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THERMAL ANALYSIS OF AIR-COOLED ENGINE FINS

[1]Vedant Gore,[2]Sandeep Kore,[3] Dattatray Nalawade

[1]Student,[2]Assistance Professor,[3]Associate Professor
[1,2,3] Vishwakarma Instiyute of Information Technology,Pune

Abstract: When IC engines were introduced in this world, the main problem that arose, was to cool down the engine. Because the combustion of the air and fuel takes place at thousands of degrees Celsius. Hence it should be strong enough to withstand high temperature variations, thermal stresses and pressure forces. If the engine is not cooled properly it may lead to critical failure and damage of the engine, resulting in lower engine efficiency and high thermal stresses. This led to the invention of fins on the engine. It increases the rate of heat transfer, hence cooling down the engine. To avoid lower thermal efficiency and to get proper cooling of engine, analysis of fin is important. By performing steady state thermal analysis on the engine cylinder block, it is helpful to know the heat dissipation inside the cylinder. The main aim of the paper is to analyze the thermal properties of fins by varying geometry and thickness of cylinder fins.

Index Terms **- Heat transfer, fins, fin thickness, Steady-state heat transfer.**

I. INTRODUCTION

In air-cooled motorbike engines, fins are extended surfaces which are used to increase the heat transfer rate through convection process by transmitting the heat into the surrounding. This air-cooling mechanism is influenced by fin shape, design, surface area, thickness, material, fin-gap, number of fins. It is also dependent on the velocity of the vehicle and the ambient temperature. During the combustion stroke, tremendous amount of heat is released and this heat is transferred to the fins via conduction. Thus, fins get hoter. Now, the air moving above these fins gets heated via convection. Since, the surrounding air keeps on moving, these hot air molecules are replaced by the new air molecules, and they also carry heat generated. This is how convection occurs in air-cooled engine. The conduction heat transfer from inner wall to fin surface is given as:

$$q = k^*(T_b - T_{fin}) \text{ W/m}^2 \quad (1)$$

The convection heat transfer from fin surface to atmosphere air by free and forced air is given as:

$$q = h^*(T_b - T_{air}) \text{ W/m}^2 \quad (2)$$

q =Heat transfer rate (W/m^2)
A = Exposed surface area (m^2)
k = Conductive heat transfer coefficient (W/m K)
T_b = Boundary temperature (°C)
T_{fin} = Fin temperature (°C)
h = Convective heat transfer coefficient (W/m^2 K)

Internal combustion engines can transform 25 to 35 percentage of the chemical energy in the fuel into mechanical energy. About 35 percentage of the heat generated is lost to the surroundings of combustion space, remainder being dissipated through exhaust and radiation from the engine. The temperature of the burning gases in the engine cylinder is about thousands of degrees Celsius. Hence, the temperature of the fins through conduction is approximately 200-300 °C. In this paper, we have discussed the effect of cooling of internal combustion engine cylinder block in free air by varying the thickness and material of the fins using ANSYS Steady-state thermal workbench.

II. LITERATURE REVIEW

Mohsin A. Ali et al. [1]In this paper they studied various research done in past to improve heat transfer rate of cooling fins by changing cylinder block fin geometry and climate condition.

Mr. Atul Chandanshive et al.[2]studied the thermal analysis was performed on the CAD model of Hero Honda Splendor cylinder block by providing slots, reducing fin thickness and increasing the number of fins. Experimental setup was done to get the approximate temperature generated within the cylinder block and to take reading of the temperature distribution over the fins.

Mahendra Kumar Ahirwar et al. [3] investigated transient thermal analysis for actual and proposed design of engine cylinder in order to optimize its fin design parameters.

Deepak Tekhre et al.[4]in their work of optimizing the fins of stock 150cc Honda Unicorn engine by providing holes of different diameters and using the materials like Al 6063 and AlN (Aluminium Nitride).

