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Modeling and Thermal Analysis of Engine Block

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Abstract: **In the realm of internal combustion engines, the engine block plays a pivotal role, where the combustion of the air-fuel mixture occurs. Due to this combustion process, high heat is released and transferred to the walls of the engine block. If this heat is not dissipated properly to the outside, it will affect the engine's performance. Hence the heat should be removed from the engine block. The heat removal rate from the engine block mainly depends on the material's thermal conductivity. Hence, this study endeavors to conduct thermal analysis on an engine block composed of various materials using ANSYS Workbench software, and modeling was done in Creo Parametric. The findings are meticulously analyzed to identify the material offering superior heat transfer performance.**

Index Terms: **Engine block, modeling, thermal analysis, Creo Parametric, and Ansys Workbench.**

I. Introduction

The performance of vehicles is predominantly reliant on the performance of the engine. The selection and manufacturing of the optimal engine design hinges greatly upon the choice of materials, as the performance of internal combustion engines is directly linked to the thermal behavior of these materials. Thermal analysis, a branch of material science, delves into the properties of materials affected by temperature variations. It is frequently utilized to study heat transfer phenomena in structures such as internal combustion engines, molding blocks, and various other applications where heat transfer occurs through conduction and convection.

This paper endeavors to identify the most suitable material for the engine block. To achieve this, a thermal analysis of the engine block was conducted using different composite materials. The engine block design was modeled using CREO software. Heat transfer simulations were executed using ANSYS workbench software to ascertain the temperature distribution across the various materials of the engine block. The rate of heat transfer is contingent upon factors such as the engine block model, number of fins, wind velocity, and primarily the material of the block. Hence, this paper conducts a thermal analysis of the engine block using different materials.

II. Literature Survey

Shubham Shrivastava et al [1] have conducted a thermal analysis of a Cylinder Block with Fins Perpendicular to the Axis of the Piston Movement using different alloys like AA 1050, Aluminum alloy, gray cast iron, and Magnesium alloy. In the results, it is concluded that Aluminum alloy was chosen for a better heat transfer rate.

Pulkit Sagar et al [2] have done Heat transfer analysis and optimization of engine fins of varying surface roughness. In this paper authors have taken roughness 250 microns, 300 microns, and 400 microns. AUTODESK INVENTOR 2014 is used for modeling and simulation in Nastran 2015. The complete analysis is done by using Aluminum alloy 6061. In the results, it is concluded that by increasing the surface roughness value heat release rate also increased.

Thornhill, D. et al [3] have done experimental work on the surface heat transfer coefficient of finned metal cylinders in a free stream. In this paper, the authors have used eight cast aluminum alloy cylinders with four different pitches and five various fin lengths. The results show that at lower air speeds the exponent related velocity to the fin surface heat transfer coefficient.

Esfahanian et al [4] have analyzed SI engine piston using three combustion boundary condition techniques. It has been concluded that employing a spatial and time-averaged combustion side boundary condition proves more effective compared to utilizing surface and time-averaged boundary conditions in piston thermal analysis. Furthermore, the application of transient boundary conditions is noted to be time-intensive; however, within engineering approximations, it demonstrates minimal influence on the results of piston thermal analysis. Similarly, the utilization of a time-varying piston temperature boundary condition throughout the engine cycle does not markedly impact the outcomes of combustion analysis.

III. Materials and Properties

A. Mechanical Properties of Materials Aluminium Alloy:

TABLE I.
Mechanical Properties Of Materials Aluminum Alloy

S. No	Material Properties	Units	Values
1	Density	Kg/m3	2770
2	Specific heat	J/Kg -ºC	875
3	Coefficient of thermal expansion	1/K	$23x\ 10^{-6}$
4	Compressive yield strength	Pa	$2800x\ 10^{-5}$
5	Young's modulus	GPa	71
6	Bulk modulus	Pa	$6.9608x\ 10^{10}$
7	Shear modulus	Pa	$2.6992x\ 10^{10}$
8	Thermal conductivity	W/m-k	120-160
9	Tensile ultimate strength	Pa	3100
10	Poisson's ratio	-----	0.33

Table. I show the Mechanical properties of aluminum alloy.

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B. Mechanical Properties of Materials Grey cast iron:

TABLE II.
MECHANICAL PROPERTIES OF MATERIALS GREY CAST IRON

S. No	Material Properties	Units	Values
1	Density	Kg/m3	7200
2	Specific heat	J/Kg -ºC	447
3	Coefficient of thermal expansion	1/K	11x 10^{-6}
4	Compressive ultimate strength	Pa	8.2 x 10^{8}
5	Young's modulus	GPa	110
6	Bulk modulus	Pa	8.33x 10^{10}
7	Shear modulus	Pa	4.2969x 10^{10}
8	Thermal conductivity	W/m-k	52
9	Tensile ultimate strength	Pa	2.4x 10^{8}
10	Poisson's ratio	-----	0.28

Table. II shows the Mechanical properties of grey cast iron.

