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Steady State Thermal Analysis of Engine Cylinder Fins with Different Circular Holes by Using CFD

Vishal Kumar Singh*, Prof. Rohit Soni**

*(Mechanical Engg. Department, Trinity Institute of Technology and Research, Research Scholar, RGPV Bhopal)

**(Mechanical Engg. Department, Trinity Institute of Technology and Research, Professor, RGPV Bhopal)

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Abstract:

Motors are ineffectual, so more warmth vitality enters the motor than turns out as mechanical power; the variety is squander warm which must be expelled. Inside ignition motors take out waste warmth through cool admission air, hot fumes gases, and unambiguous motor cooling. Motors with higher proficiency have more vitality clear out as mechanical movement and less as waste warmth. The cylinder block is an integrated structure comprising the cylinder of a reciprocating engine and regularly a few or the majority of their related encompassing structures (coolant passages, admission and fumes sections and ports, and crankcase).In this investigation the model of motor cylinder block is structured and examined in the ANSYS 22 R1. The primary spotlight on the investigation is to make as quick as warmth exchange from the cylinder block. For this the gaps are made in the cylinder block holes because of which the warmth exchange rates are expanded as quick. The results demonstrate that aluminum amalgam cylinder blocks with circular holes are more effective than those without circular holes.

Keywords:Cylinder block, Steady State Thermal, ANSYS, Heat flux, Temperature, Circular hole

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I. INTRODUCTION

The Cylinder is one of the key components of a motor, or, to put it another way, high temperature variants and heated loads. Blades are placed on the cylinder's surface to increase the rate of heat exchange in order to cool the cylinder. Balances, which are mostly a mechanical system, are used to convectively and conductively cool other kinds of structures. Expanded blades are notable for improving the warmth move in IC motors. The development of air-cooling framework is exceptionally less complex. In this manner it is critical for an air-cooled motor to use the blades adequately to acquire uniform temperature in the Engine cylinder. A motor is said to be inner burning if a fuel is ignited in a flaming chamber. Here, a part of the motor, such as a combustion chamber, the turbine blades, or a spout, receives coordinated power from the spreading of the elevated temperatures and high-weight gases produced by burns. This power exchanges the segment over a separation, creating helpful mechanical vitalityWater-cooled motors have overtaken air-cooled motors as the most efficient option, however all of the motorcycles still use air-conditioned engines because to their reduced weight and smaller size requirements. Additionally, after switching from heat-to-heat control, a cycle of heat evacuation has to be performed. By using methods involving liquids like air and moisture, warmth is transferred to the weather. Warmth is transported to the climate via motors using low-temperature liquids. The temperature of the engine fluctuates during the power because of the burning process. In the event that excessive heat is not released, motor components inevitably fail due to the high temperatures.

earth's temperature is increasing. The carbon capture in heat sinks or radiators, fins are used as heat exchange fins to control temperature. Fins are surfaces that increase the rate of heat flow to or from the earth by enhancing convective in the study of heat exchange. The heat exchange may be expanded by increasing the temperature angle between the protest and the soil, the convective heat exchange coefficient, or the protest's surface area. Expanding the surface area of a protest by adding a balance may be a practical solution for problems with heat transfer.

II. LITERATURE REVIEW

Various researches carried out in past decade shows that heat transfer through fin depends on number of fins, fin pitch, fin design, wind velocity, material and climate conditions

K.K. Risal, Sharon Z. Vargheseet al. (2022) In this paper, we investigate the optimal design of engine fins for maximum heat dissipation. The total heat flux through a fin array is optimised with each dependent parameter varied within their physical ranges. ANSYS 19 is used for the purpose of modelling and analysis. Genetic algorithm (GA) is used to optimise the factors affecting the heat transfer. The steady state analysis solver in ANSYS participates in the fitness evaluation, an integral part of GA. A technique where ANSYS software is fully integrated with the genetic algorithm increases both the accuracy and speed in obtaining the results. The program flow automatically alternates between the Python program and ANSYS until the convergence criteria is met.

Shivangi Sachar,Yusuf Parvezet al. (2023), The two most important scientific challenges that need worldwide attention are the energy crisis and air pollution. The fast depletion of fossil resources, which has increased fuel prices, is the main cause of a spike in energy expenses. According to an analysis of IC engines, more than half of the energy obtained from fossil fuels is lost to the planet due to thermodynamic limitations. An engine's performance and attributes may be changed by extended use at high temperatures. Regulating and maintaining the temperatures of the engine within the acceptable range is one technique to reduce these losses. In order to transport heat away from the engine surface, cylinder blocks frequently contain expanded surfaces known as fins. The purpose of this research is to illustrate how changes in fin efficiency and horsepower may be achieved by changing the material, type, quantity, and design of the fins. The optimal number of fins has been shown to considerably increase fin efficiency, and fin extension may increase heat transmission by 5% to 13%.

Haseeb Tariq, Ramisha Sajjad et al. (2023) Ansignificant option to increase energy efficiency in industrial operations is waste heat recovery. Effective heat recovery uses heat exchangers. As a result, heat exchangers play a significant part in waste heat recovery systems. A heat exchanger's exclusive heat transfer may be improved through a variety of techniques, including changing its geometries and adding micro-additives at varying concentrations. In this follow-up, a redesigned finned heat exchanger shape is created using CFD analysis. Fins are added to the interior pipe of the modified heat exchanger to enhance heat transmission. Working fluid is injected with varied quantities of graphene oxide particles. Utilising ANSYS Fluent and the k-omega turbulence theory of exhaust flow, a steady computer model is carried out.

