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Investigation on Cooling Rate of Different Fin Design of an I.C. Engine by use of CFD

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Abstract: *The Cylinder block is most important components in IC engine vehicles, which is under very high temperature stresses. To control the engine in efficient way we required to cool the cylinder, extended surface is provided on the cylinder to increase the speed of temperature reducing. By doing thermal analysis on the cylinder block fins, it is helpful to find the heat transfer outside the cylinder. The principle use in this research is to improve the heat dissipation rate by using the surrounding air flow direction and new geometry. We all know that, by expanding the surface area we can improve the heat transfer rate, so designing fin geometry. The main aim of using these cooling fins is to cool the engine cylinder by environmental air. The main aim of the research is to analyze the thermal properties by varying geometry, material and thickness of cylinder fins. Model is created to analyze and simulation purpose in solid works software. The models are created by varying the geometry and shape of fin. Present thickness and shape of the fin is changed. The 3D modelling software used is Solid works. In the current year Material used for manufacturing cylinder block's fin body is Aluminium Alloy 204 it has thermal conductivity of 110-150W/mk. In this research, it is replaced with aluminium alloy 6061 and analysis is done in Ansys.*

Keywords: IC Engine, Fins, Solid works, Ansys, CFD Analysis, etc.

I. INTRODUCTION

A. ENGINE COOLING

A very high temperature stress generated in side ic engine of automobile around 2300-2500 ^{O}C. such high temperature is problematic for the lubricating oil and the moving parts. So cool down engine at optimum temperature is must require. More cooling is also reducing the thermal efficiency. Hence, main objective of cooling system is to maintain the engine running at its most proficient working temperature. It is known to us that the engine is moderately inefficient when it is cold and thus the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. [1]

B. ADVANTAGES OF AIR-COOLED SYSTEM

- Light system than the water system because doesn't require a radiator and pump
- No chances of Cooling water leakages
- Not required Coolant and antifreeze solutions
- It is suitable for cold seasons and creates no problem of frizzing
- It is less effective than a water-cooling system
- Use air vehicles and motorbikes

C. GENERAL TYPES OF FINS ARE

a) Rectangular fins
b) Triangular fins
c) Cylindrical fins
d) Parabolic fin
e) Trapezoidal fins etc.

II. LIERATURE WORK

Abhishek et al.[2] published paper on Comparative numerical investigation of rectangular and elliptical fins for air cooled IC engine in which they used CREO software for modelling and for analysis they used Analysis software. Performed the analysis with 673 °K temperatures of inner of engine cylinder block. [2]

- The average static temperature for elliptical fin tip is 656 °K and for rectangular fin tip is 657 °K.
- the rate of heat transfer is high due to its geometric effect in case of elliptical fin than rectangular fin.
- Average surface heat transfer coefficient for elliptical fin is 57.04 W/m2K and for rectangular fins it is 54.15 W/m2K.

J. Laxmi Prasad, et. al[3] find that Thickness of the fins lowered and increasing no of fins this analysis carried out by providing slots on fins also Trapped air flow over it and due to the swirl of the air into slots it will cause more heat transfer and cools engine more effectively.

B.J. Patil[4] find that the step design fin is most effective and is able to remove the more amount of heat from the cylinder.

P. Senthilkumar[5]**,** shows Triangle profile fins yield a lower tip temperature distribution than other profiles like circular and rectangle, V-type fin array design performs better than rectangular vertical fin array.

C. Thiagarajan[6] research on Heat transfer analysis and optimization of engine cylinder liner using different materials like cast iron, magnesium alloy and titanium alloy and finds magnesium alloy gives higher thermal flux than another alloy [6].

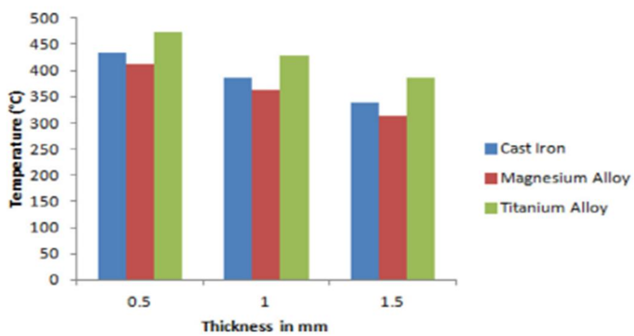

Fig. 12. Temperature changes (°C).

