Heat Transfer Analysis of Engine Cylinder Block with Different Material Alloys

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Abstract- **In the heat engine if heat is not dissipated properly then it causes to development of detonation and it finally decreases the working efficiency of the engine, hence the heat removal rate from the cylinder is one of the important and interesting task and prime considerations for the selection of material for cylinder block and fins.**

In this paper an attempt has been made to find out the best material in respect of finest heat transfer rate through it for cooling as primary consideration, Safe working of Engine, High strength , Light in weight and also Lower Cost that is used for cylinder block.

The objective of the present work is

"To find out the best suitable material among the eight selected alloys for the application of Engine cylinder block used for Vespa Scooters on the basis of various parameters i.e Heat dissipation capability, strength, economy etc."

For the analysis Finite Element Method has been employed using Ansys Software as a Simulation tool.

Index Terms- **heat transfer rate, finite element methods, piston, cylinder head etc.**

I. INTRODUCTION

1.1 General

The Internal Combustion Engine (ICE) has been a part of society since the early 19th century. Although the fuel was different (petroleum was not commercially produced until the 1850s) the concept was the same. The first combustion engines were mainly used in industrial applications, but were later introduced into vehicles now capable of moving by themselves. The first modern car was designed and produced by Karl Benz in 1885, it was called the Motorwagen and ≈ 25 of them were sold between 1888 and 1893. In the following years more and more car manufacturers entered the market and started building, designing, and selling cars. The first car produced in an affordable way was Ransom Olds Oldsmobile in 1902. [1]

An engine is a device that converts thermal energy into mechanical work. The thermal energy is created by the combustion of air fuel blend inside the cylinder by methods for a start delivered by the start plug. Since it utilizes thermal energy it is called as thermal engines. It is a wellspring of energy for some applications.[3,4]

The cylinder head closes one side of the cylinder. They are normally given a role as a solitary piece and are rushed to the highest point of the cylinder. Between the cylinder and the cylinder head, gasket is given Gasket is given with a specific end goal to go about as fixing (to prevent gases escaping during the expansion stroke) and furthermore to decrease stun. [5,6]

II- LITERATURE REVIEW

The previous study by the researchers are as:

"Thermal Analysis of cylinder block with fins for different materials using ANSYS", 2016, Obula Reddy Kummitha, B.V.R. Reddy, Materials Today: Proceedings 4 (2017) 8142–8148

In this paper an attempt has been made to find out the thermal analysis of cylinder block with fins for different materials by using ANSYS, and the results has been analyzed to find out the best material that gives the better heat transfer rate and consists of light weight.

"Thermal Analysis of Engine Cylinder having thick tip fin with varying slot sizes and material", 2017, Divyank Dubey, Dinesh Singh, Abhishek yadav, Satyajeet pal,Harishchandra Thakur, Materials Today: Proceedings 4 (2017) 7636–7642

In this examination work authors utilized Bajaj Caliber thus he can rechecked the outcome with past research comes about. It was contrasting its execution and others come about by utilizing distinctive material, for example, Aluminum Alloy 6061, Aluminum Alloy C443 and Aluminum Alloy 2014 which having higher thermal conductivities. Consequence of these different examination demonstrates that the engine utilizing Aluminum 2014 keeping the space width 75mm have high thermal heat dissemination rate as others openings width of others materials.

"Effect of solution heat treatment on residual stress in Al alloy engine blocks using neutron diffraction", 2017, A. Lombardi, D. Sediako, A. Machin, C. Ravindran, R. MacKay, Materials Science & Engineering A 697 (2017) 238–247

A heating system, consisting of coiled tubular heaters in the cylinder bores and strip heaters along the front and side faces of the engine block, was designed and built to heat the blocks to the solution temperatures The results indicated that solutionizing at 470 °C caused a gradual relief of tensile residual strain up to approximately 5 h, where strain was completely relieved. At 500 °C, the strain relieved more rapidly, which resulted in complete relief in under 0.5 h.

"Design, Analysis and Optimization of Four Stroke S.I. Engine Piston using Finite Element Analysis in ANSYS software", 2016, Ankit Kumar Pandey, Prof. Sandeep Jain, Dr. Lokesh Bajpai, International Journal of Advance Engineering and Research Development Volume 3, Issue 9, September -2016

The aim of this paper is to design, analysis and optimization of four stroke S.I. engine piston, which is strong and lightweight using finite element analysis with the help of ANSYS Software.

III - RESEARCH METHODOLOGY

3.1 Finite-Element Analysis

Mechanical components as simple bars, beams, and so on., can be examined easily by basic methods of mechanics that give closed-frame solutions. Genuine com-ponents, be that as it may, are once in a while so simple, and the designer is compelled to less powerful approximations of closed-frame solutions, experimentation, or numerical methods.

3.2 CFD Principles

The plain idea of CFD is to divide a great composite flow in smaller simpler flows, and to define them with practicable mathematical expressions.

3.3 Geometry Modeling

The existed Vespa scooter cylinder block was considered for the study of thermal analysis. This model was generated with the help of AutoCAD modeling package as shown in Figure 3.1 and 3.2.