T R Chinnusamy et al. [5], focuses primarily on the design optimization of fins by changing its geometrical parameters such as fin thickness. They have performed the simulation on ANSYS Fluent and obtained the results on velocity distribution, temperature distribution, total heat flux and directional heat flux**.**

Nandipam Prudhvi raj et al. [6], modeled the cylinder block of Honda Shine and Bajaj Discover bikes and performed analysis on ANSYS by using the fin material as Al 2024 and gray cast iron. Calculations for peak temperature produced in the engine cylinder have also been performed. They have also varied the fin thickness and added perforations to the fins to analyze its effects on heat transfer rate.

K. Sathishkumar et al. [7]In this paper their goal was to increase the heat transfer rate by adding holes and notches to the fins and analyzing them in ANSYS and comparing the results. Apart from this, calculations have been done to calculate the heat transfer rate of the different fins.

Chidiebere Okeke-Richard et al. [8]carried **t**hermal analysis of engine cylinder block of Honda, TVS and Yamaha by varying the surrounding temperature and it was concluded that surrounding temperature has a significant impact on the heat transfer from fins.

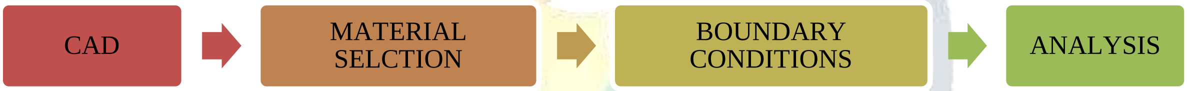
A.C.Deshpande et al. [9] tested fins of Honda Shine and Bajaj Discover two wheeler automotives to investigate effect on heat transfer rate by changing the Cross-section, Fin Pitch, Fin Material and Fin Thickness. Heat dissipated, heat flux through fin and fin surface temperature is calculated using empirical formulations, analytically and experimentally.

Siyaram Shah et al.[10] studied the effect of different materials on the heat transfer of fins and performed transient thermal analysis. Different materials used were Aluminium alloy, Al 6061 and Al-MMC (Aluminium metal matrix composition). It was concluded that Al 6061 has a better heat transfer rate as compared to the other materials.

Manir Alam et al. [11] analyzed the engine cylinder block fins with changing the fin gap, thickness, geometry and material as well.

III. RESEARCH METHODOLOGY:

In the present analysis the fin with 2.5 mm and 5 mm thickness is analyzed with aluminum and gray cast iron material. The modeling ,meshing and simulation is done in Solidwork. The results are presented in the form heat flux. The Fig. 1.1 and 1.2 shows the geometry created in CAD for 2.5 mm and 5 mm thickness.



1. CAD Design:

Solid Works is a solid modelling software that allows you to design products in 3 dimensions.. The following cylinder block is modeled and assembled in SolidWorks 2020 software.

