Design and Thermal Analysis on Engine Cylinder Fins by Modifying its Material and Geometry

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Abstract: The major component which is subjected to high amount of thermal variations is the engine cylinder fin. The cooling of the engine cylinder is increased by increasing the surface area of the engine fin. The main aim of this paper is to investigate the thermal dissipation of the heat from the engine fin for higher rate of cooling. This can be analyzed by changing the geometry and applying different materials for it. The geometry used for this analysis is circular, rectangular, helical, tapered, longitudinal, angular. The materials used for this analysis are Grey Cast iron and Aluminium Alloy 6061. The design is created in Creo 3.0 and the thermal analysis is done in Ansys Workbench 16.1. Based on our analysis Aluminium Alloy 6061 shows maximum thermal dissipation and higher rate of cooling, specifically circular fin has maximum value.

I. INTRODUCTION

The high working temperature inside combustion engine causes difficulty in engine construction and operation. No known materials are capable of enduring continuously the high temperature to which the cylinder, piston and the values are subjected, while at the same time retaining sufficient strength to withstand the high working loads. The temperature of the gases in the cylinder of an internal combustion engine may be of the order of 40ºC or less on the lower side and 2500ºC or more on the higher side, during the cycle. If external cooling for the cylinder is not employed, the cylinder walls will have average temperature of the order of 1000ºC near the region of the exhaust valves. Such high temperatures for metals are not tolerable. Therefore, cooling systems are employed to maintain the cylinder parts at a temperature lower than the mean gas temperatures to enable the heat transfer to take place from the gases to the walls. This heat transfer during the working cycle leads to loss of power and efficiency, besides posing problems of cooling system design. But it is imperative for the normal running of the engine. The present investigation aims at determining the suitable design and material for engine cylinder fin.

II. DESIGN AND MODELLING

The present study is to design engine cylinder fin for 15cc bike by changing the various geometries like angular, circular, rectangular, tapered, helical accordingly to it. Table 1. Shows the properties of material used for the engine cylinder fin. Table 2. Shows the types of fin design geometry.

Materials	Thermal Conductivity (W/mK)	Heat transfer co-efficient (W/m^{2}k)	Density (g/cc)
Aluminium 6061	167	25	2.7
Grey Cast Iron	49	25	7.2

Table 1. The properties of material used for the engine cylinder fin

S.No	Types of Geometry
1	Circular Fin
2	Rectangular Fin
3	Tapered Fin
4	Helical Fin
5	Longitudinal Fin
6	Angular Fin

Table 2. Types of fin design geometry.

