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Comparative study of heat transfer enhancement comparative study of IC engine fins using CFD analysis

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ABSTRACT

Extended surfaces commonly known as fins offer an economical and trouble free solutions in many situations demanding heat transfer. Rectangular and Triangular fin with no perforated and with perforated have been investigated through CFD in free and forced convection to find out temperature and heat transfer coefficient of all fins in order to achieve the high rate of heat transfer of fin material. Heat transfer rate is compared under same dimension and equal volume conditions for all fins. The results show that in case of forced convection through perforated fins the airflow over the perforated surface hence reduces the total area of heat transfer, which reduces the overall heat transfer

Keywords: *Perforated Fin, Perforated, Heat transfer, Nusselt Number, force convection, CFD Modelling*

1. INTRODUCTION

Internal combustion engines are those in which the combustion takes place inside the engine cylinder, this chemical process of combustion generates the very high amount of thermal energy up to 2500ºC. This high temperature is unbearable by the fluid film between various moving parts of the engine and the fluid film may evaporate. This temperature may also cause severe damage to various parts of the engine like piton, valves etc, as it generates very high rates of thermal stresses, to protect them from the damages the temperature should be reduced up to required working condition temperature of the engine. The reduction in the temperature is only permissible up to a limit, after the limit this temperature cannot be reduced further otherwise it may affect the thermal efficiency of the engine. About 25-35% of the total generated thermal energy could be used for useful mechanical work and rest is ejected into the atmosphere.

Fins are the extended surfaces purposely provided at a place from where heat is to be removed. The amount of conduction, convection, or radiation of an object determines the amount of heat it transfers. Increasing the temperature gradient between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Fins are widely used for cooling of IC engines.

The different types of fin geometries that can be used for an IC engine are-

- Rectangular fins: The cross-section of fins is rectangular in shape
- Triangular fins: The cross-section of fins is triangular in shape.
- Trapezoidal fins: The cross section is trapezoidal in this case providing a greater surface area for heat transfer.
- Pin fins: The area for heat transfer is in the form of small pin-shaped fins called as Pin fins.