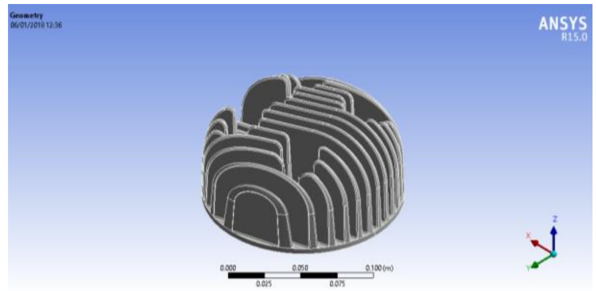

Figure 3.1 Geometry of Vespa Scooter Cylinder block

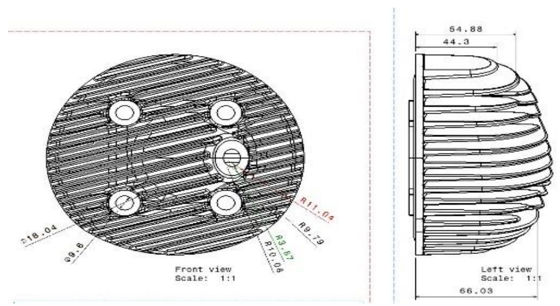

Figure 3.2 (a) Side View and Front View of the Drawing

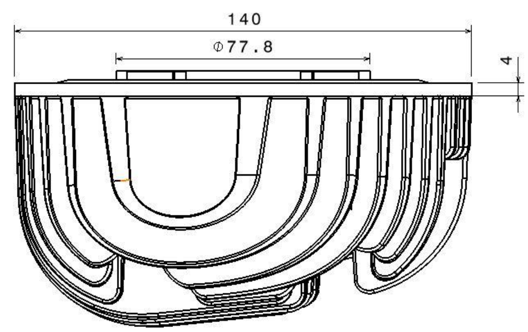

Figure 3.2 (b) Top View of the Drawing

Figure 3.2 AutoCAD generated drawing of Cylinder block

Table 3.1 Properties of Cylinder Block

Property	Value
Volume	4.0093×10^{-4} m^3

3.4 Mesh Generation

The system of components and hubs that discretize a region is alluded to as a work The work density increments as more components are set inside a given region.

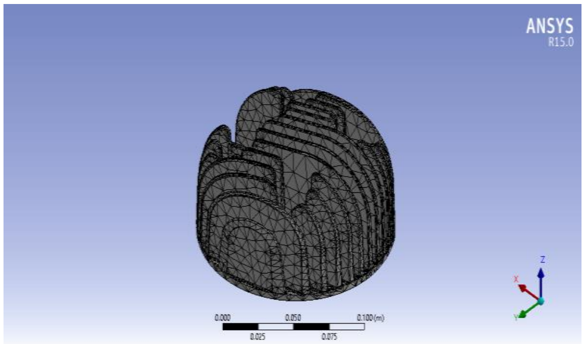

Figure 3.3 Generated Mesh.

3.5 Boundary Conditions

Figure 3.4 demonstrates the boundary conditions connected for the investigation.

The thermal boundary conditions are time-invariant, i.e. the heat fluxes are not cycle settled due to the thermal inactivity of the solid segments.

Boundary conditions were given as far as temperature as takes after,

Maximum temperature = 900 ˚C

Temperature load boundary condition has been given to within surface territory of the chamber and convection heat exchange boundary condition was considered for the interminable surface of barrel with blades.

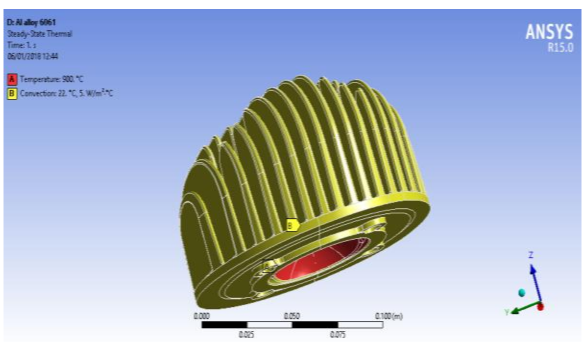

Figure 3.4 Boundary Condition

3.6 Material Selection for the Study

Thermal analysis of cylinder block was analyzed with ANSYS software. In these simulations different alloys has been considered by taking the conductivity, density and specific heat as major material properties for thermal analysis. Materials that are used for present analysis are aluminium, Magnesium and cast iron alloys. The properties of these materials are given in table 3.2.

Table 3.2 Properties of material used for the study [Obula Reddy Kummitha, B.V.R. Reddy]

Material	Tensile strength (Mpa)	youngs moduls (Gpa)	density (kg/m^3)	specific heat (j/kg.k)	thermal conducivity (W/m.k)
A356	234	48	2670	963	151
A360	303	71	2630	963	113
A380	324	75	2760	963	109
Al metal matrix alloys (Al-MMC)	345	80	2760	963	109
Mg Alloy	230	45	1810	1050	72
Aluminium Alloy 6061	310	73	2700	1256	167
Grey Cast Iron	255	54	7200	45	46
Structural Steel	250	46	7850	434	60.5

IV - RESEALT ANALYSIS

The Finite element analysis using Ansys software has been carried out for the study. The analysis is carried out using Steady state Thermal analysis work bench for comparing the different materials for the cylinder block application.

The results obtained are as:

4.1 Temperature Distribution

Figure 4.1 to 4.8 shows the Temperature distribution contour for all the 8 materials respectively.

