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Computer Aided Modeling and Simulation of Engine Block Fins with Various Fin Materials

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***Abstract* – Internal combustion engines are using the chemical energy of the fuel to convert it into the mechanical work. As the fuel is ignited in power stroke either it is spark ignition engine as in case of petrol engine or compression ignition engine as in case of diesel engine the power is produced and piston moves continuously between the top dead centre and bottom dead centre. In internal combustion engine this piston movements are very fast and as the engine speed increases it is even faster. This movement together with the fuel burning creates lot of heat inside the cylinder and ultimately results in poor engine performance in terms of operation and durability. So one need to think about the heat dissipation from the engine cylinder. As far as the heat dissipation is concerned we need to increase the surface area of the cylinder outer body for this reason the fins are used as extended surfaces and the rate of heat transfer to the atmosphere can be increased. In this work we are focusing on the various fin materials for optimum performance of engine. For this we have modeled an IC engine cylinder and then we have applied various fin materials to the cylinder block and we have analysed the block using at actual operating conditions that is maximum internal temperature at the inner side of the cylinder taken as 920 oC and convection parameters obtained theoretically for different materials. We will be using CATIA software for the modeling purpose and ANSYS software tool for analysis work. Once we obtain the results we will do a comparative study and will conclude our analysis.**

***Keywords* –IC engine, Fins, CATIA, ANSYS, Heat flux, Convective heat transfer.**

I. INTRODUCTION

Fins are elongated surfaces designed to increase the heat transfer rate at a certain surface temperature or to decrease the surface temperature at a certain heat transfer rate. The heat transfer due to convection between the surface and the surrounding fluid can be increased by attaching to the surface, the so-called ribs. To keep the system stable, conductive heat must be continuously dissipated into the environment through concrete, walls or boundaries. In many technical applications, large amounts of heat had to be dissipated in small areas. Fins increase the usable surface area and therefore increase convective heat transfer. The rectangular and triangular wings are straight wings. Triangular fins are attractive because they require much less volume than rectangular fins for the same heat transfer. As a result, fins are of practical importance because they provide maximum heat flux per unit mass while being easy to manufacture.

Methods to increase the heat transfer rate:
1. By increasing the contact area with air or by adding fins. 2. Increase surface heat transfer coefficient.
3. Increase the temperature of the hot surface or increase the temperature difference between the hot and cold bodies.

II. LITERATURE REVIEW

Sharma, S. K et. al., 2013 [1] presents the results of computational numerical analysis of air flow and heat transfer in a light automobile engine, taking into account three fins of different morphologies. **Sathish kumar et. al., 2017 [2]** fins with different configurations were prepared using CREO 2.0 and analysed using CFDFluent to detect the heat transfer rate. In theory, the software detects this and claims that rectangular notched fins have a higher heat transfer rate than non-notched fins, aperture fins, and V-notched fins.

Barhatte, S. H., et. al. 2011 [3] The heat transfer of natural convection of vertical rectangular fin networks with and without a central cut has been studied experimentally and theoretically. In addition, cuts of different geometries were analysed, for comparison and optimization.

S. E. Ghasemi1 et. al., 2014 [4] A simple and highly accurate semi-analytical method called differential transformation method (DTM) was used to solve the equation for non-linear temperature distribution in a massively porous longitudinal rib with temperature-dependent internal heat release.

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G. Babu et. al., 2013 [5] The main objective of the work is to analyse thermal properties by varying the geometry, material and thickness of cylinder fins. Parametric models of a ribbed cylinder have been developed to predict unstable thermal behaviour.

Sujan Shrestha et. al., 2019 [6] This study is useful in determining the best fin geometry and material for the greatest heat dissipation and engine cooling. In this project author used a common material such as gray cast iron for the cylinder block. The components are developed with Solid-Works and performs ANSYS analysis.

Varun Singh et. al., 2008 [7] A heat exchanger model is presented that can simulate a heat exchanger in which some pipes are separated from each other by intermittent fins. The model shows an improvement in heat exchanger performance due to intermittent fins.

T. Abhilash Mallikarjunarao et. al., 2018 [8] this work deals with computer simulations of a vertical tube with spiral fins, which are used to improve heat transfer during natural convection.