Figure 1.1: Temperature Changes in Different Alloy

S. Padmanabhan,[7] published paper and finds- Rectangular-shaped fin transfer 10% extra heat transfer than the triangular-shaped fin in all strokes of the test engine in both CFD and analytical methods.

Dr. S. C. Kongre[8] finds the perforated fin system enhances heat transfer. Along with the geometry of perforation the spacing between two perforations & thermodynamic properties of material also have significant impact on the heat convection process. More number of fins results in cooler system, stack of modified fin is found to be more effective in heat transfer also results in material reduction.

Pardeep Singh [9]works on fin with extension with creating model in AutoCAD software and done analysis in Ansys software and finds- Fin with extensions provide near about 5 % to 13% more enhancement of heat transfer as compare to fin without extensions, Heat transfer through fin with rectangular extensions higher than that of fin with other types of extensions, The effectiveness of fin with rectangular extensions is greater than other extensions.

Deepak Tekhre et al. [10] get outcome [10]

- The turbulence of air also gets increased by creation on holes.
- Fin arrays with rectangular extensions provide near about 13 % to 21% more enhancement of heat transfer as compare to other type of fins.
- Large number of fins with less thickness can be preferred in high-speed vehicles than thick fins with less numbers as it helps inducing greater turbulence and hence higher heat transfer.

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III. MODELLING AND ANALYSIS OF IC ENGINE FINS

Model is created with the data gain from the present model of cylinder block of hf deluxe bike. current material used were aluminum alloy 204 with thermal conductivity 120 w/m^{0}k.

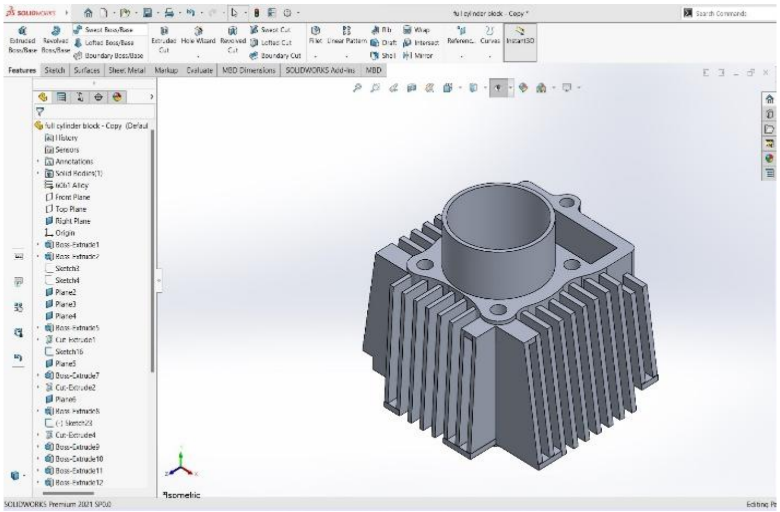

Figure 1.2: Modelling of Cylinder Block of Existing Bike

Boundary Conditions: -

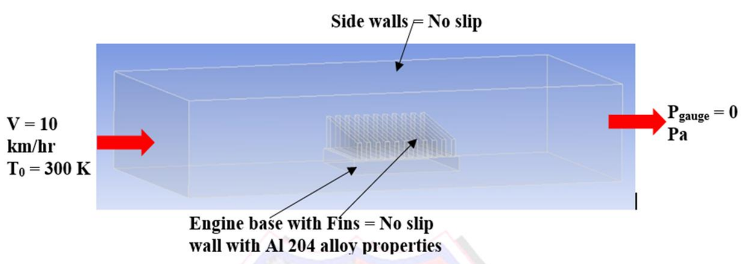

Figure 1.3: Boundary Condition

The generated grid is imported to ANSYS Fluent solver for the computational fluid dynamics analysis. A step-by-step procedure is mentioned for the solver set-up. Analysis type is Steady state analysis. The energy equation is turned ON due to Temperature involvement in the stated problem.