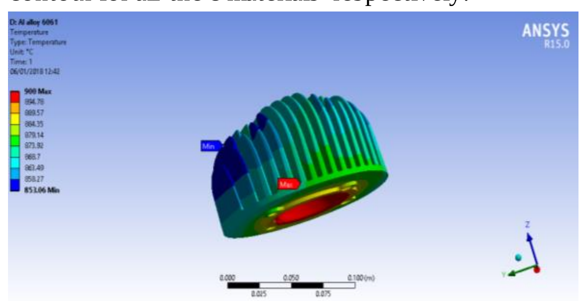

Figure 4.1 Temperature Distribution for Al Alloy 6061

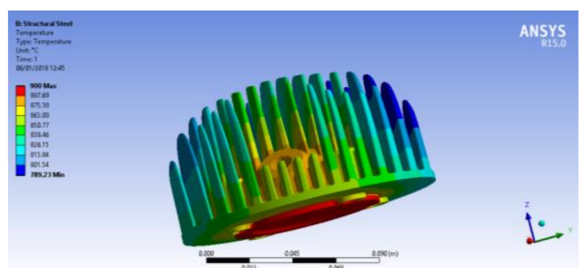

Figure 4.2 Temperature Distribution for Structural Steel

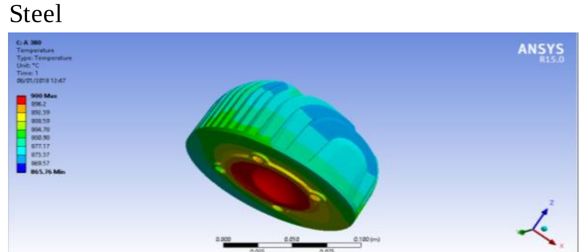

Figure 4.3 Temperature Distribution for A 380

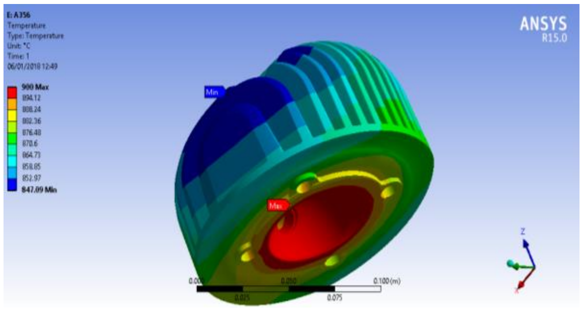

Figure 4.4 Temperature Distribution for A 356

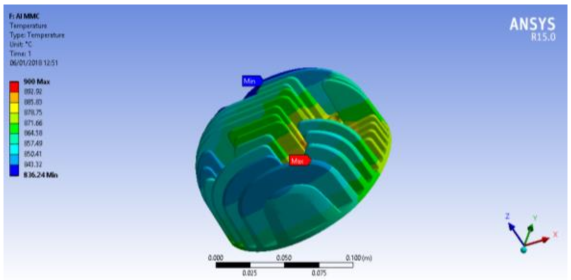

Figure 4.5 Temperature Distribution for Al metal matrix alloys (Al-MMC)

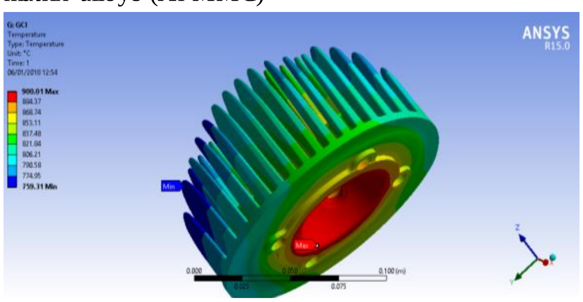

Figure 4.6 Temperature Distribution for Grey Cast Iron

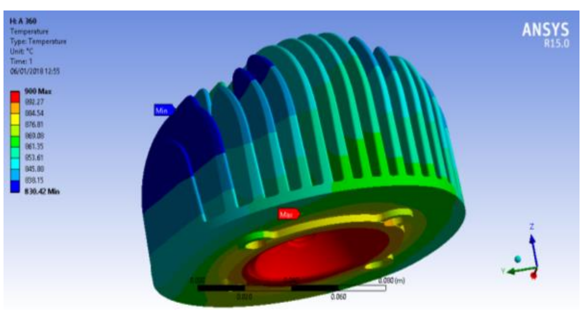

Figure 4.7 Temperature Distribution for A360

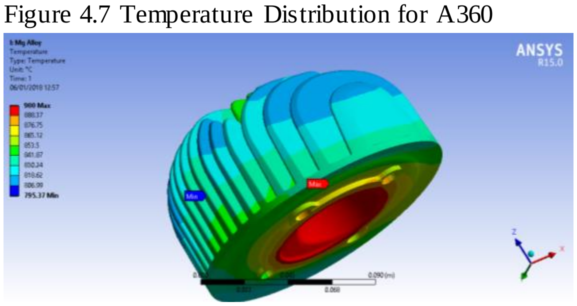

Figure 4.8 Temperature Distribution for Mg Alloy

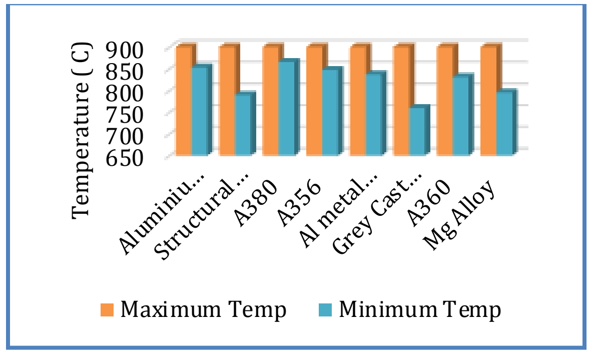

Figure 4.9 Comparison of materials on the basis of minimum temperature achieved

Table 4.1 Temperature Distribution for Different Materials

Material	Maximum Temp	Minimum Temp	Difference
Aluminium Alloy 6061	900	853.06	46.94
Structural Steel	900	789.23	110.77
A380	900	865.76	34.24
A356	900	847.09	52.91
Al metal matrix alloys (Al-MMC)	900	836.24	63.76
Grey Cast Iron	900	759.31	140.69
A360	900	830.42	69.58
Mg Alloy	900	795.37	104.63

4.2 Total Heat Flux Distribution

Figure 4.10 to 4.17 shows the Total Heat Flux distribution contour for all the 8 materials respectively.

