A Computational Study of Various Cast Iron Fin Performance

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Abstract:- The present work depicts a computational analysis of heat transfer through various fin geometries fitted over an engine cylinder. The study presents the prediction of temperature distribution and total heat flux across the fin. The temperatures of cylinder inner wall have been varied to check the effect of internal heat generation. The performance of the various fin geometries has been compared for a defined case. It was found out that fin with wavy geometry shows better effectiveness than the other. It was also indicated that modifying the rectangular fin with curved edges can enhance the fin performance.

Keywords*:- Fins; heat flux; cast iron; wavy fin; performance.*

I. INTRODUCTION

Internal Combustion engines are subjected to very high temperature variation and thermal stress. To cool the cylinder fins are provided which increases the surface area of the engine hence increasing the rate of heat dissipation by convection. There are various types of fin geometries that can have potential usage in automotive industries. The weight of the fins also plays an important role from the economic point of view. A large number of investigations of fin materials can be found in literature like Illan et al. (1), Wang et al. (2) and Azarkish et al. (3) based on the optimization of fin performance. Harish P. et al. (4) investigated the effect of fin material and geometry on heat flux and found Aluminium Alloy 6082 is best suited. In a similar research, Gowd et al. (5) carried out a comparative study of several fin materials like Al-Alloy 204, 7075 and Mg-Alloy. They concluded that, heat transfer is more pronounced for Beryllium than other materials which can be further enhanced by reducing the thickness of the fin. Gupta et al. (6) investigated the effect of change in material, thickness and geometry of the fins of a motorcycle engine and found that circular fin has better heat loss and effectiveness.

In an investigation by Ghasemi et al. (7) a semi-analytical method was used for solving the nonlinear temperature distribution in a longitudinal fin with heat generation. Several other works carried out on cylinder surface temperature estimation for several fin modifications include Natrayan et al. (8), Singh et al. (9) and Trujillo et al. (10). The effect of fin material and size on a slotted fin was investigated by Gupta et al. (11) which inferred that 75mm slotted fin of Al-alloy 2014 can provide maximum heat transfer. However cast iron fins are still widely used as they can be made directly with engine cylinder. In the present work thermal analysis is done on circular fins, rectangular fins with curved edge, curved fins and wavy fins considering the base material as cast iron. In most of the literature circular and rectangular fins have been discussed. In the present case study, rectangular fins modified with curved edges have been taken consideration. The comparative study is focused on optimizing the fin performance for a standard range of temperatures. Also the temperature distribution and total heat flux have been predicted. The weight of the fin is also considered as a varying parameter with fin types to judge the economic optimization.

II. DESCRIPTION OF THE CASE STUDY

A 100 cc engine is selected for the investigation where the cylinder bore is 54.52 mm, stoke length is 96.28mm, fin length is 22.74mm and fin thickness is 2mm.The material of the fin used here is Cast Iron which is widely used as a fin material and also it is cheap. Cast iron has thermal conductivity of 46 W/m-k, density of 7.5 g/cm2 and melting point of 1180°C. The temperature attained by the engine cylinder due to internal combustion is around 2000 to 2500°C. In this investigation analysis is done to find the temperature distribution in the various fin geometries for 1000°C, 1500°C and 2000°C. It is assumed that all the parts other than the inner part of the cylinder experiences heat transfer due to convection. Standard fin dimensions have been taken into consideration for the 3D modeling done using CATIA. Fig. 1 shows the various fin geometries with appropriate dimensions. The mesh was accomplished using ANSYS workbench. Tetrahedron shaped mesh is used with each mesh size equal to 0.001mm. Average mesh quality of all the fin geometry was moderate with aspect ratio between 1.5 to 2 and average orthogonal quality 0.94 (Table 1).

	Circular Fin	Rectangular Fin	Curved Fin	Wavy Fin
NODES	654595	705004	702972	842900
ELEMENTS	419870	452820	451746	540985
Orthogonal quality	0.94	0.96	0.95	0.92