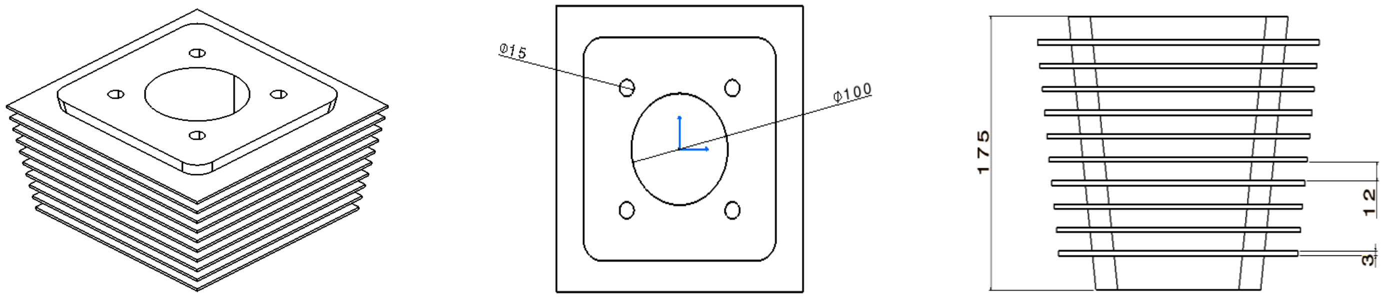

Fig 1. Dimension of Engine Cylinder Fin

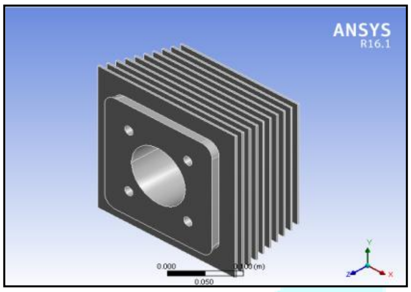

Fig 2. Rectangular fin design

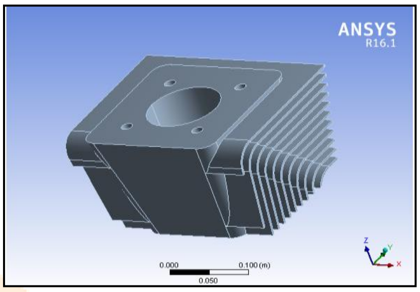

Fig 3. Angular fin design

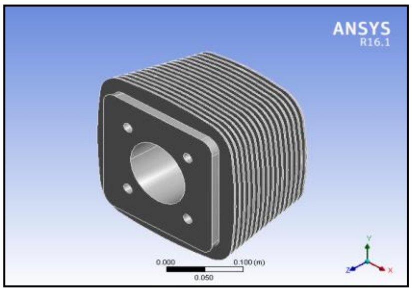

Fig 4. Circular fin design

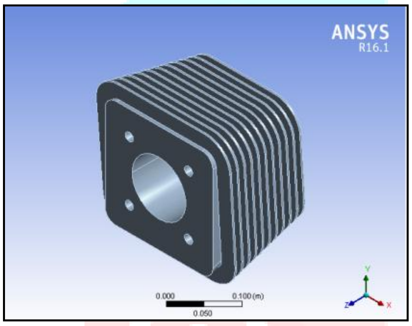

Fig 5. Tapered fin design

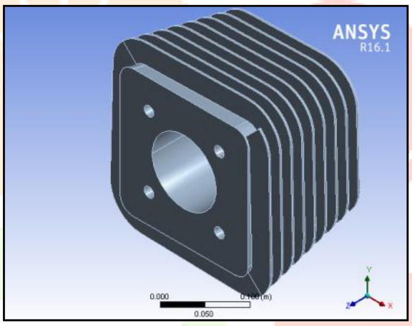

Fig 6. Helical fin design

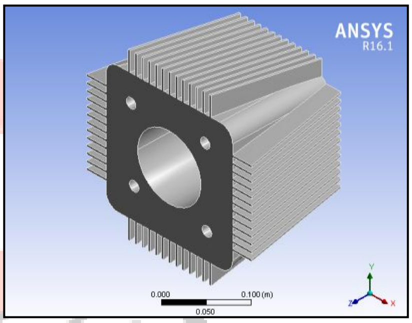

Fig 7. Longitudinal fin design

III. FINITE ELEMENT ANALYSIS

The method yields approximate values of the unknowns at discrete number of points over the domain. To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function. FEA is a good choice for analyzing problems over complicated domains, when the domain changes, when the desired precision varies over the entire domain, or when the solution lacks smoothness. FEA simulations provide a valuable resource as they remove multiple instances of creation and testing of hard prototypes for various high fidelity situations.

IV. RESULTS AND DISCCUSSION

STEADY STATE THERMAL ANALYSIS

In a steady state thermal analysis, the behavior of the system or process is unchanging with time. The parameters used for the analysis is set at pre-determined standard values. Table 3. Shows the values used for analysis purpose

Temperature (K)	**Film Coefficient(W/m^2k)**	**Ambient Temperature (K)**
746	25	25

Table 3: Values required for steady state thermal analysis

Temperature and Heat Flux Distribution of Modified Engine Fins with Aluminium Alloy 6061:

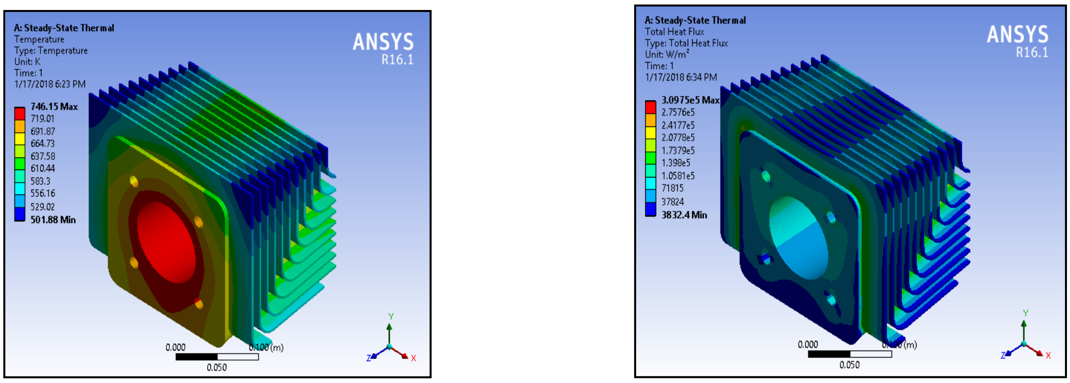

Fig 8. Steady state temperature and Heat flux distribution of angular type fin

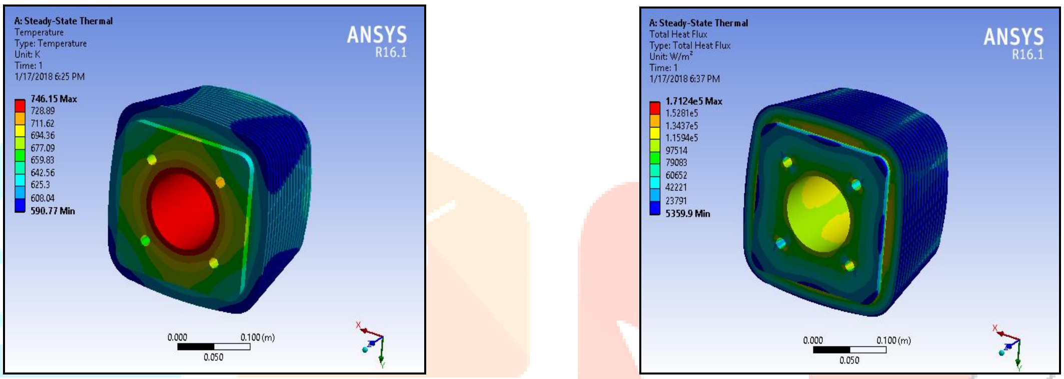

Fig 9. Steady state temperature and Heat flux distribution of circular type fin

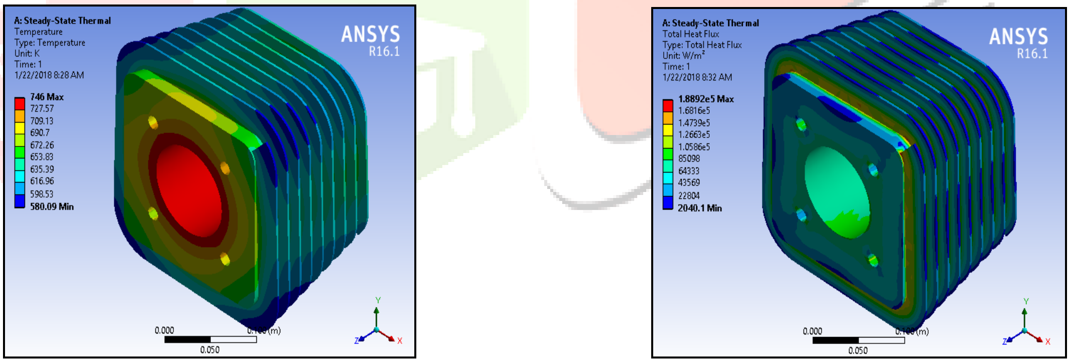

Fig. 10. Steady state temperature and Heat flux distribution of helical type fin

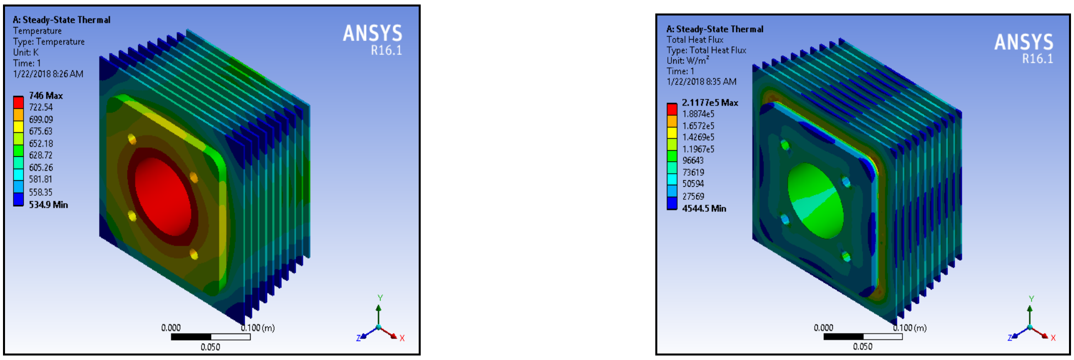

Fig. 11. Steady state temperature and Heat flux distribution of rectangular type fin

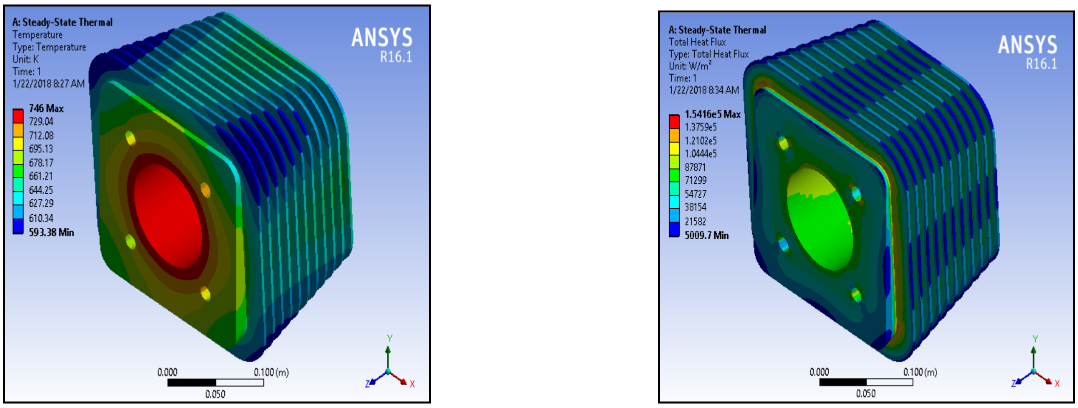