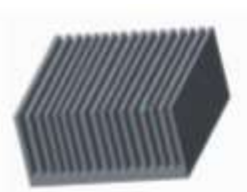


Fig. 1: Rectangular fins

Fig. 2: Triangular fins

Fig. 3: Trapezoidal fins

Fig. 4: Pin Fins

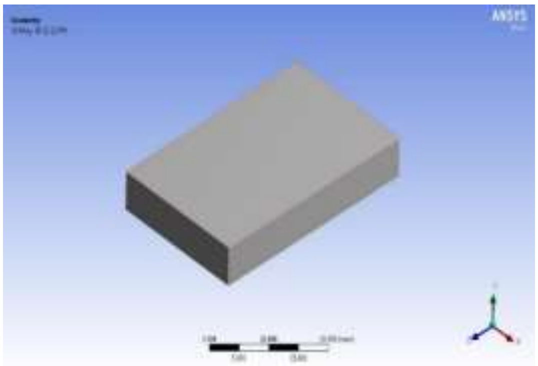
2. LITERATURE REVIEW

Ajay Sonkar (2017) performed thermal analysis, temperature variations w.r.t. the distance at which heat flow occurs through the fin is analyzed. Extensions on the finned surfaces are used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increases the more fluid contact to increase the rate of heat transfers from the base surface as compared to fin without the extensions provided to it. In comparison, trapezoidal extensions provide on fin gives the greatest heat transfer than that of other extensions having the same length and width attached to the finned surface. Abhishek Mote (2016) performed analysis of heat transfer across finned surfaces is done using CFD software. The CFD software was used to simulate the heat transfer across the fins under two different air velocities around the fins. Experiment based research done by different researchers in the past is a time-consuming process; hence CFD software was used to simulate the heat transfer across fins of an IC Engine. The simulated results were found to be comparable with experimental results. G. Bahadur Vali & Krishna Veni (2016) design an assemble cylinder and cylinder head. they used two different Aluminum alloys 6061 and 7475 performed Thermal analysis on the cylinder to determine the thermal behavior for aluminum alloys for the original model and also by changing the thickness of the cylinder head. They further explained that by reducing the thickness, the weight of the component reduces. By observing the thermal analysis results heat flux is more for the modified model than for original model. After comparing the result between two alloys, the heat flux is more for Aluminum alloy 6061 than aluminum alloy 7475. Abhishek Mote (2016) they analyzed heat transfer crosswise finned surfaces using CFD software. they thought that experiment-based research done by different researchers in the past is a time-consuming process, hence CFD software was used to simulate the heat transfer across fins of an IC Engine and simulated results compared with experimental results. Vijayakumar (2016) enhancing the performance of the I.C engine, in order to change the fin materials and geometry. It is an attempt to study and analyze the internal combustion engine fins for maximizing the performance by considering different geometrical profile, fin material, and variable fin length for weight reduction. Also, an attempt has been made to decrease the engine heat transfer. Mohsin A. Ali and (Dr.) S.M Kherde (2015) simulated the heat transfer using CFD for different shape and geometry of Fins to analyze effects on the rate of heat dissipation from fins surfaces. The heat transfer surfaces are modeled in CATIA and simulated in FLUENT software. The main aim of this work is to study different shapes and geometry of fins to improve heat transfer rate by changing fin geometry under different velocity. S. Chaitanya et.al.(2014) presented work on a cylinder fin body. Modeled and transient thermal analysis is done by using Pro/Engineer and ANSYS. Aluminum alloy 6061 is compared with Aluminium Alloy A204. R Kamboj et.al. (2014) studied the winglet type of VGs (TWPH & CTWPH) are fitted in a rectangular channel, the effect on the heat transfer (Nu) or Colburn factor (j), friction factor (f) and thermal performance factor (h) have been investigated numerically by using ANSYS-14.

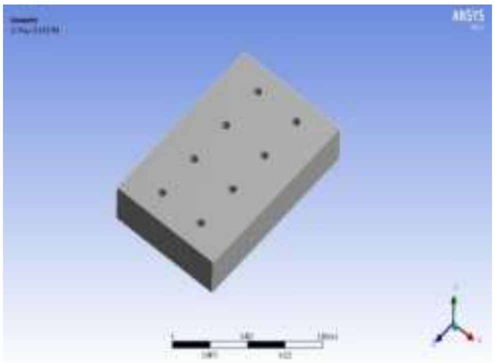
3. METHODOLOGY

3.1. Modeling and Design

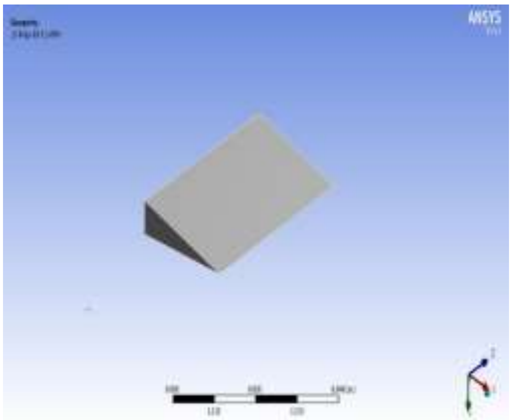
The Design of different geometrical shape of Fins was in CATIA and Analysis did by the ANSYS FLUENT software. The computational domain consists of a rectangular volume of large dimensions containing the finned body at its Centre. It was focused on the fins and appropriate boundary conditions were applied at the domain ends to maintain continuity. A fine mesh has been created near the fins to resolve the thermal boundary layer which is surrounded by a coarse external mesh for better results and fast solution. A face mesh has been done by Tetrahedron element as shown in Fig. 5.