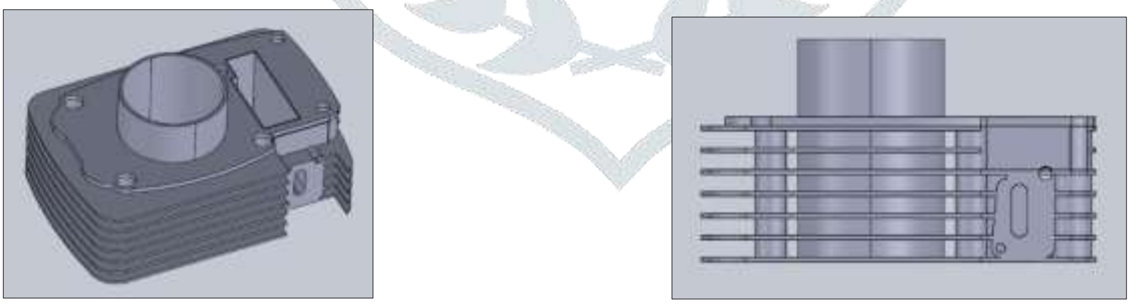


Fig 1.1: Engine cylinder block with 2.5 mm fin thickness

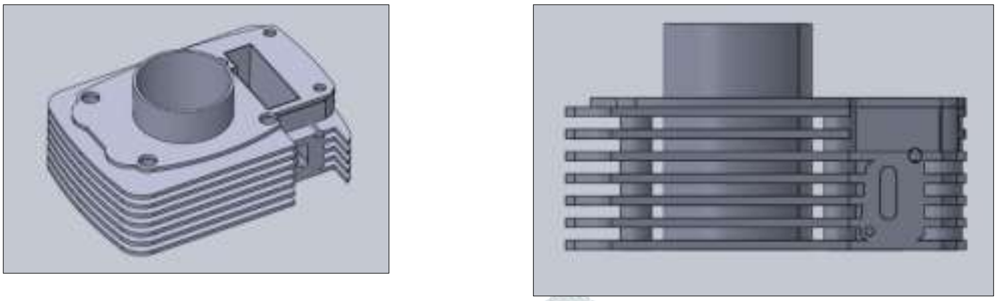


Fig 1.2: Engine cylinder block with 5 mm fin thickness

a. **Aluminium:** The simulation is carried out with aluminium as a block material. The properties of aluminium of the aluminium used for the simulation is as per Table 1.2. Fig.1.3 shows variation of conductivity with temperature. Fig.1.3 shows variation of coefficient of thermal expansion with temperature.

Table 1.1: Al 6061 Material Properties

Material properties	
Thermal Conductivity (W/m^2-K)	200
Specific Heat (J/kg-K)	896
Density (kg/m^3)	2700
Melting Point (K)	923

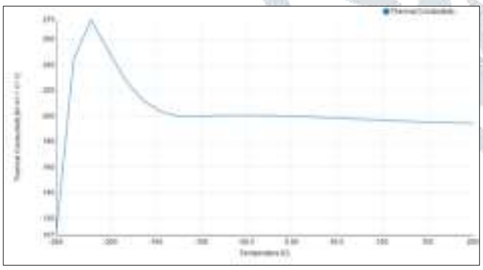


Fig 1.3: Isotropic Thermal Conductivity

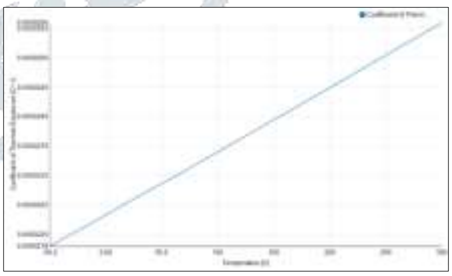


Fig 1.4: Coefficient of Thermal Expansion

Most of the engine cylinder blocks have Aluminium alloy fins. This is because aluminium is lighter in weight and even its thermal conductivity is higher. It has excellent corrosion resistance; good machinability and it possess good strength and ductility as well. Hence, it provides a greater heat transfer rate as compared to other metals or alloys.

b. **Gray Cast Iron –**

Engine cylinder is made up of gray cast iron to sustain high temperatures, forces, pressure and thermal stresses and strains. It has relatively low cost, good machinability, good vibration/damping capability, excellent compressive strength and ability to withstand thermal cycling. Therefore, it makes a suitable material to be used for manufacturing engine cylinders. The properties of gray cast iron are given in Table 1.2.

Table 1.2: Gray Cast Iron Material Properties

Material properties	
Thermal Conductivity (W/m²-K)	52
Specific Heat (J/kg-K)	447
Density (kg/m³)	7200
Melting Point (K)	1533.15

2. **Boundary Conditions:**

The boundary conditions used for the analysis are as under.

a. Ambient/initial/surrounding air temperature is considered to be 30°C.

b. Since, 35% of the total heat generated is transferred to the fins and other parts via conduction. The temperature at the inner wall of the cylinder is considered to be 200°C.

c. Convection film coefficient for ambient air is considered to be 10 W/m² °C and all the surfaces exposed to the surroundings are selected for convection boundary.