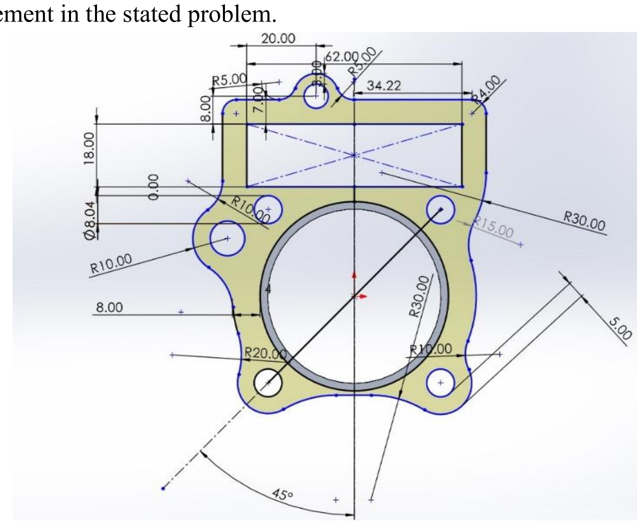

Figure 1.4: Dimensions of Existing Cylinder Block

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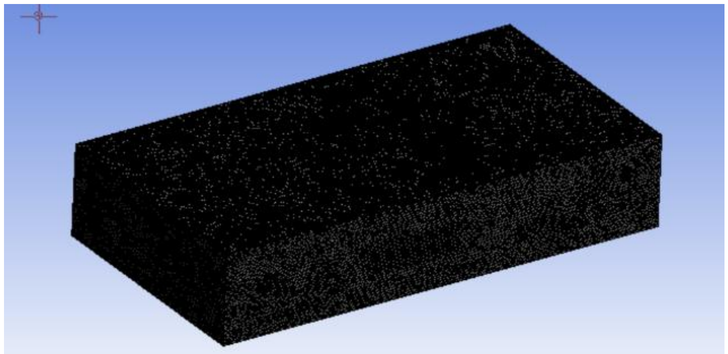

Figure 1.5: Domain Grid

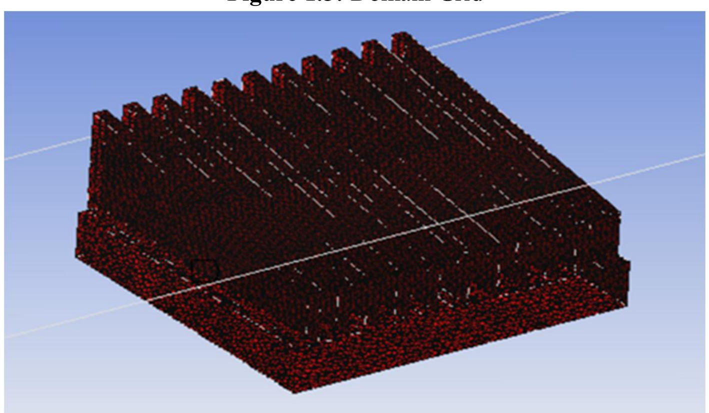

Figure 1.6: Grid for Engine Fins

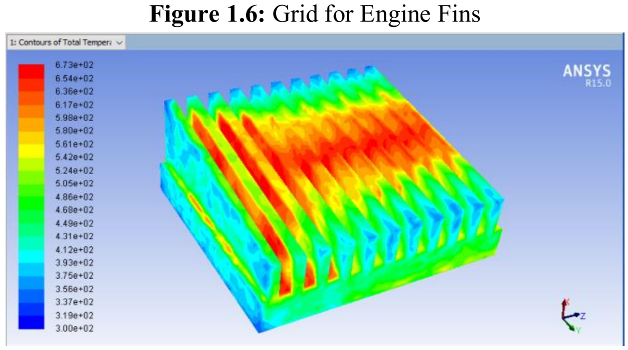

Figure 1.7: Contour of Total Temperature (base model)