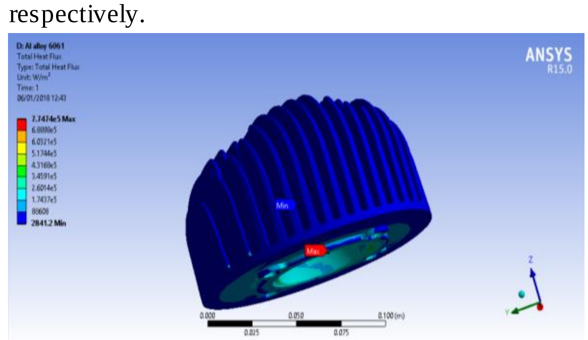

Figure 4.10 Total Heat Flux Distribution for Al Alloy 6061

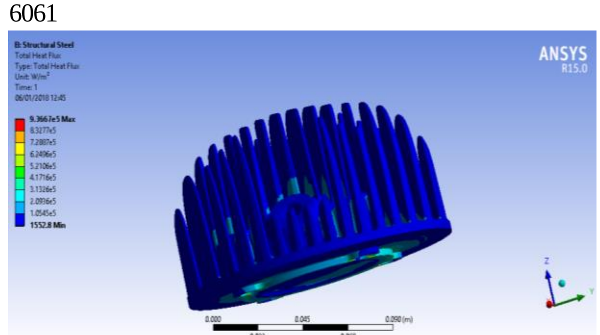

Figure 4.11 Total Heat Flux Distribution for Structural Steel

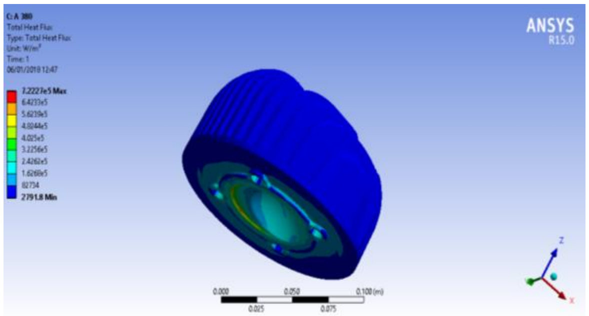

Figure 4.12 Total Heat Flux Distribution for A 380

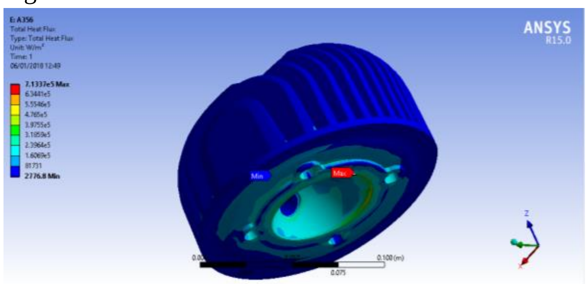

Figure 4.13 Total Heat Flux Distribution for A 356

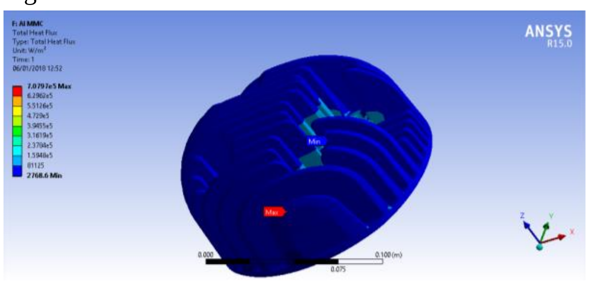

Figure 4.14 Total Heat Flux Distribution Al metal matrix alloys (Al-MMC)

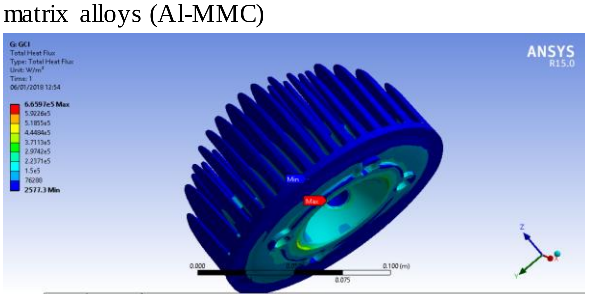

Figure 4.15 Total Heat Flux Distribution for Grey Cast Iron

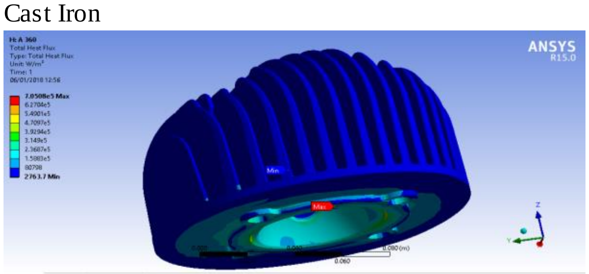

Figure 4.16 Total Heat Flux Distribution for A 360

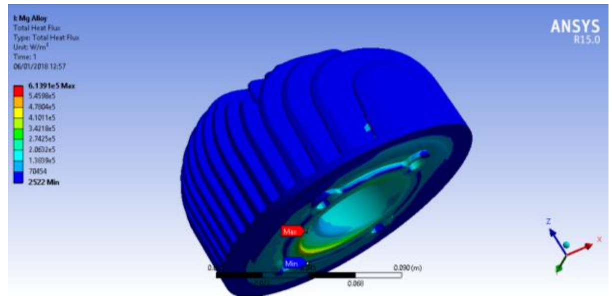

Figure 4.17 Total Heat Flux Distribution for Mg Alloy

Table 4.2 Total Heat Flux for Distribution for All The Materials

Material	Total Heat Flux
Aluminium Alloy 6061	7.147×10^5
Structural Steel	6.397×10^5
A380	7.223×10^5
A356	7.134×10^5
Al metal matrix alloys (Al-MMC)	7.080×10^5
Grey Cast Iron	6.660×10^5
A360	7.051×10^5
Mg Alloy	6.139×10^5

4.3 Directional Heat Flux Distribution

Figure 4.19 to 4.42 shows the Directional Heat Flux distribution contour for all the 8 materials for all the three axis x, y and z respectively