Hence, considering these boundary conditions, steady-state thermal analysis is performed in ANSYS 2019R1 workbench.

a. Meshing:

The meshing is carried out in Ansys with hexahedral mesh. Fig.1.5 and 1.6 shows the mesh created in Ansys.

Mesh size is kept constant for both 2.5 mm and 5 mm fin cylinder block.

Mesh size = 5 mm

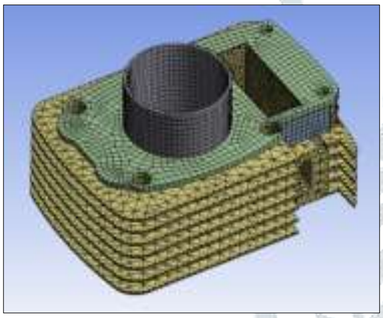
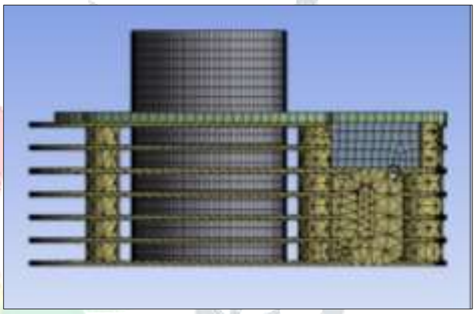



Fig. 1.5: Meshing of 2.5 mm fin cylinder block

Number of nodes = 93089

Number of elements = 37115

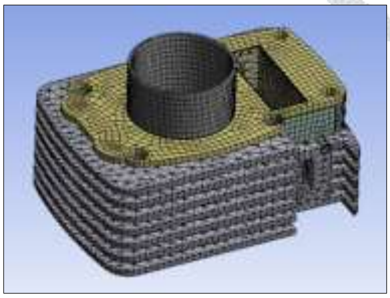
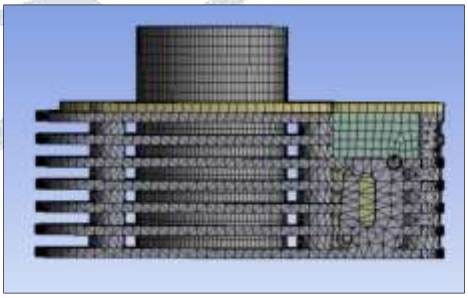



Fig. 1.6: Meshing of 5 mm fin cylinder block

Number of nodes = 89600

Number of elements = 34539

Material properties	
Thermal Conductivity (W/m²-K)	52
Specific Heat (J/kg-K)	447
Density (kg/m³)	7200
Melting Point (K)	1533.15

Results:

The analysis is carried out at three different temperatures 200º C,250º C and 300º C as per different operating conditions of engines. The convective heat transfer coefficient of surrounding air is kept constant which is 10 W/m^2 °C. The results are presented in the form of temperature and heat flux contours. Fig. 1.7 to 1.18 shows contours for temperature and heat flux for 2.5 mm and 5 mm thickness fin for three different temperatures.

At **T = 200.00 °C**

i. 2.5 mm fin cylinder block –

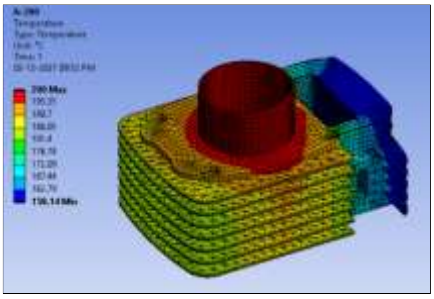


Fig 1.7: Temperature distribution

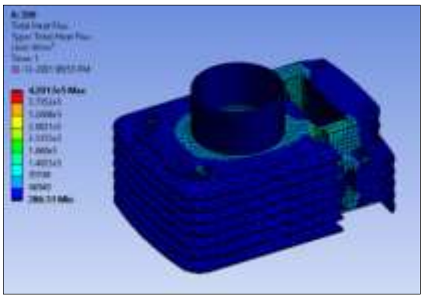


Fig 1.8: Total heat flux distribution

Max. Temperature = 200.00 °C
Min. Temperature = 158.14 °C
Max. Heat flux distribution = 4.2017e+05 W/m^2
Min. Heat Flux Distribution = 286.5100 W/m^2
Temperature of the fin around the cylinder is found to be in the range of 180 - 190 °C.