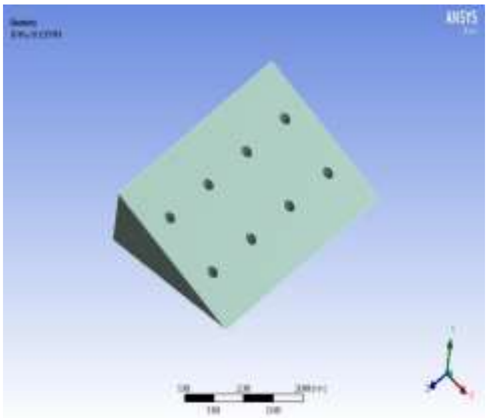
(a) Rectangular fin model



(b) Rectangular with hole (perforated) model

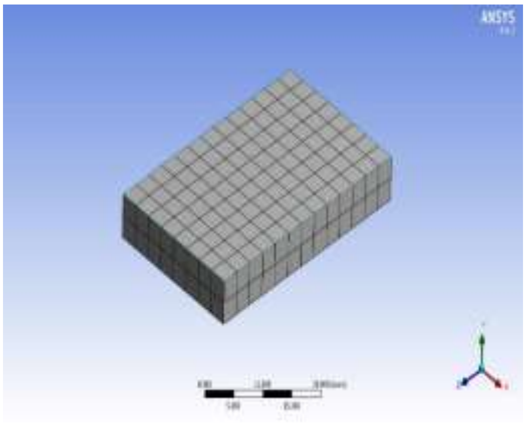


(c) Triangular fin model

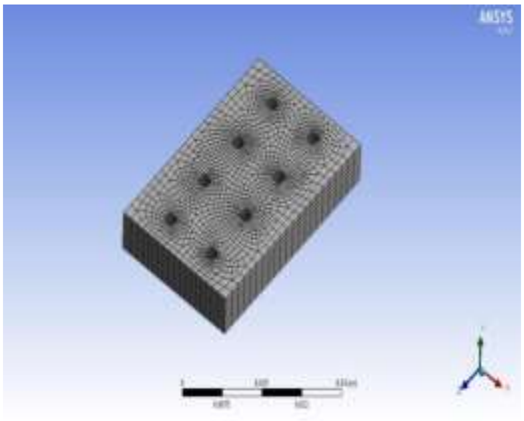


(d) Triangular with hole (perforated) model

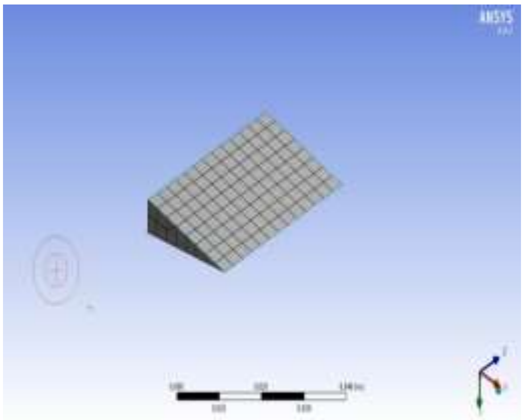
Fig. 5: Fin models



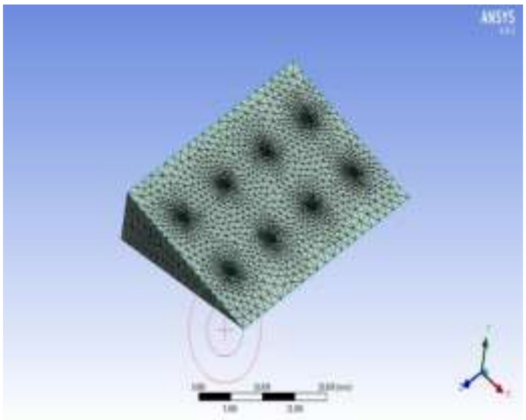
(a) Rectangular fin mesh model



(b) Rectangular with a hole (perforated) mesh, model



(c) Triangular fin mesh model



(d) Triangular with hole (perforated) mesh model

Fig. 6: Mesh models

3.2. Problem setup in Fluent

The flow around the fin has been solved at airflow velocities of 1.8 m/s and air temperatures are at 300°C. A three-dimensional steady-state heat transfer analysis has been done by assuming a constant temperature on the inner surface of the wall. The heat flux at combustion inside the engine is 5500 W/m^2. For obtaining the relation between heat transfer coefficient and velocity, the temperature was maintained constant and the simulations were carried out. Heat transfer characteristics for different configuration of the pin were obtained.