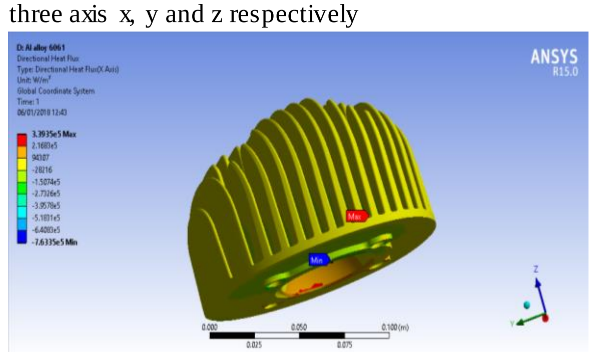

Figure 4.19 Directional Heat Flux Distribution (x axis) for Al Alloy 6061

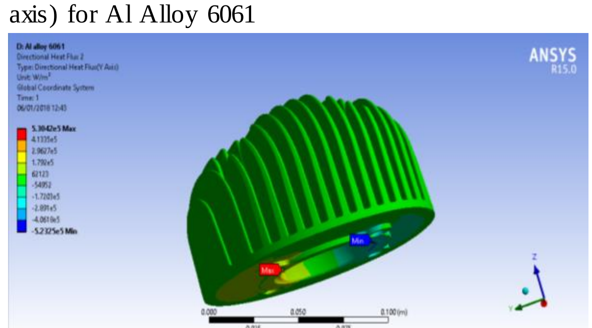

Figure 4.20 Directional Heat Flux Distribution (y axis) for Al Alloy 6061

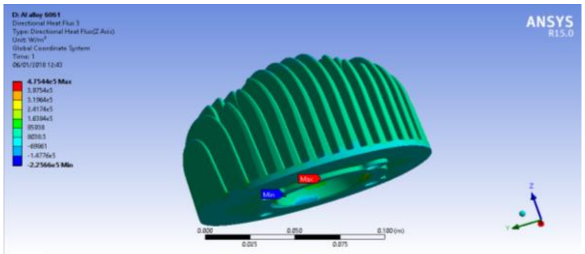

Figure 4.21 Directional Heat Flux Distribution (z axis) for Al Alloy 6061

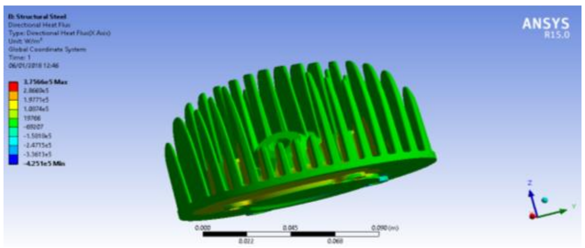

Figure 4.22 Directional Heat Flux Distribution (x axis) for Structural Steel

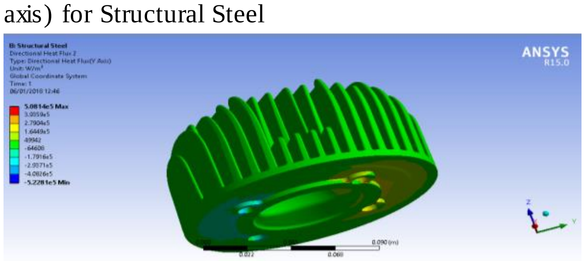

Figure 4.23 Directional Heat Flux Distribution (y axis) for Structural Steel

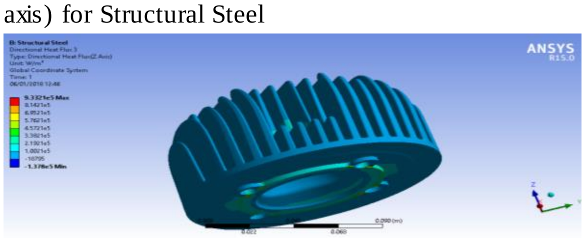

Figure 4.24 Directional Heat Flux Distribution (z axis) for Structural Steel

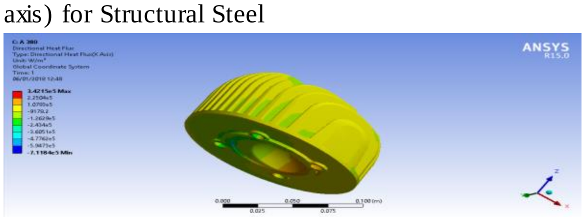

Figure 4.25 Directional Heat Flux Distribution (x axis) for A 380

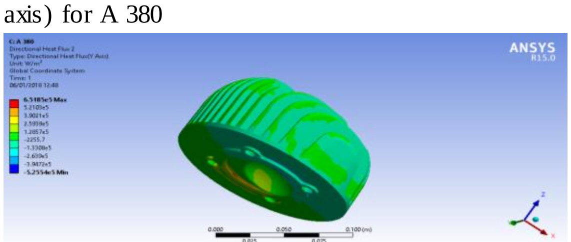