ii. 5 mm fin cylinder block –

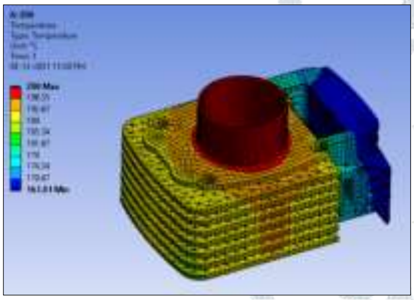


Fig 1.9: Temperature distribution

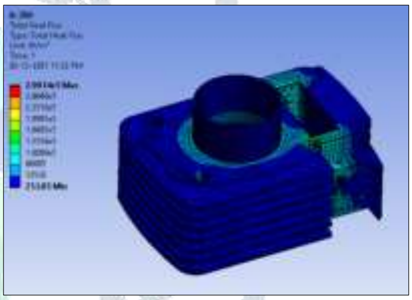


Fig 1.10: Total heat flux

Max. Temperature = 200.00 °C
Min. Temperature = 167.01 °C
Max. Heat flux distribution = 2.9974e+05 W/m^2
Min. Heat Flux Distribution = 253.8500 W/m^2
Temperature of the fin around the cylinder is found to be in the range of 189 - 196 °C

At **T = 250.00 °C**

iii. 2.5 mm fin cylinder block –

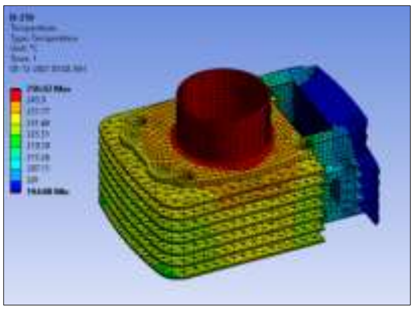


Fig 1.11: Temperature distribution

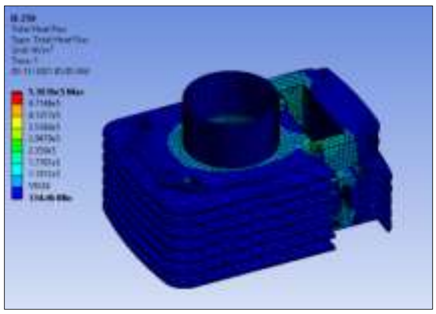


Fig 1.12: Total heat flux

Max. Temperature = 250.00 °C
Min. Temperature = 194.88 °C
Max. Heat flux distribution = 5.3036e+005 W/m^2
Min. Heat Flux Distribution = 334.4600 W/m^2
Temperature of the fin around the cylinder is found to be in the range of 225 - 237 °C.

iv. 5 mm fin cylinder block –

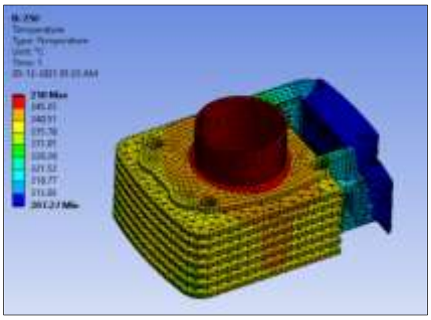


Fig. 1.13: Temperature distribution

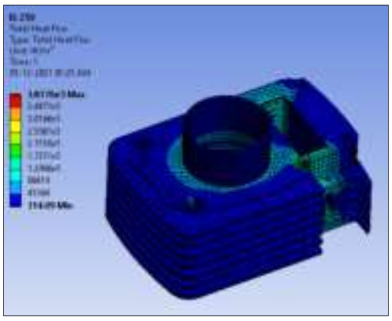


Fig. 1.14: Total heat flux

Max. Temperature = 250.00 °C
Min. Temperature = 207.27 °C
Max. Heat flux distribution = 3.8776e+005 W/m²
Min. Heat Flux Distribution = 314.0900 W/m²
Temperature of the fin around the cylinder is found to be in the range of 235 - 245 °C.