III. MATHEMATICAL CALCULATIONS

For the given case of the internal combustion engine, the following parameters are to be considered for the calculation of heat flux distribution and temperature distribution for different materials of the IC engine. Although there are a variety of materials are available for the selection of cylinder of the automobile but we have selected three materials for calculation and analysis. For the aforesaid purpose mild steel, aluminium alloy and anodized aluminium alloy have been selected for the purpose. Specifications of the fin and cylinder configuration are mentioned below:
The bore of the cylinder: 50 mm
Stroke length of the cylinder: 100 mm
Thermal conductivity of the mild steel: 50w/m-k
Thermal conductivity of the aluminium alloy: 180w/m-k
Thermal conductivity of the anodized aluminium alloy: 200w/m-k
The temperature of the atmospheric air: 27 °C Maximum temperature in the cylinder: 920 °C
During combustion in the cylinder, there will be convective heat transfer in the gasoline and again this heat will be transfer to the cylinder of thickness t. Heat will be transfer by a conductive phenomenon in the cylinder and from cylinder to atmosphere convective heat transfer will be there. Convective heat transfer can be calculated using the following relation:
Q = hAdT
Where,
h is the heat transfer coefficient in w/m-k
A is the surface area inside the cylinder.
dT is the difference in temperature i.e the difference of maximum temperature to minimum temperature.

Nusselt number can be used to calculate the heat transfer coefficient for a given case. The cylinder is working as a tube for the heat flow; following correlations are used for calculation of heat transfer coefficient (h).
hL/K = 3.66
Using the above relation heat transfer coefficient for mild steel is calculated and found 0.00183 w/m^2-k. Similarly for aluminium alloy and anodized aluminium alloy 0.00658 w/m^2-k and 0.007649 w/m^2-k respectively.

Table .1 Different materials with thermal conductivity and corresponding heat transfer

Sr. No.	Material	Thermal Cond. In W/m-K	Heat Transfer W/m^2-K
1	Mild Steel	50	0.00183
2	Al. Alloy	180	0.00658
3	Anodized Al. Alloy	200	0.00764

Table 2 Different materials with corresponding maximum temperature and mini. Temp.

Sr. No.	Material	Maximum Temperature	Minimum Temperature
1	Mild Steel	920 °C	287.39 °C
2	Al. Alloy	920 °C	235.12 °C
3	Anodized Al. Alloy	920 °C	49.907 °C

IV. MODELLING AND SIMULATION

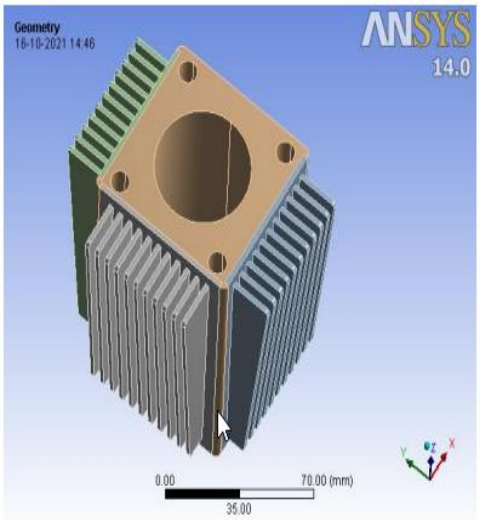

Figure 1 3D model of Engine Block.