Fig. 12. Steady state temperature and Heat flux distribution of tapered type fin

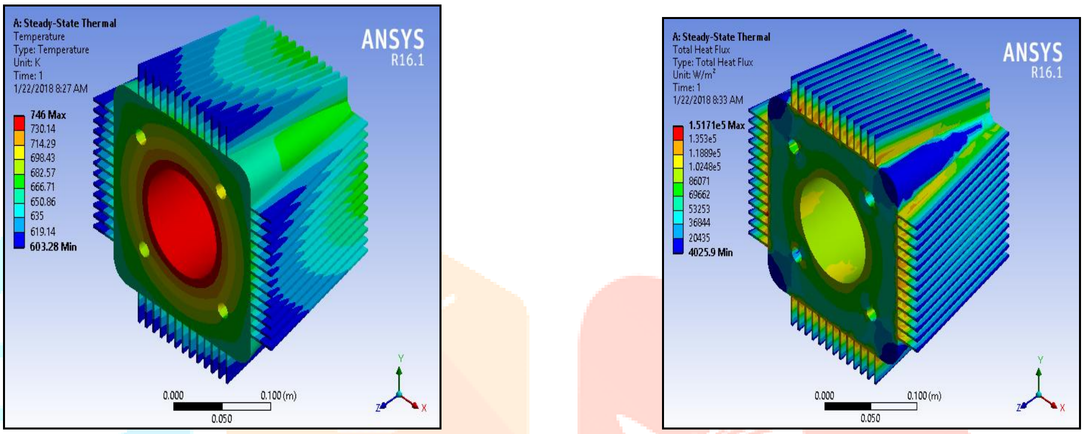

Fig. 13. Steady state temperature and Heat flux distribution of longitudinal type fin

From the figures 8 to 13 it is observed that circular fin shows the maximum thermal dissipation and cooling rate during operation of engine. Also the tapered fin is showing good result compared to other fin designs. Table 4. Shows the analysis details for each fin design and the temperature variation and heat transfer coefficient of each fin.