Table 1. Mesh Metrics for different cases

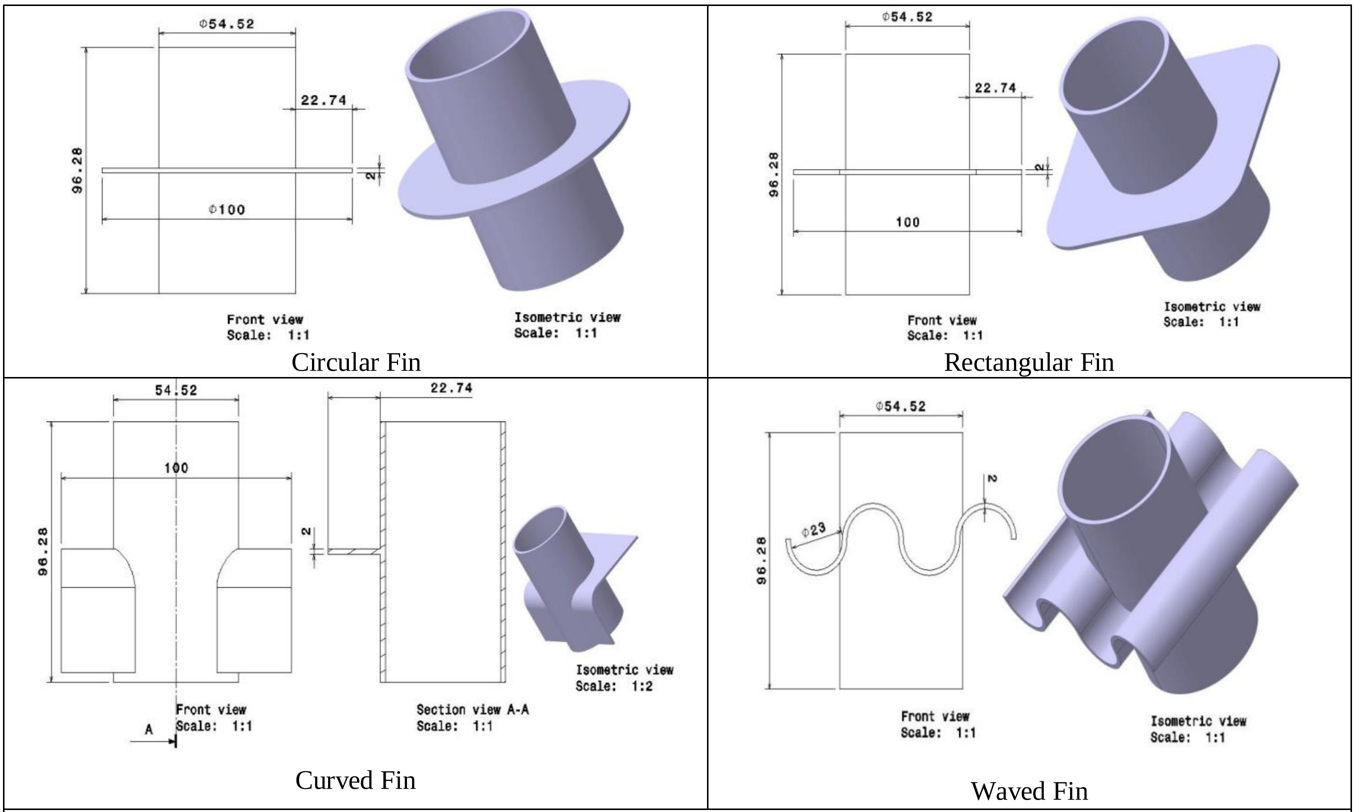

Fig 1:- Models of various fin geometries (All dimensions are in mm)

III. RESULTS AND DISCUSSION

A. Comparison of Temperature distribution

It is observed from the analysis that for circular fin at 1000°C the temperature drop is around 22.72°C which is increased to 34.3°C for 1500° and 45.9°C for 2000°C. Similar trend was observed in all fin types. But in case of rectangular fins the temperature drop was higher like 40.66°C, 61.4°C and 82.2°C respectively. Similarly, for curved fins, the temperature drop was found to be 47.36°C, 71.6°C and 95.8°C whereas in case of wavy finds the effect was more pronounced with the figures as large as 71.32°C, 107.8°C and 144.2°C respectively. It was prominent that with the increase in the inner cylinder temperature, more temperature drop is monitored in all the fin geometries. However wavy fins were found to be excellent with highest temperature drops while circular fins were not up to the mark. Fig. 2 shows the temperature distribution in various fin geometries at 1000°C, 1500°C and 2000°C inner wall temperature.

B. Comparison of Total heat flux

The maximum heat flux for circular fin is 2.3068×105 W/m2, for rectangular fin it is 2.5564×105 W/m2, for curved fin it is 2.6072×105 W/m2 and for wavy fin it is 4.6486×105 W/m2. The heat flux increases as the temperature of the cylinder increases. It can be observed from Fig. 3 that there is a considerable decrease in the total heat flux along the length of the fin with maximum being near the cylinder and minimum at the furthest edge of the fin. Wavy fin shows the maximum heat flux density while the circular fin shows the minimum. Curved fin also shows quite high heat flux density. The results obtained are quite analogous to the observations made by Karthikeyan et al. (12) and Chaitanya et al. (13).