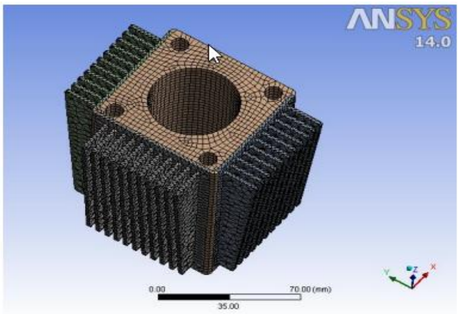

Figure 2: Meshed Model of Engine Block

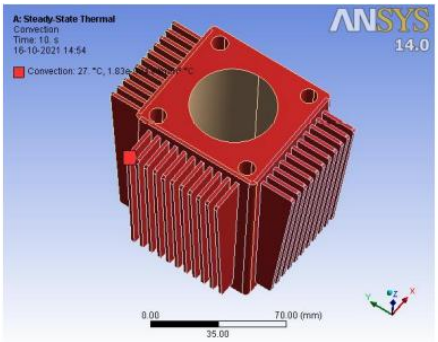

Figure .3: Boundary Condition (convection) structural Steel Material

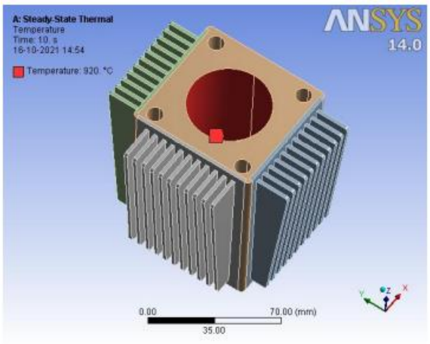

Figure 4:Boundary Condition (Temperature) for structural steel material

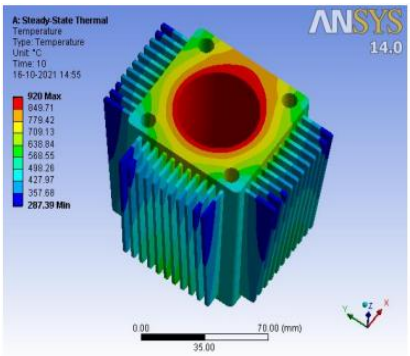

Figure 5: Temperature Distribution for structural steel material

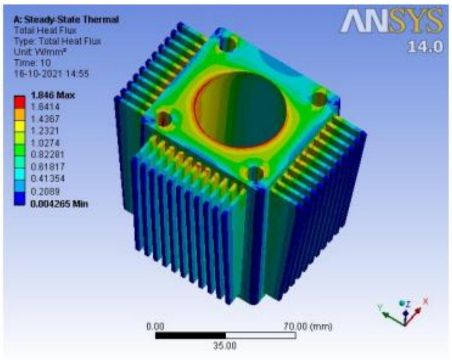

Figure 6: Heat Flux Distribution for structural steel material.

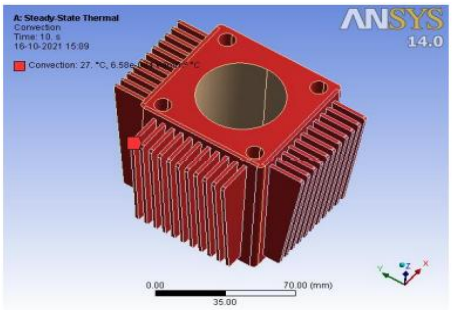

Figure 7: Boundary Condition (Convection) for Aluminium Material

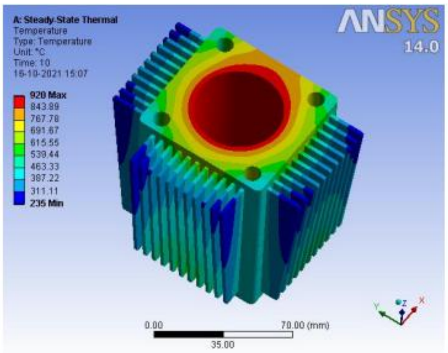

Figure 8: Boundary condition (Temperature) for Aluminium Material

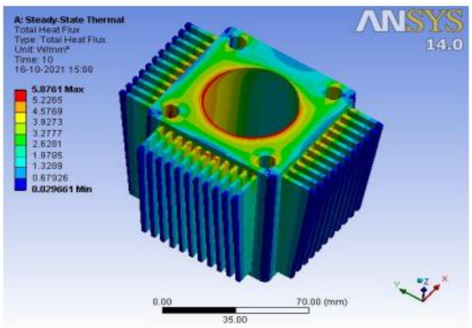

Figure 9 Temperature distribution for Aluminium alloy material

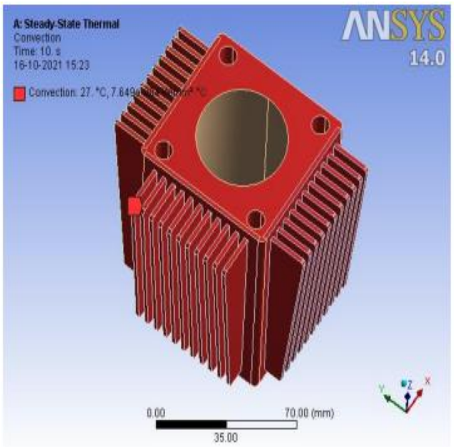

Figure 10 Heat flux distribution for Aluminium alloy material.

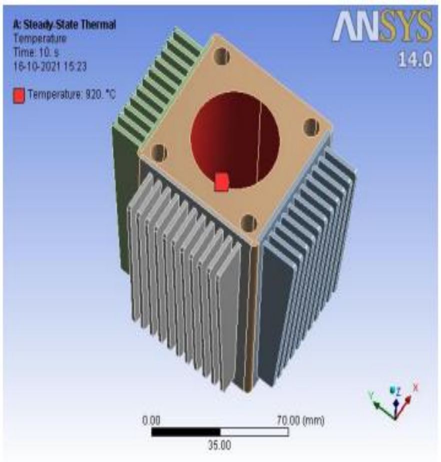

Figure 11 Boundary condition (Convection) for anodized aluminium alloy.