C. Mechanical Properties of Materials Structural steel:

TABLE III.
MECHANICAL PROPERTIES OF MATERIALS STRUCTURAL STEEL

S. No	Material Properties	Units	Values
1	Density	Kg/m3	7850
2	Specific heat	J/Kg -ºC	420
3	Coefficient of thermal expansion	1/K	$1.2 \times 10-5$
4	Compressive ultimate strength	Pa	2.50E+08
5	Young's modulus	Pa	2.079E+11
6	Bulk modulus	Pa	1.725E+11
7	Shear modulus	Pa	7.9615E+10
8	Thermal conductivity	W/m-k	45
9	Tensile ultimate strength	Pa	2.5E+08
10	Poisson's ratio	-----	0.3

Table. III shows the Mechanical properties of structural steel.

IV. FINITE ELEMENT MODELLING

Creo Parametric is used for modeling engine blocks.

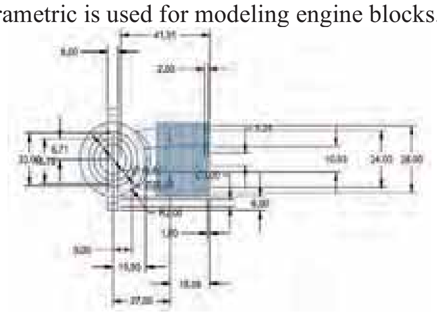

Figure 1. Engine block dimensions.

Fig.1 shows the dimensions of the engine block which is used for modeling in Creo Parametric.

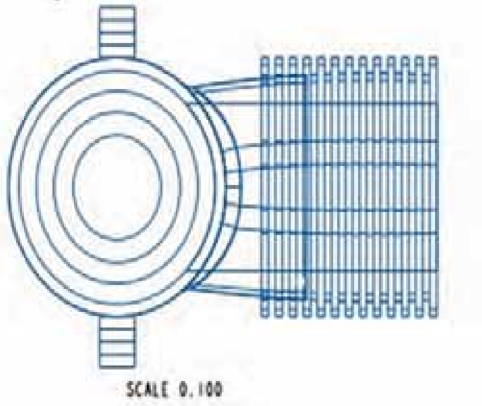

Figure 2. Top view of the Engine block.

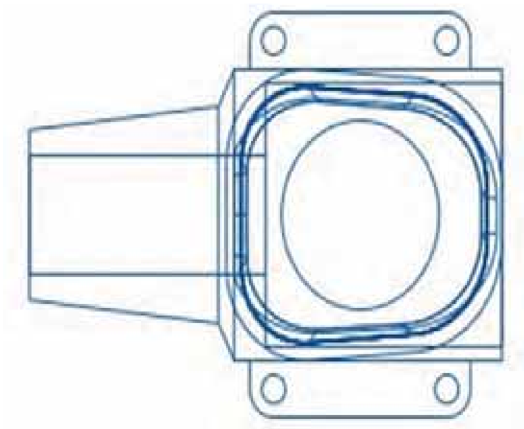

Figure 3. Side view of the Engine block.

Figure 4. 3D-View of the Engine block

Fig.2 shows the Top view, Fig.3 shows the side view and Fig.4 shows the 3D view of the Engine block.

V. THERMAL ANALYSIS

TABLE IV.
MESHING OF ENGINE BLOCK

Nodes	Elements	Elements Size
59371	35317	0.2m

Table. IV shows the nodes, elements, and elemental sizes that are taken into consideration in the engine block for thermal analysis.

Figure 5. The meshing of the Engine block

Fig.5 shows the meshing of the engine block.

A. Aluminum alloy:

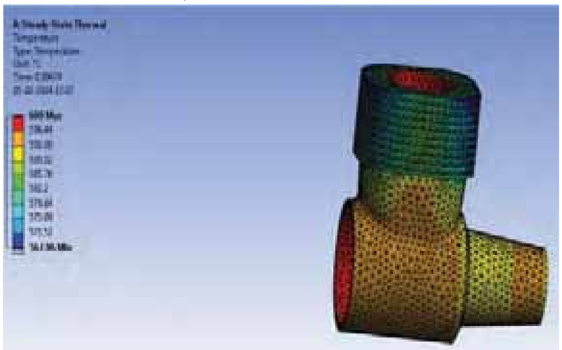

Figure 6. Temperature distribution in the Engine block using aluminum alloy

Fig.6 shows the temperature distribution in the engine block using aluminum alloy as a material and it is observed that the max temperature induced is 600°C and the minimum temperature is 567.96°C.

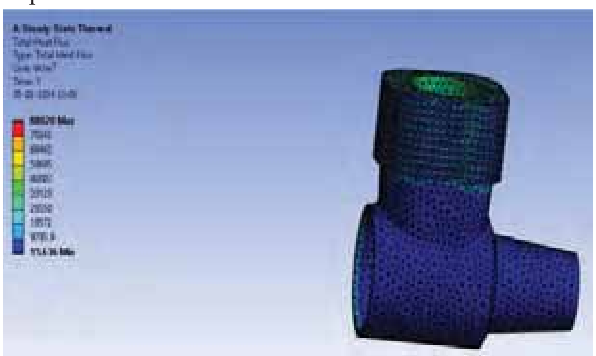

Figure 7. Heat flux distribution in the Engine block using aluminum alloy

Fig.7 shows the Heat flux in the engine block using aluminum alloy as a material and it is observed that the max heat flux is 88020 W/m² and the minimum heat flux is 15.636 W/m².