C. Variation of temperature with length

Fig. 4 shows the variation of temperature along the length of the fin. It can be observed that temperature varies linearly with the length of the fin for all the fin geometries. The slope of the line representing wavy fin is maximum and for circular fin it is minimum i.e. the temperature is decreasing at a greater extent along the length of the wavy fin and at a lower extent for circular fin. The slope of the line in all the graph representing rectangular fin and curved fin is almost the same hence the temperature distribution for both this fin is almost the same.

D. Effect of temperature on total heat flux

Fig. 5 shows the variation of total heat flux with temperature. It is evident from the graph that the total heat flux varies linearly with increase in maximum temperature. For wavy fin the total heat flux increases to a large extent with the increase in temperature which is a desirable characteristic of a fin. The behavior of rectangular and curved fin is almost same hence temperature has almost same effect on both. The variation of total heat flux with increasing temperature is minimum for circular fin.

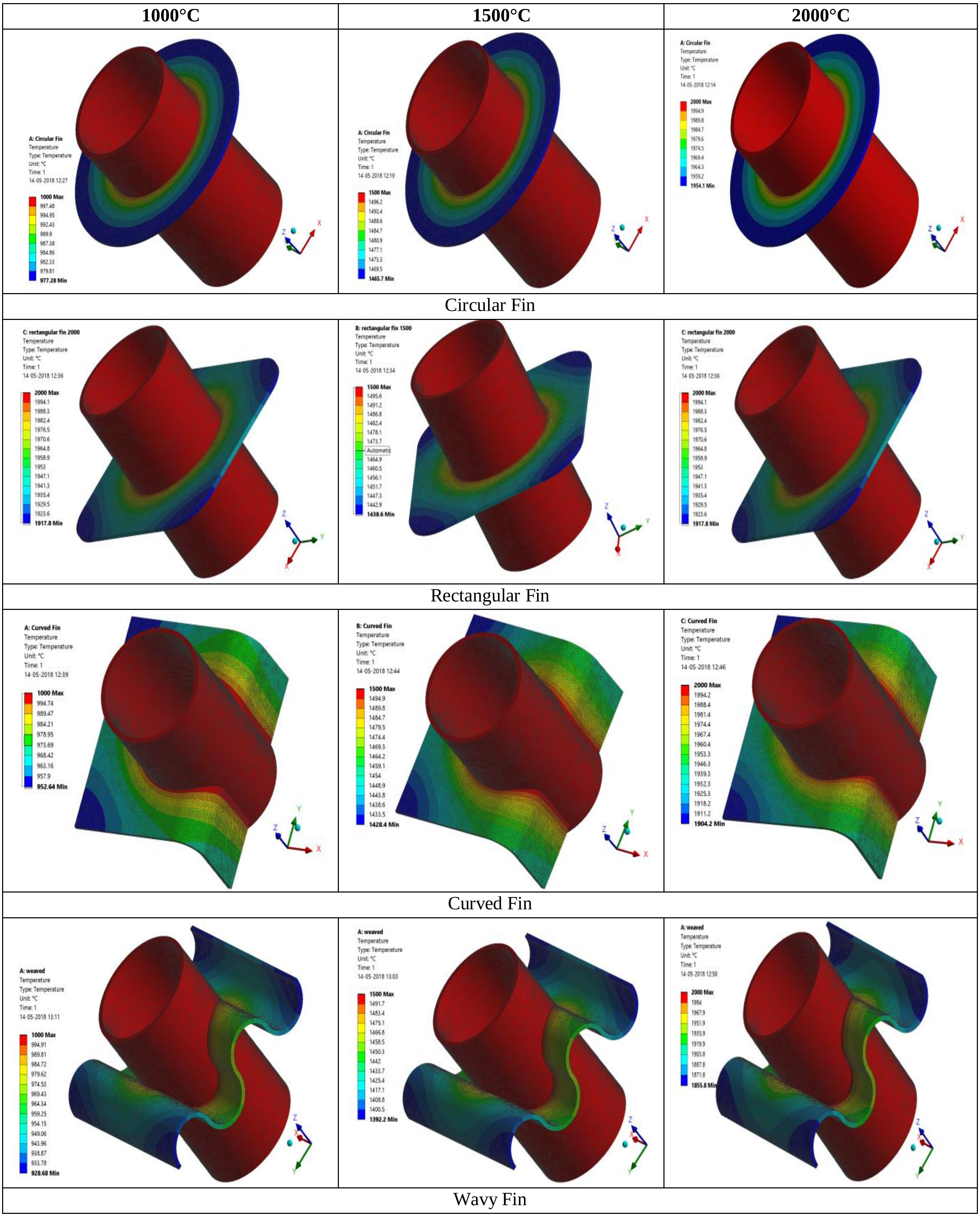

Fig 2:- Comparison of temperature distribution in fin geometries for different temperatures