S.No	Design Configuration	Temperature (K)		Heat Flux (W/m^2)	Temperature difference (K)	Heat Transfer Coefficient (W/m^2K)
		Max	Min			
1.	Angular fin	746.15	501.88	3832.4	244.27	15.68
2.	Rectangular fin	746.15	534.9	4544.5	211.25	21.51
3.	Helical fin	746.15	580.09	2040.1	166.06	12.28
4.	Tapered fin	746.15	593.38	5009.7	152.77	32.78
5.	Circular fin	746.15	590.77	5359.9	155.38	34.49
6.	Longitudinal fin	746.15	603.28	4025.9	142.87	28.17

Table 4. Temperature variation, Heat flux and Heat transfer coefficient of each fin

From the above table it can be observed that circular fin has the maximum heat transfer coefficient and cooling rate compared to other types of engine fins.

Temperature and Heat Flux Distribution of Modified Engine Fins with Grey Cast Iron:

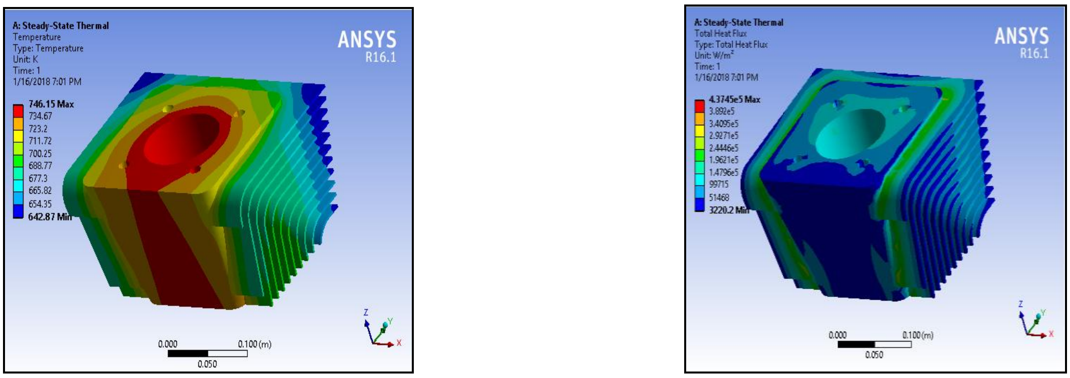

Fig. 14. Steady state temperature and Heat flux distribution of angular type fin

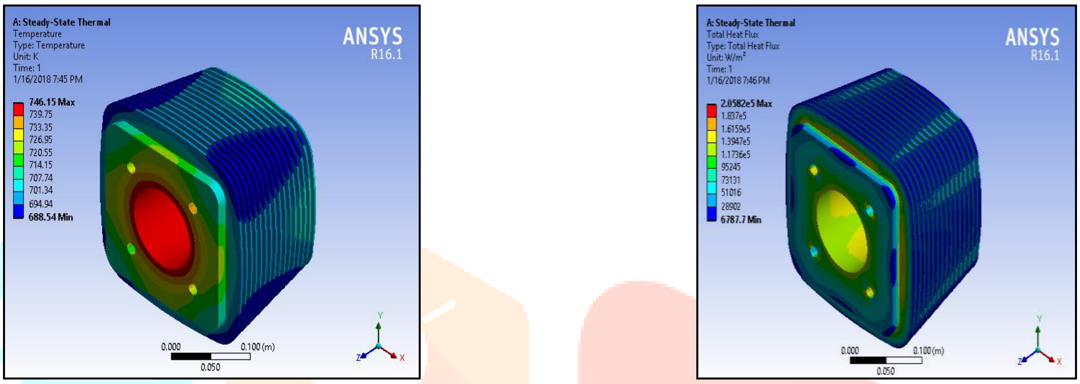

Fig. 15. Steady state temperature and Heat flux distribution of circular type fin