Figure 4.26 Directional Heat Flux Distribution (y axis) for A 380

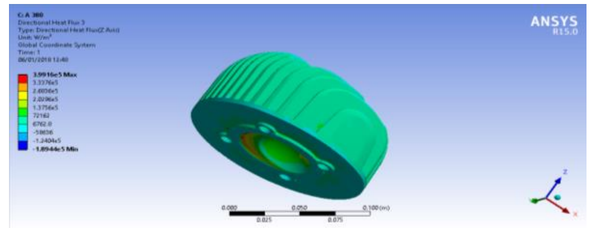

Figure 4.27 Directional Heat Flux Distribution (z axis) for A 380

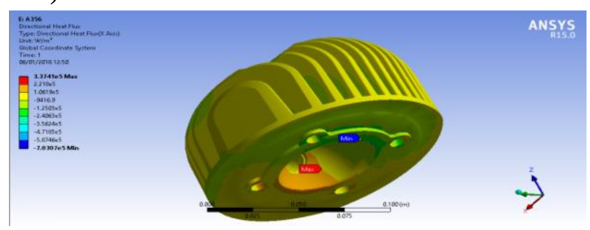

Figure 4.28 Directional Heat Flux Distribution (x axis) for A 356

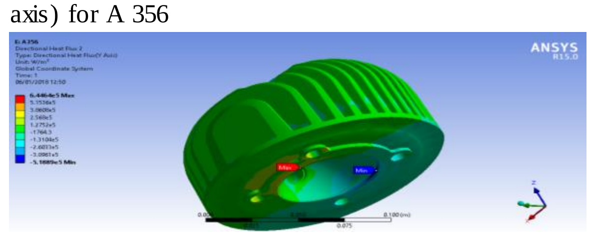

Figure 4.29 Directional Heat Flux Distribution (y axis) for A 356

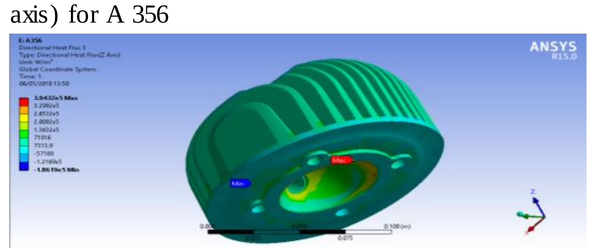

Figure 4.30 Directional Heat Flux Distribution (z axis) for A 356

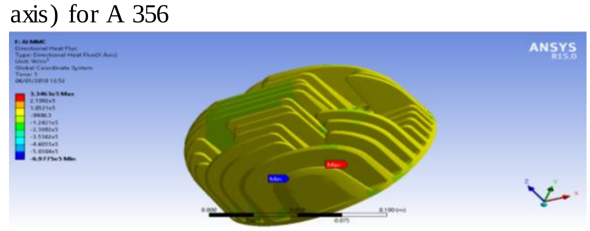

Figure 4.31 Directional Heat Flux Distribution (x axis) for Al metal matrix alloys (Al-MMC)

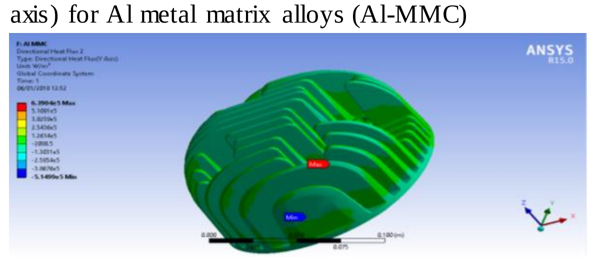

Figure 4.32 Directional Heat Flux Distribution (y axis) for Al metal matrix alloys (Al-MMC)

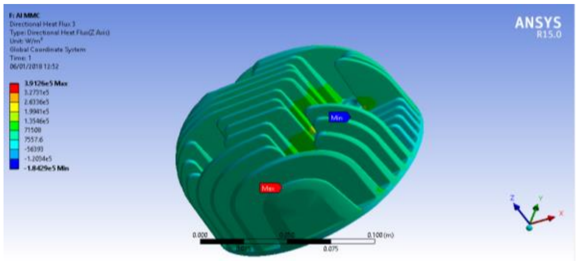

Figure 4.33 Directional Heat Flux Distribution (z axis) for Al metal matrix alloys (Al-MMC)