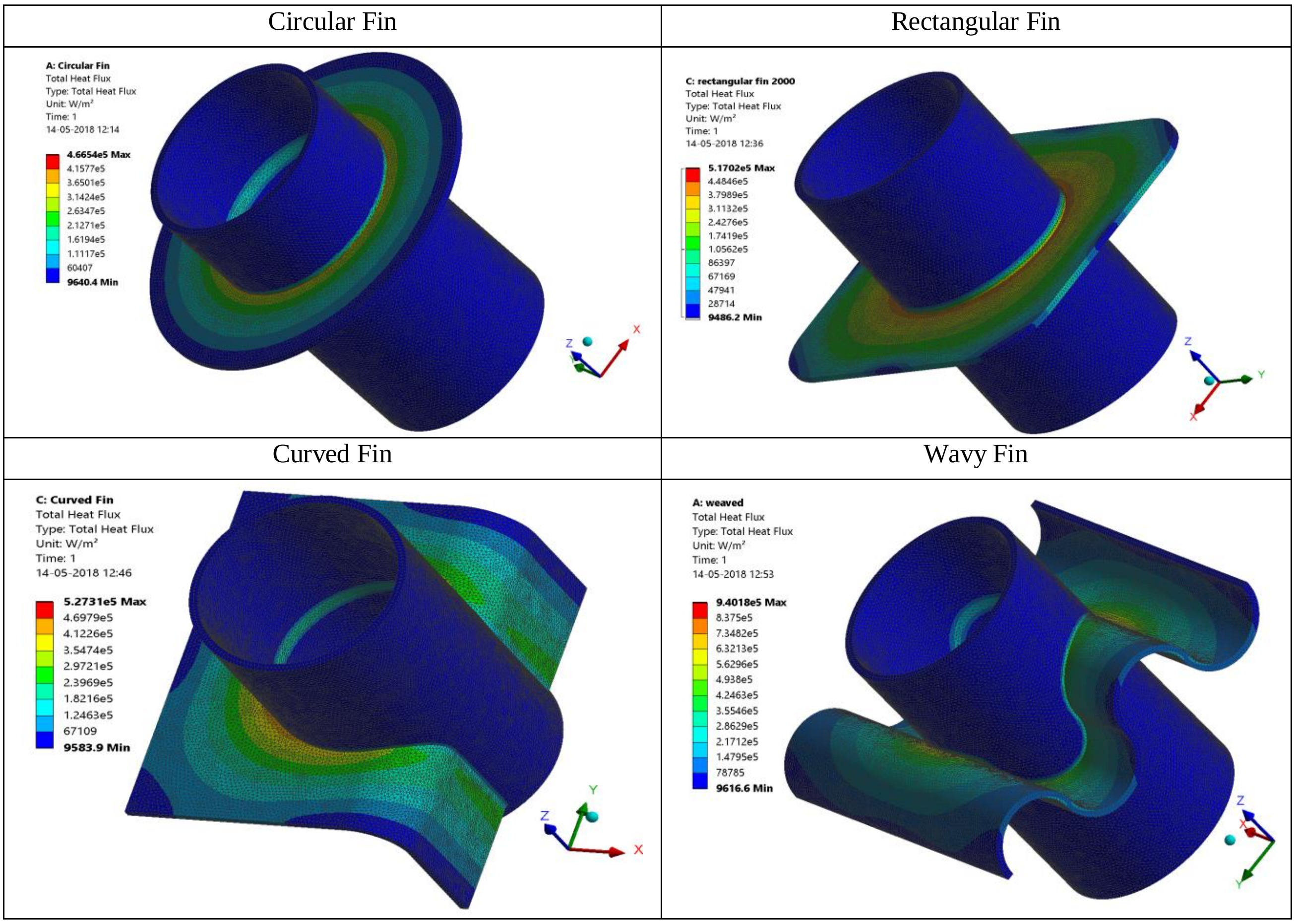

Fig 3:- Comparison of total heat flux at 2000°C temperature inside Cylinder

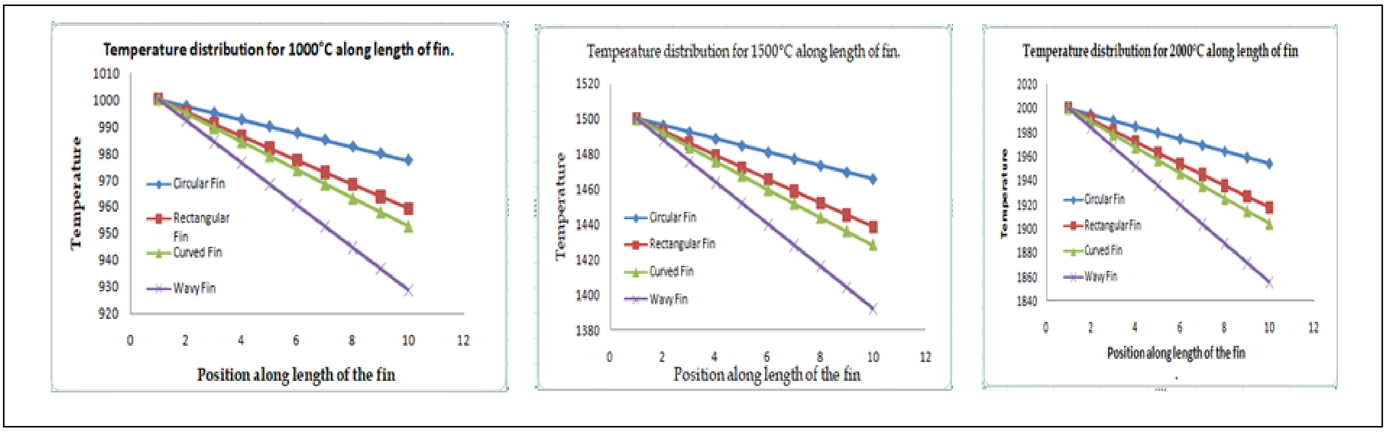

Fig 4:- Variation of temperature with the length of fin

In a similar work Gupta et al. (5) found out that for rectangular fins without slots there is a temperature drop of 19.03°C and with 75mm slots the temperature drop is of 25.28°C when the maximum temperature inside the cylinder is 285.03°C the material used in the investigation was Al 2014 alloy but in the present work the temperature drop for rectangular fin with curved edges is much more. Similarly, Rao et al. (14) concluded that for rectangular fins of Al-alloy A204, a fin thickness of 2.5mm provides a temperature drop of 43°C with circular orientation. For a maximum temperature of 558°C, a drop of 84.044°C was monitored. The temperature due to the increased turbulence and convection caused by the outside air around this type of fins.

drop for rectangular fin with curved edges is more. Hence it can be observed that the curved edges play an important role in improving the temperature drop in the fin. In the investigation by Mehul et al. (7) a C.F.D analysis was performed on