B. Grey Cast Iron:

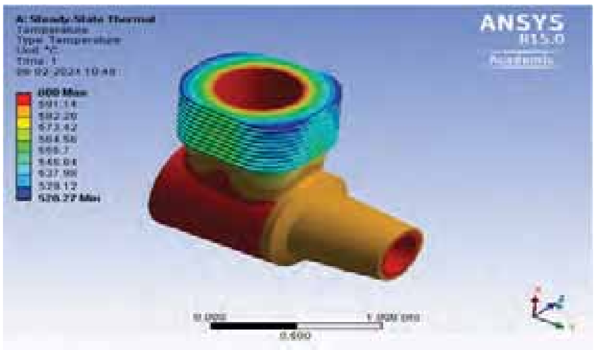

Figure 8. Temperature distribution in the Engine block using grey cast iron

Fig.8 shows the temperature distribution in the engine block using grey cast iron as a material and it is observed that the max temperature induced is 600°C and the minimum temperature is 520.27°C.

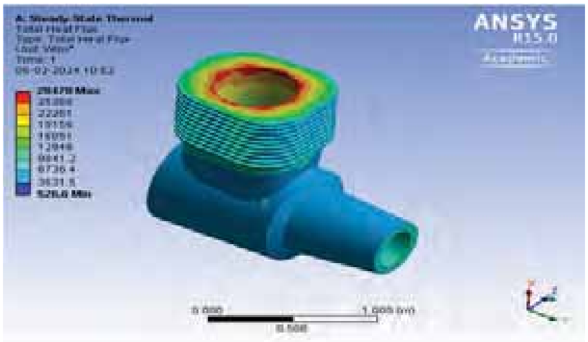

Figure 9. Heat flux distribution in the Engine block using aluminum alloy

Fig.9 shows the Heat flux in the engine block using grey cast iron as a material and it is observed that the max heat flux is 28470 W/m² and the minimum heat flux is 526.6 W/m².

C. Structural Steel:

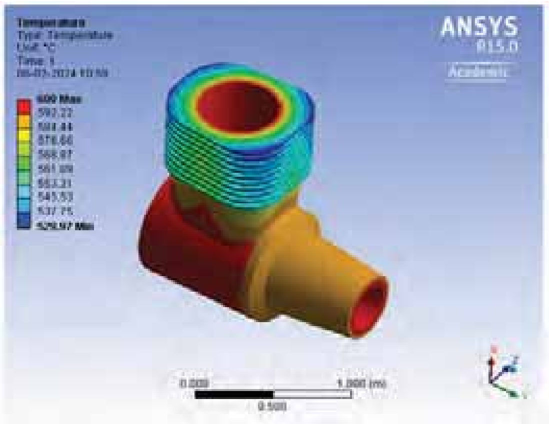

Figure 10. Temperature distribution in the Engine block using structural steel

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Fig.10 shows the temperature distribution in the engine block using structural steel as a material and it is observed that the max temperature induced is 600°C and the minimum temperature is 529.97°C.

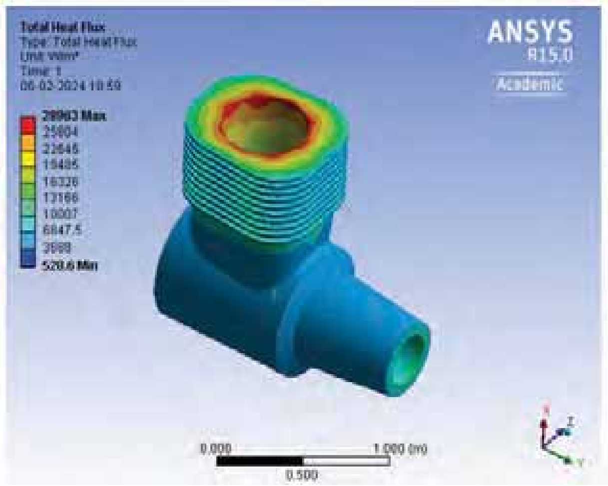

Figure 11. Heat flux distribution in the Engine block using structural steel

Fig.11 shows the Heat flux in the engine block using structural steel as a material and it is observed that the max heat flux is 28963 W/m^2 and the minimum heat flux is 528.6 W/m^2.

VI. Conclusions

TABLE V.
COMPARISON BETWEEN DIFFERENT MATERIALS

S. No	Material	Temperature(°C)		Heat flux(W/m^2)	
		Min	Max	Min	Max
1	Aluminum alloy	567.96	600	15.636	88020
2	Grey cast iron	520.25	600	526.6	28470
3	Structural steel	529.97	600	528.6	28963

Table. V shows the comparison between temperature distribution and Heat flux in the engine block using different materials respectively.

It is observed that Heat flux values are higher for Aluminum alloy compared to grey cast iron and structural steel. Higher values of the heat flux are to be higher the heat release rate to the atmosphere.

References

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