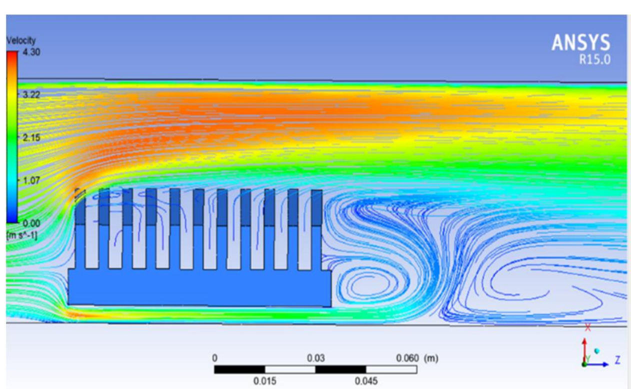

Figure 1.8: Velocity Contour (base model)

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- Inlet boundary layer growth is observed upstream to fins by approaching flow.
- Front four fins dissipates more heat by accelerating flow and trapping within it. Later does not.
- Flow accelerates from the tip of the first fin and forms separated flow.

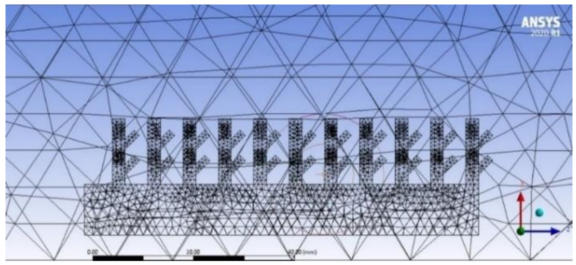

Figure 1.9: Grid for Engine with Type (1) Modified Fins

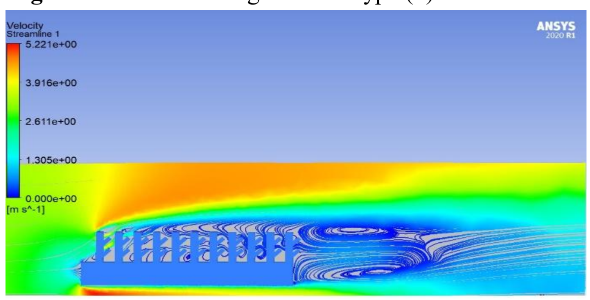

Figure 2.0: Streamlines Modified Model 1

IV. OBSERVATIONS

- Trapping of the upcoming flow within first few fins are clearly observed.
- Swirl creation in between fins is observed.
- Downstream to fins, wake zone is formed.
- Flow separation region is observed
- Low velocity within the trapped flow in fins. This helps in heat dissipation.