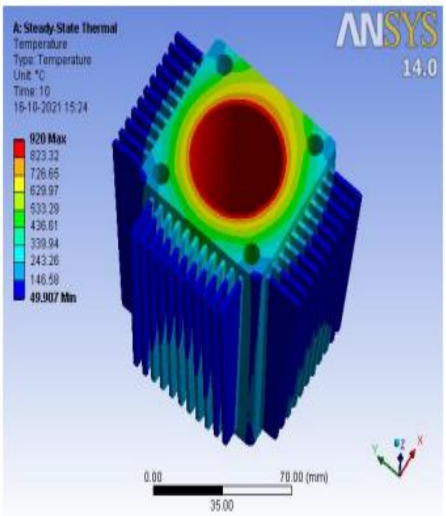

Figure 12 Figure 4.13: Temperature distribution for anodized aluminium alloy material.

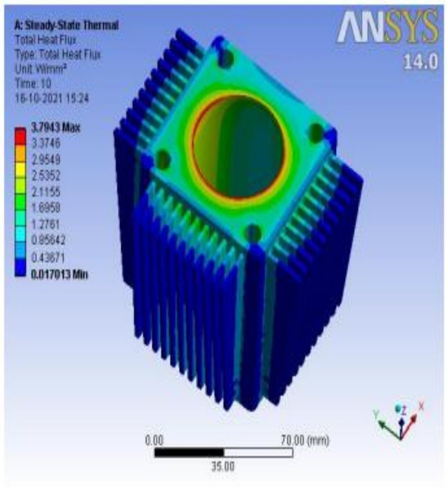

Figure 13 Heat flux distribution for anodized Aluminum alloy material.

V. RESULTS

Following table shows the results obtained from the theoretical and simulation work.

Table 3 Result Table

Sr. No.	Material	Convective heat transfer coefficient	Temp-erature Distribution (Minimum)	Heat flux distribution (Maximum)
1	Mild Steel	0.00183 w/m2 -k	287.39 °C	1.846 w/mm^2
2	Al. Alloy	0.00658 w/m2 -k	235.12 °C	3.795 w/mm^2
Sr. No.	Material	Convective heat transfer coefficient	Temp-erature Distribution (Minimum)	Heat flux distribution (Maximum)
3	Anodized Al. Alloy	0.00764 w/m2 -k	49.907 °C	5.876 w/mm2

From the above results and discussion we can conclude that the rates of heat transfer per unit area (i.e., the heat flux) in anodized aluminium alloy as fin material are much higher than the rate of heat transfer per unit area through the aluminium alloy as fin material. It can also be seen that the rate of heat transfer per unit area of aluminium alloy as fin material is also much higher as compared to the structural steel material. Similarly, if we see the minimum temperate achieved for anodized aluminium alloy is much lower as compared to the aluminium alloy and the minimum temperature achieved from aluminium alloy is also much lower then the structural steel as fin material.

VI. CONCLUSION

From the above results and discussion we can conclude that the rates of heat transfer per unit area (i.e., the heat flux) in anodized aluminium alloy as fin material are much higher than the rate of heat transfer per unit area through the aluminium alloy as fin material. It can also be seen that the rate of heat transfer per unit area of aluminium alloy as fin material is also much higher as compared to the structural steel material. Similarly, if we see the minimum temperate achieved for anodized aluminium alloy is much lower as compared to the aluminium alloy and the minimum temperature achieved from aluminium alloy is also much lower than the structural steel as fin material. Hence for the IC engine application the following order of material should be selected as per the material performance suitable for the given application:

Anodized Al. alloy > Al. Alloy > Structural Steel

VII. FUTURE SCOPE

The following are the future scope of this work:

1. In present analysis only 3 different materials are analysed and compared for the temperature distribution and heat flux for IC engine applications, in future one can also take a number of different materials for carrying out the same analysis.
2. In present work ANSYS steady state heat transfer module is used to solve the thermal analysis model. In future the same analysis can be carried out for time dependent thermal analysis as well as with some different FEA solver.
3. Different fin geometries can be taken into consideration (as discussed in introduction) in future to see which geometry is best suited for the heat transfer though IC engines

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