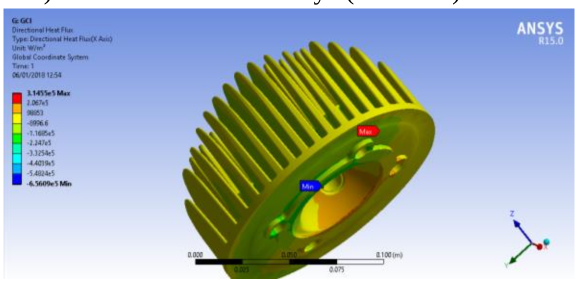

Figure 4.34 Directional Heat Flux Distribution (x axis) for Grey Cast Iron

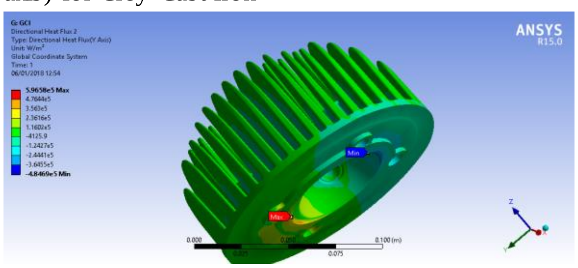

Figure 4.35 Directional Heat Flux Distribution (y axis) for Grey Cast Iron

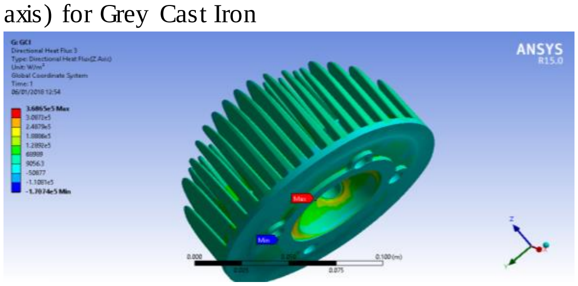

Figure 4.36 Directional Heat Flux Distribution (z axis) for Grey Cast Iron

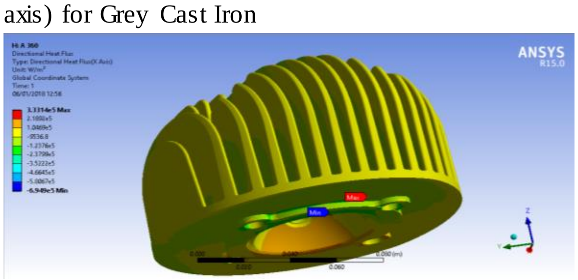

Figure 4.37 Directional Heat Flux Distribution (x axis) for A 360

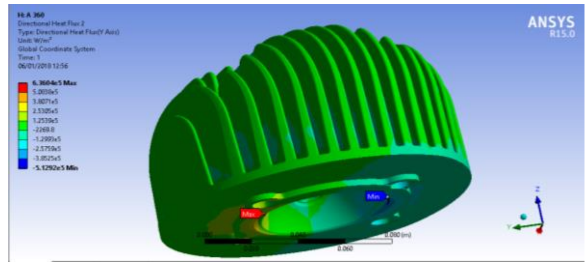

Figure 4.38 Directional Heat Flux Distribution (y axis) for A 360

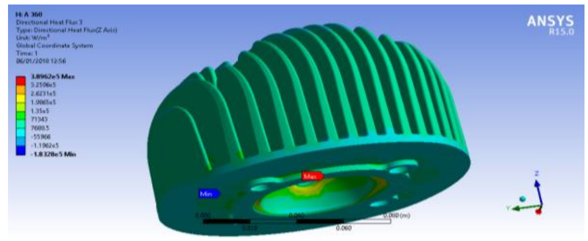

Figure 4.39 Directional Heat Flux Distribution (z axis) for A 360

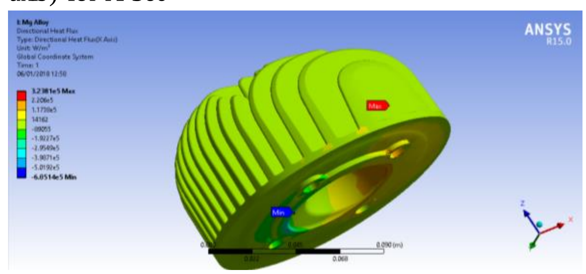

Figure 4.40 Directional Heat Flux Distribution (x axis) for Mg Alloy

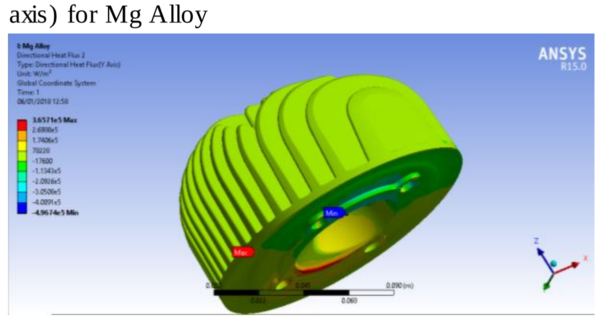

Figure 4.41 Directional Heat Flux Distribution (y axis) for Mg Alloy

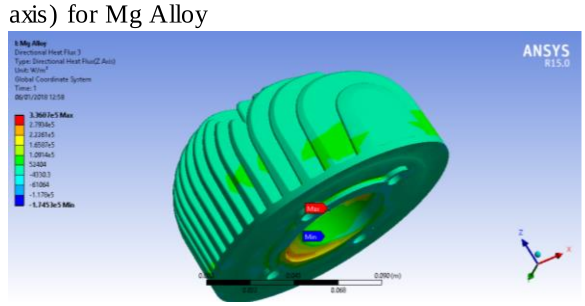

Figure 4.42 Directional Heat Flux Distribution (z axis) for Mg Alloy

Table 4.3 Directional Heat Flux for all the material

Material	Directional Heat Flux (W/m²)		
	x axis	y axis	z axis
Aluminium Alloy 6061	339350	530420	475440
Structural Steel	375660	508140	933200
A380	342150	651850	399160
A356	337410	644640	394320
Al metal matrix alloys (Al-MMC)	334630	639040	391260
Grey Cast Iron	314550	596580	368650
A360	333140	636040	636040
Mg Alloy	323810	365710	365710

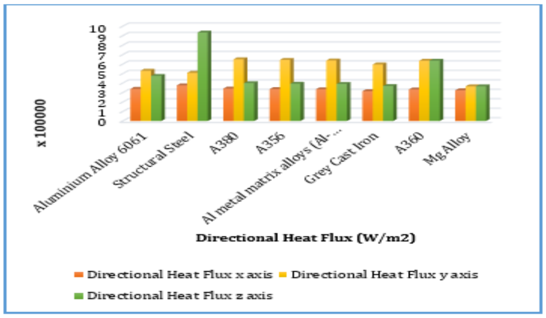

Figure 4.43 Directional Heat Flux for all the Materials Cylinder Block

4.4 Discussion

The cylinder block was subjected to high temperature during the combustion of fuel, hence the best performance of engine is greatly depends on the best selection of cylinder block material.

Table 4.4 Comparison in Weight for each Material

Material	Weight (kg)
A356	1.092831
A360	1.076459
A380	1.129668
Al metal matrix alloys (Al-MMC)	1.129668
Mg Alloy	0.740833
Aluminium Alloy 6061	1.10511
Grey Cast Iron	2.94696
Structural Steel	3.213005

The transfer mechanism of heat through the material is greatly affected by the conductivity of that material hence the final selection of material is mainly depends on thermal conductivity and high strength of material with light weight.

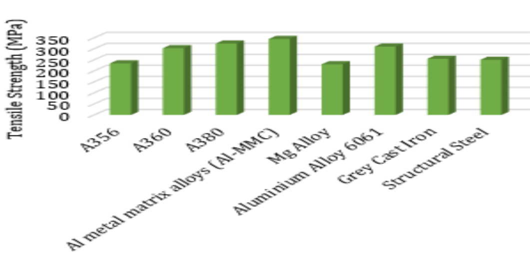

Figure 4.44 Comparison of Tensile Strength of all the Material

Table 4.4 Comparison on the basis of Cost for each Material

Material	Price/kg (App.)
A356	120
A360	139
A380	140
Al metal matrix alloys (Al-MMC)	220
Mg Alloy	195
Aluminium Alloy 6061	280
Grey Cast Iron	55
Structural Steel	40