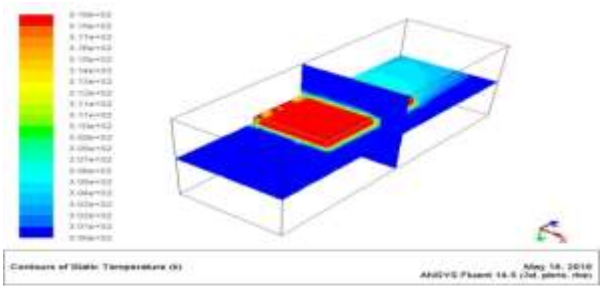
4. RESULTS AND DISCUSSION

In this work comparative study of the different fin at velocity 1.8 m/s with heat flux, 5500 W/m^2 have been analyzed. A commercial finite volume analysis package, ANSYS FLUENT 15.0 selected to perform numerical analysis on the model. The realizable green-gauss cell-based turbulence model with standard wall function was set for each model. The Segregated 3D solver with an implicit formulation was set to solve the models.

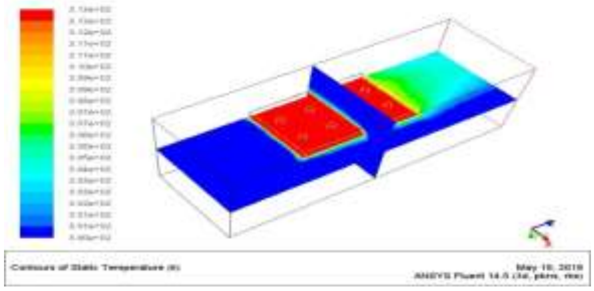
Table 1: Performance of rectangular fin and heat transfer rate at 1.8 m/s

Fin type	Convection type	Heat transfer rate, W
Triangular	Natural	1.319
Triangular	Forced	1.559
Triangular with hole(perforated)	Natural	1.137
Triangular with hole(perforated)	Forced	1.293
Rectangular	Natural	1.320
Rectangular	Forced	1.732
Rectangular with hole(perforated)	Natural	1.334
Rectangular with hole(perforated)	Forced	1.655

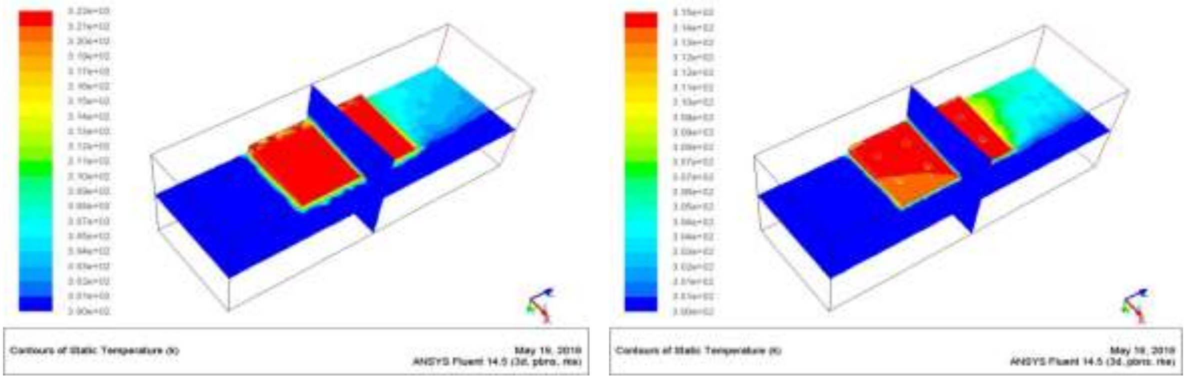
4.1 Temperature contour:



(a) Rectangular fin



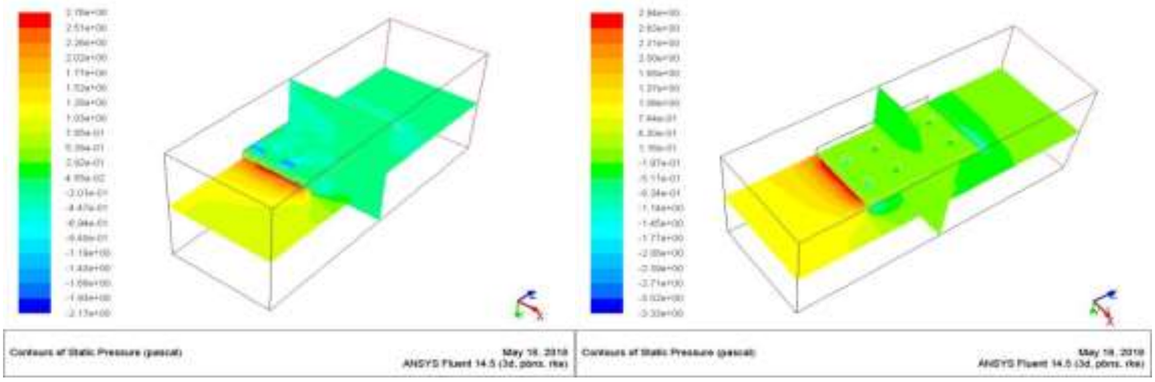
(b) Rectangular fin with hole (perforated)



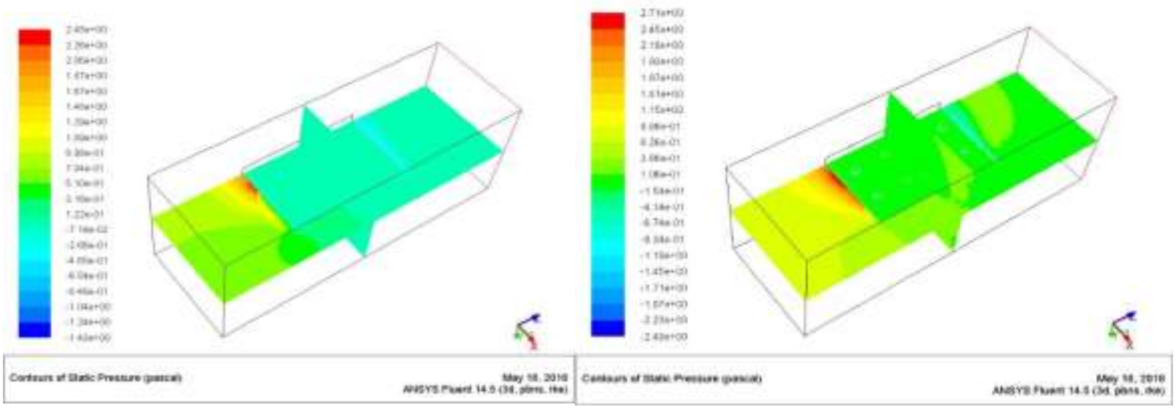
(c) Triangular fin **(d) Triangular with a hole (perforated)**