various types of fins like square, circular, wavy etc. In the present investigation similar results were found through computational prediction for the case studied. At steady state heat transfer was primarily found to be a function of inner wall temperature for all the cases. However the case of wavy fin completely stands alone superior in performance comparison

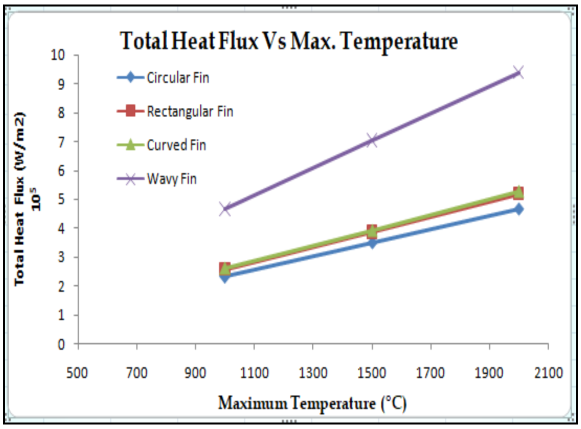

Fig 5:- Effect of Wall temperature on Total heat flux

IV. CONCLUSION

From the above case study of a 100 cc engine, it is evident that wavy fin is much more superior than other fin geometries in for all the temperature range studied. For higher temperatures similar trend is expected to continue. However the weight of wavy fin is higher than the others increasing the total weight of the engine. At the same time it compensates the load on engine coolant by transferring maximum amount of heat. The rectangular and curved fin shows almost same characteristics. Rectangular fin with curved edges more temperature drops than that without curved edges. The circular fin is advantageous for its lower weight but has the least heat transfer capacity.

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