At **T = 300.00 °C**

v. 2.5 mm fin cylinder block –

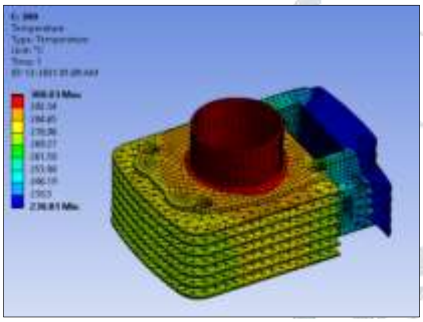


Fig 1.15: Temperature distribution

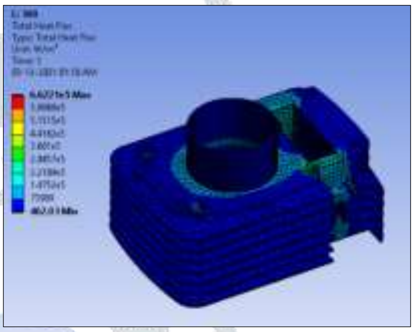


Fig 1.16: Total heat flux distribution

Max. Temperature = 300.00 °C
Min. Temperature = 230.81 °C
Max. Heat flux distribution = 6.6221e+005 W/m²
Min. Heat Flux Distribution = 462.03 W/m²
Temperature of the fin around the cylinder is found to be in the range of 269 - 284 °C.

vi. 5 mm fin cylinder block –

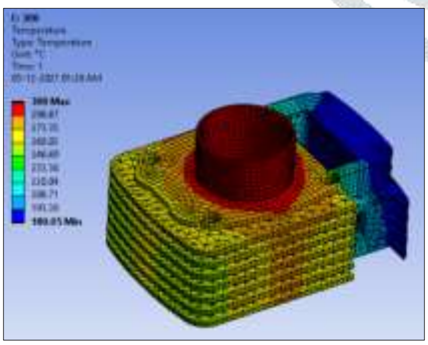


Fig 1.17: Temperature distribution

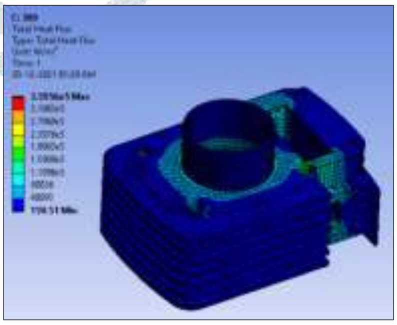


Fig 1.18: Total heat flux distribution

Max. Temperature = 300.00 °C
Min. Temperature = 180.05 °C
Max. Heat flux distribution = 3.5956e+005 W/m²
Min. Heat Flux Distribution = 159.51 W/m²
Temperature of the fin around the cylinder is found to be in the range of 246 - 273 °C

IV. CONCLUSION

Comparing the above obtained FEA results, the lowest obtained temperature for 2.5 mm fin cylinder block is 158 °C and that for 5 mm fin cylinder block is 167 °C. This shows that, as we increase the fin thickness the heat transfer rate of fins decreases because the fin gap is decreasing; which certainly means that the mass of air in that region becomes less. And we know that, lesser the number of air molecules, lesser will be their heat carrying capacity. Hence, as the fin gap decreases or fin thickness increases the heat transfer rate of fins decreases. From this we establish that, the fin thickness should be small.

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