Fig. 7: Temperature plot

4.2 Pressure contour



(a) Rectangular fin **(b) Rectangular fin with hole (perforated)**



(c) Triangular fin **(d) Triangular with a hole (perforated)**

Fig. 8: Pressure plot

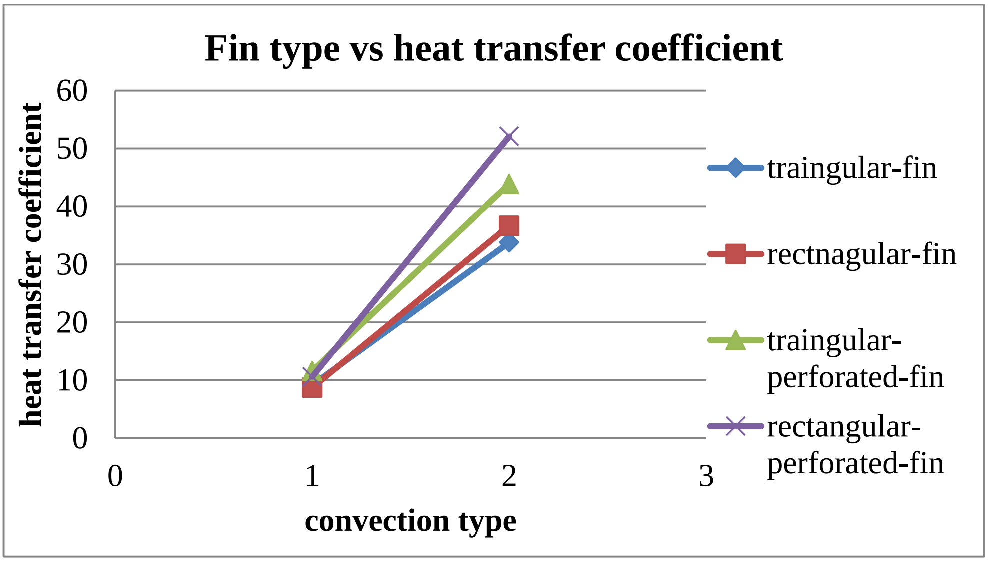


Fig. 9: Heat transfer coefficient for different fins

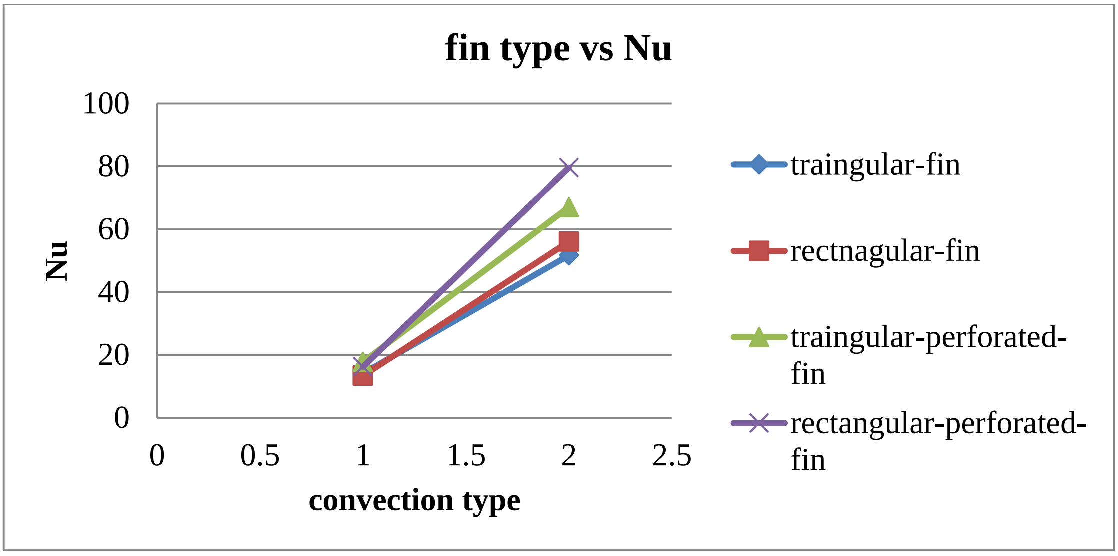


Fig. 10: Nusselt no. for different fins

5. CONCLUSION

Based on the results obtained through CFD simulation the following conclusion can be drawn:

1. The fin model is simulated with and without forced convention for different types of fins.
2. Heat transfer differs in both free and forced convection. And from the data, it can be deduced that normal fins perform better than perforated fins in all cases
3. Heat transfer rate in rectangular fins is better than triangular fins in all the cases (normal, perforated, free convection, forced convection)
4. Heat transfer rate increases during forced convection in all the cases (rectangular, rectangular perforated, triangular, triangular perforated) when compared to free convection
5. Heat transfer in perforate fins decreases as compared to full fins in all cases (free and forced convection)
6. Heat transfer in rectangular perforated fins decreases from its other counterpart in both the cases (free and forced)
7. Heat transfer in triangular perforated fins decreases from its other counterpart in both cases (free and forced)
8. The difference in Heat transfer in case of free convection in both perforated and its counterpart be it rectangular or triangular is very less. BUT in case of forced convection, the difference in heat transfer increases drastically
9. It can be deduced that in case of forced convection through perforated fins the airflow over the perforated surface hence reduce the total area of heat transfer, which reduces the overall heat transfer

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