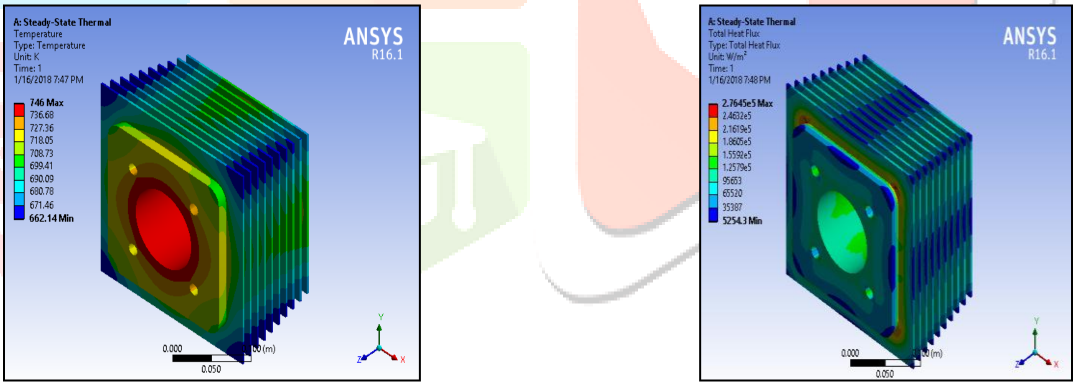

Fig. 16. Steady state temperature and Heat flux distribution of rectangular type fin