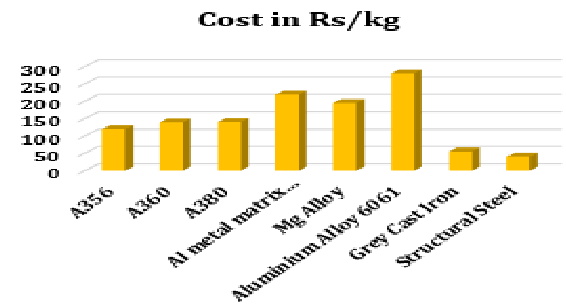

Figure 4.45 Comparison of Cost in Rs/kg of all the Material

V-CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

In this present work, steady state thermal analysis of cylinder block using Finite Element Method, Ansys as a tool were performed with eight different alloys to find out the best suitable material which gives the

- Finest heat transfer rate through it for cooling as primary consideration
- Safe working of Engine
- Having high strength
- Light in weight and also
- Lower Cost

Following conclusions have been made

- ✓ By having temperature distribution contours for all the materials it is to be observed that the distribution of temperature through the material is high for the grey cast iron with about 140.69 ˚C temperature difference and minimum for A 380 material about 34.24 ˚C temperature difference.
- ✓ The value of Total Heat Flux is higher for Structural Steel and lower for Mg Alloy which shows that the higher amount of heat is transferred by Structural Steel material and the lower is transferred by Mg alloy material cylinder block.

- ✓ It is found that the heat transfer in z axis is more compare then other two axis. This gives the information about to improve the design of fin in x and y axis to acquire high heat transfer.
- ✓ Cast iron and structural steel material cylinder block shows higher weight and Mg allow material shows the lower weight. These materials are not that much suitable for light vehicles due to its more weight.
- ✓ By observing the results it is to be identified that the grey cast iron and Structural Steel are giving the better heat distribution and maximum temperature difference
- ✓ Cast iron and structural steel are the best material that satisfies the above desirable properties except that it has a low thermal conductivity and it is a comparatively heavy material.
- ✓ Cylinder blocks are subjected to high strengths due to combustion of fuel; hence strength is also one more important parameter needs to be considered for the selection of material. Al MMC shows the highest strength while Mg alloy shows the lowest strength while the other materials showing moderate strength.
- ✓ Cost of raw materials which is one of the important consideration for selecting the material for the cylinder block manufacturing of economical vehicles in developing countries. Apart of all the other materials Grey cast iron and Structural steels are more economical.

REFERENCES

[1] Lombardi, D. Sediako, A. Machin, C. Ravindran, R. MacKay, "Effect of solution heat treatment on residual stress in Al alloy engine blocks using neutron diffraction", 2017, Materials Science & Engineering A 697 (2017) 238–247

[2] Ankit Kumar Pandey, Prof. Sandeep Jain, Dr. Lokesh Bajpai, "Design, Analysis and Optimization of Four Stroke S.I. Engine Piston using Finite Element Analysis in ANSYS software", 2016, International Journal of Advance Engineering and Research Development

[3] Branimir Krstic , Bosko Rasuo, Dragan Trifkovic , Igor Radisavljevic , Zoran Rajic, Mirko Dinulovic, "Failure analysis of an aircraft engine cylinder head", 2013, Engineering Failure Analysis 32 (2013) 1–15

[4] Branimir Krstic, Bosko Rasuo, Dragan Trifkovic , Igor Radisavljevic, Zoran Rajic, Mirko Dinulovic "Failure analysis of an aircraft engine cylinder head", 2013

[5] Divyank Dubey, Dinesh Singh, Abhishek yadav, Satyajeet pal,Harishchandra Thakur, "Thermal Analysis of Engine Cylinder having thick tip fin with varying slot sizes and material", 2017, Materials Today: Proceedings 4 (2017) 7636–7642

[6] Esmail M.A. Mokheimer "Performance of annular fins with different profiles subject to variable heat transfer coefficient", International Journal of Heat and Mass Transfer, 2002

[7] Fabio Berni, Giuseppe Cicalese, Stefano Fontanesi, "A modified thermal wall function for the estimation of gas-to-wall heat fluxes in CFD in-cylinder simulations of high performance spark-ignition engines", 2017

[8] Fredrik Ohrby, "Numerical modeling of subcooled nucleate low boiling in engine cooling systems", 2014, Master's thesis in the Applied Mechanics programme

[9] G. Babu, M. Lavakumar "Heat Transfer Analysis and Optimization of Engine Cylinder Fins of Varying Geometry and Material", 2013

[10] J. Wen, H. Huang, H. Li, G. Xu, Y. Fu, Thermal and hydraulic performance of a compact plate finned tube air-fuel heat exchanger for aero-engine, Applied Thermal Engineering (2017), doi:http://dx.doi.org/10.1016/j.applthermaleng.2017.07.103

[11] Martin Gonera, Olle Sandin, "Thermal Analysis of a Diesel Piston and Cylinder Liner using the Inverse Heat Conduction Method", 2015, Chalmers University Of Technology

[12] Mirko Bovo, "Principles of Heat Transfer in Internal Combustion Engines from a Modeling standpoint", 2014, Chalmers University of Technology

[13] Mohsin A. Ali1 and Prof. (Dr.) S.M Kherde2 , Heat Transfer Analysis by CFD Simulation for Different shapes of Fins, Volume 3 Issue II, February 2015 (ISSN: 2321-9653).

[14] Obula Reddy Kummitha, B.V.R. Reddy, "Thermal Analysis of cylinder block with fins for different materials using ANSYS", 2016,

Materials Today: Proceedings 4 (2017) 8142–8148

[15] P. Sai Chaitanya, B. Suneela Rani, K. Vijaya Kumar "Thermal Analysis of Engine Cylinder Fin by Varying Its Geometry and Material", 2014

[16] Padhiyar Abhesinh J*, Vasim G Machhar**, Air cooling effect of fins on a Honda shine bike, Padhiyar Abhesinh J Int.Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 5, Issue 5, (Part -3) May 2015, pp.82-92.