Steady – State Thermal Analysis of Engine Cylinder with fins has been completed. The Analysis is done in ANSYS Workbench in Steady – State Thermal Analysis System.
- Designs of Engine Cylinder with fins are made in software CREO PARAMETRIC 2.0.
- By observing ANSYS result we can say concave fin is better than rectangular fin in terms of temperature drop and total heat flux.
- Implanting Holes on the fin surface increases temperature difference between the base and the tip of the fins. It also proves from ANSYS result that, hole increases temperature difference and total heat flux of the fin.
- By observing result, we can say that Engine Cylinder with Concave Shape fins with holes is better than others.

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