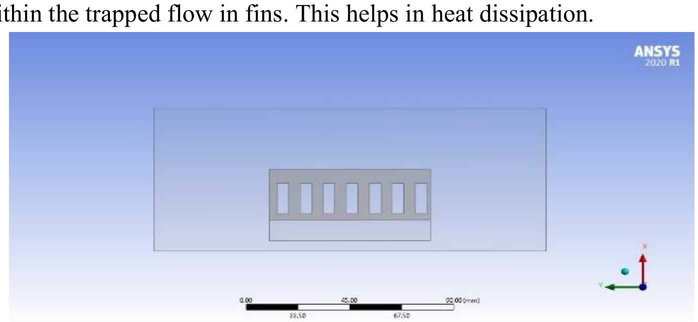

Figure 2.1: Modified Fin2

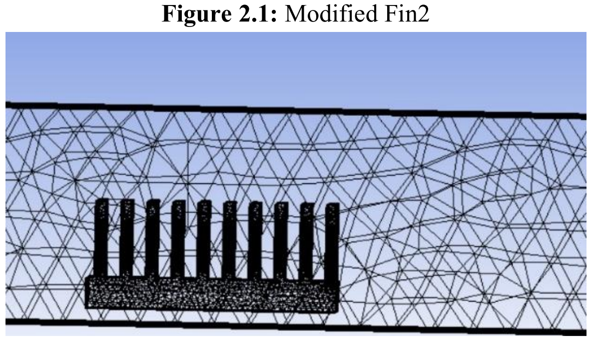

Figure 2.2: Domain Grid

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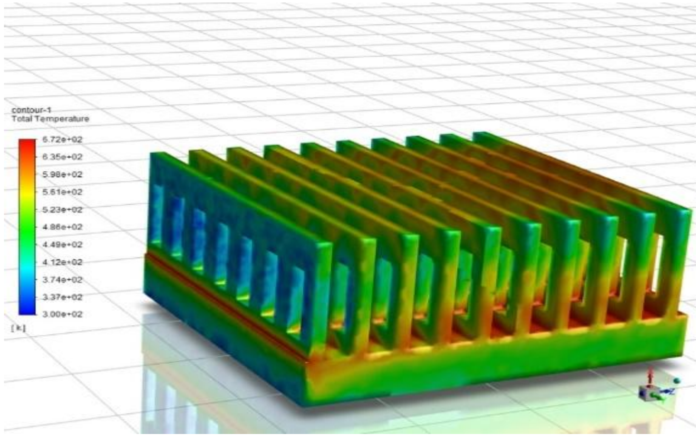

Figure 2.3: Total Temperature Contour (Isometric view)

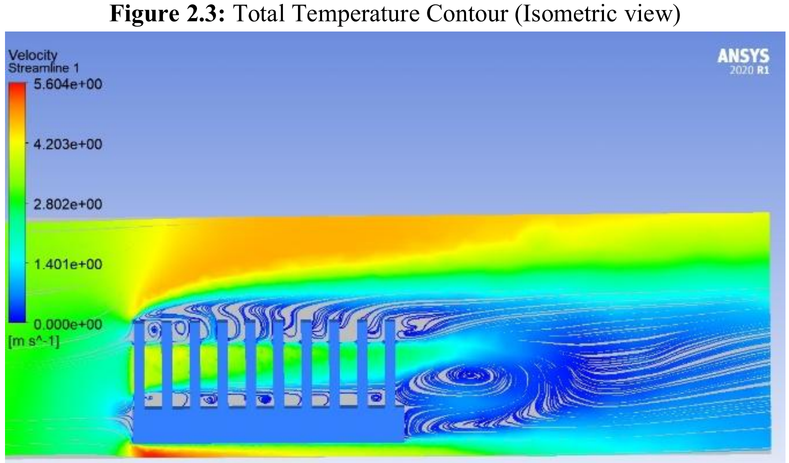

Figure 2.4: Streamlines Modified Model 2

Observations:

- Reduction in trapping of the upcoming flow within first few fins are clearly observed as compered previous cases.
- Downstream to fins, wake zone is formed.
- Flow separation region is observed
- Low velocity within the trapped flow in fins. This helps in heat dissipation

V. RESULT AND DISCUSSION

The thermal analysis of fins by modifying its geometry has been completed. By observing the analysis, the results of aluminium alloy 6061 fins, the result from CFD are shown by means of graphical comparison. The following images shows the temperature contour of normal fins, modified fins 1 and modified fins 2.

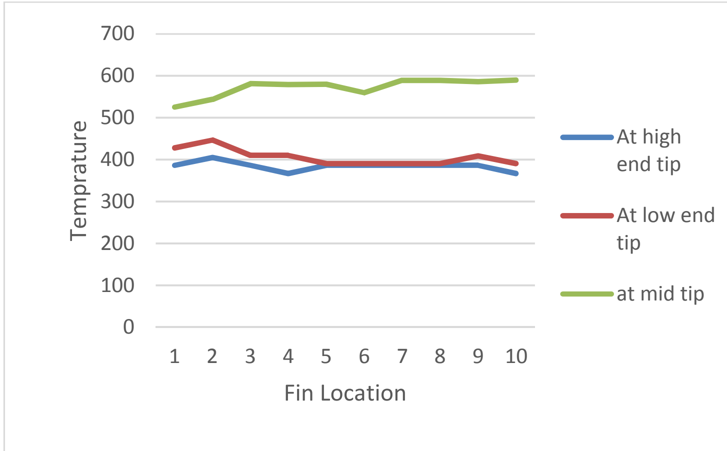

Figure 2.5: Temperature Graph on Original Fins

- For original fins the `average temperature on the tip of the high end of the fin is 384.1 K, average temperature at low end tip is 405.9 K, and temperature on the mid end of the fin is 572.3 K
- Minimum temperature observed on the original fin is 367 K