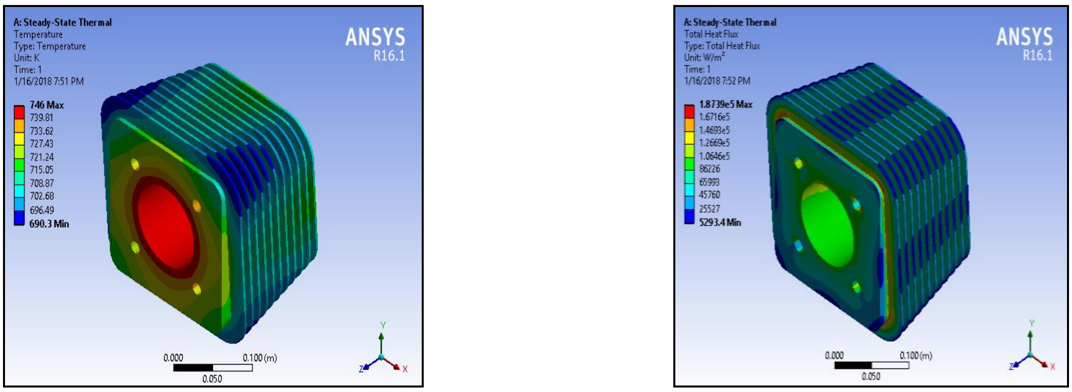

Fig. 17. Heat flux and Steady state temperature distribution of tapered type fin

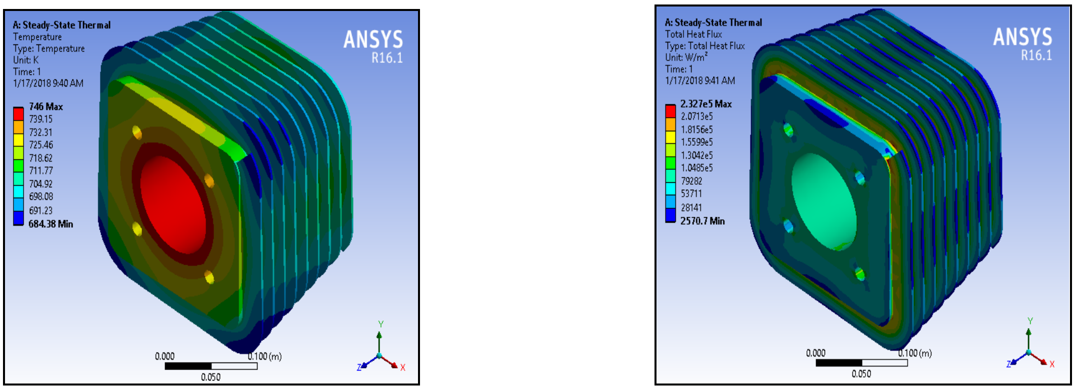

Fig. 18. Heat flux and Steady state temperature distribution of helical type fin

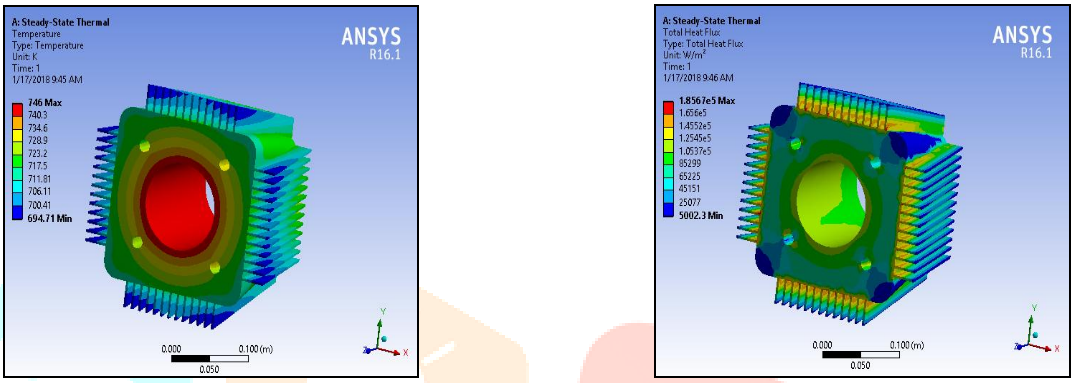

Fig. 19. Heat flux and Steady state temperature distribution of longitudinal type fin

From the figures 14 to 19 it is observed that circular fin shows the maximum thermal dissipation and cooling rate during operation of engine. Also the longitudinal fin is showing good result compared to other fin designs. Table 5. Shows the analysis details for each fin design and the temperature variation and heat transfer coefficient of each fin.

S.No	Design Configuration	Temperature(K)		Heat Flux (W/m^2)	Temperature difference (K)	Heat Transfer Coefficient (W/m^2K)
		Max	Min			
1.	Angular fin	746.15	642.87	3220.2	103.28	31.17
2.	Rectangular fin	746.15	662.14	5254.3	84.01	62.54
3.	Helical fin	746.15	684.38	2570.7	61.77	41.61
4.	Tapered fin	746.15	690.3	5293.4	55.85	94.77
5.	Circular fin	746.15	688.54	6787.7	57.61	117.82
6.	Longitudinal fin	746.15	694.71	5002.3	51.45	97.24

Table5.Temperature variation, Heat flux and Heat transfer coefficient of each fin

From the above table it can be observed that circular fin has the maximum thermal dissipation and cooling rate compared to other types of engine fins.

Comparison of results between Grey Cast Iron and Aluminium A6061:

S.No	Design Configuration	Heat Transfer Coefficient (W/m^2K)		Increase in heat transfer coefficient (W/m^2K)
		Grey Cast Iron	Aluminium Alloy 6061	
1.	Angular fin	15.68	31.17	15.49
2.	Rectangular fin	21.51	62.54	40.95
3.	Helical fin	12.28	41.61	29.33
4.	Tapered fin	32.78	94.77	61.99
5.	Circular fin	34.49	117.82	83.33
6.	Longitudinal fin	28.17	97.24	69.07

Table 6. Comparison of results between Grey Cast Iron and Aluminium A6061:

From the above results it's clear that aluminium alloy 6061 is better than grey cast iron in better cooling and it has significant rise of heat transfer coefficient from 7.29 (W/m^2K) to 89.83 (W/m^2k) and it will also contribute to lesser density which in turn will increase the fuel economy.

V. CONCLUSION

Thus with the help of minimum temperature, maximum temperature and the heat flux obtained from the analysis the heat transfer coefficient 'h' is calculated. By using the heat transfer coefficient 'h' the material and configuration which has the maximum heat transfer has been found.

S.No	Design Configuration	Heat Transfer Coefficient (W/m^2K)
		Aluminium Alloy 6061
1.	Circular fin	117.82
2.	Longitudinal fin	97.24
3.	Tapered fin	94.77
4.	Rectangular fin	62.54
5.	Helical fin	41.61
6.	Angular fin	31.17

And it is clear that Aluminium Alloy 6061 is found to be better replacement for engine and it is also lesser in weight due to its low density and it has lot of advantages.

VI. REFERENCES

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