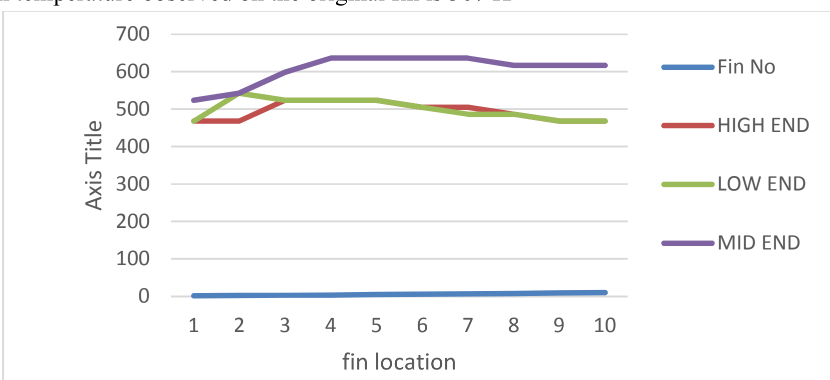

Figure 2.6: Temperature Graph on Modified Fins 1

- For modified fins 1 the `average temperature on the tip of the high end of the fin is 493.934 K, average temperature at low end tip is 499.532 K, and temperature on the mid end of the fin is 605.847 K.
- Minimum temperature observed on the modified fin 1 is 467.8 K.

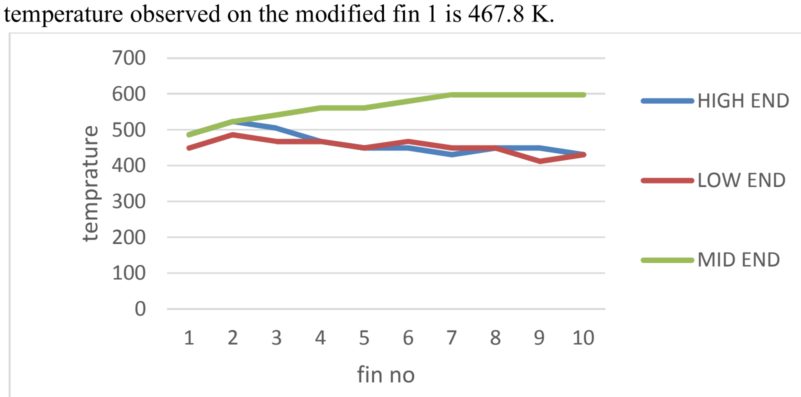

Figure 2.7: Temperature Graph on Modified Fins 2

For modified fins 2 the `average temperature on the tip of the high end of the fin is 463.744 K, average temperature at low end tip is 452.588 K, and temperature on the mid end of the fin is 564.24 K.

Table Error! No text of specified style in document.**-1:** Temperature Comparison of Three Models

	Original	**Modified 1**	**Modified 2**
Avg. temp. on left end of fin	384.1	493.934	463.744
Avg. temp. on right end of fin	405.9	499.532	452.588
Avg. temp. on mid end of fin	572.3	605.847	564.24
Min. temperature	300	300	300
Max temperature	673	673	673

From the table it can be observed that heat transfer is higher in modified model 2 as air can flow from the all the fin surfaces and the gap, also due complex geometry some following points were observed

- Front fins dissipate more heat by accelerating flow and trapping within it. Later effectiveness reduces.
- Low velocity within the trapped flow in fins. This helps in heat dissipation.

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