Moti Lal Rinawa, Prashant Chauhan et. al. (2022) This study looked into fin surfaces of different forms to ascertain the rate of heat transmission that was most effective. On the structure of fin surfaces, namely ordinary fins with rectangular cross sections (R-Fin), fins with several steps (S-Fin), and numerous step fins with creases (D-Fin), models, examinations, and studies have been done. According to conceptual and numerical analysis, fin surfaces with more surface area transmit heat more effectively. Dimpled fins enhance the outer area and heat transfer of the fins, according to numerical data. The fins are 5 mm, 4 mm, and 3 mm in diameter, and the dimples were made with varying dimensions to match them. A static analytical technique was used to analyse the dimples.

Zhentao Liu, Meiyao Sun et. al. (2022) The regular functioning of the radiators for piston aerospace engines would be hampered by the decrease in atmospheric density, which would have an impact on the aircraft's performance in all respects. In order to increase the heat transfer capacity, this research initially presented a hybrid construction made up of a plate-fin heat exchange system and a front-positioned guide plate. At various elevations, CFD (computational fluid physics) simulations were used to assess and project the improvement. Additionally, the ideal guide plate arrangement characteristics were investigated, including the shielding percentage and inclination angle. The idea of effective mass rate was initially put out in order to scientifically clarify the connection of heat dissipation, flow efficiency, and structural factors. The findings showed that at 20 km the elevation, the composite structure's increase in heat transfer rate had a maximum efficiency rate of 34.9%.

B.J. Patil et al. (2021) The key component and beating heart of the engine is the cylinder. The cylinder must have the durability to withstand extreme heat loads and temperature swings. Fins are positioned on the cylinder's surface in order to speed up heat transmission and help cool the cylinder. To determine how much heat is dissipated within the engine cylinder, thermal study of the cylinder fins is useful. On the cylinder's outside, fins are installed to help in heat transfer. We can determine the heat transfer rate by doing a thermal examination of fins. In many applications, including cooling, the fluctuation in temperature distribution over time is of interest. Critical design parameters may be able to be found for better life with the use of a realistic thermal simulation.

III. GEOMETRY SETUP AND MODELLING

A. *Assumptions for analysis*

A Steady state thermal analysis calculates the effect of steady thermal load on a system or component, analyst was also doing the steady state analysis before performing the transient analysis. We can use this analysis to determine temperature, thermal gradient, heat flow rates and heat flux in an object that do not vary with time. A Steady state thermal analysis may be either linear with constant material properties or nonlinear with material properties that depend on temperature. The thermal properties of most material do vary with temperature, so analysis is usually nonlinear.

- The temperature of the surrounding air does not change significantly.
- Constant heat transfer coefficient is considered at the air side.
- The heat generation is neglected.
- Loads are constant.
- Most of physical properties are constant

B. *Geometry of membrane*

The geometric dimension of the cylindrical block having circular fins with or without circular holes is shown in the Figure 5.1. For simulating the cylindrical block have circular fins with circular holes ANSYS 22R1 finite element control volume approach has been used.The geometry for doing simulation analysis is borrowed from K.K. Risal, Sharon Z. Varghese et al. (2022). The geometric dimension of the cylindrical block having 2.5 mm thick circular fins without modified geometry is using same as the base paper.

A cylinder block with modified geometry is using for the analysis. We are creating the 4 no. of circular hole at different dimension (3 mm, 4mm, 5mm and 6mm).

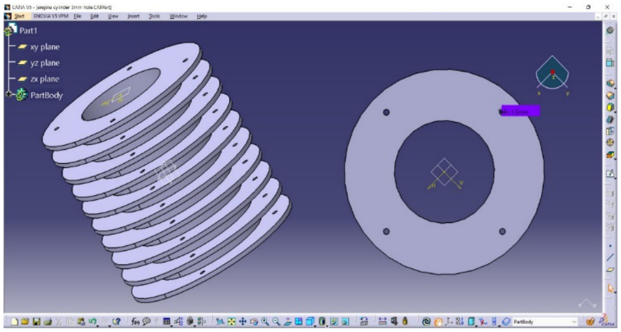

Fig. 1.1 Geometric dimension of the cylindrical block having circular fins with 3 mm circular hole.

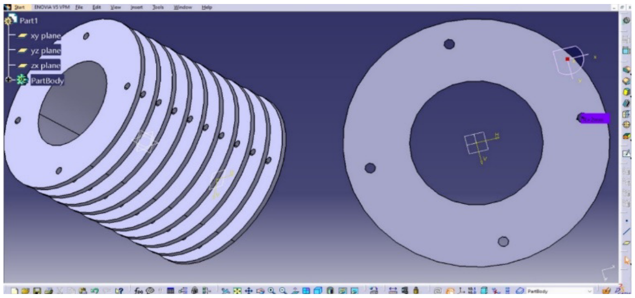

Fig. 1.2 Geometric dimension of the cylindrical block having circular fins with 4 mm circular hole.

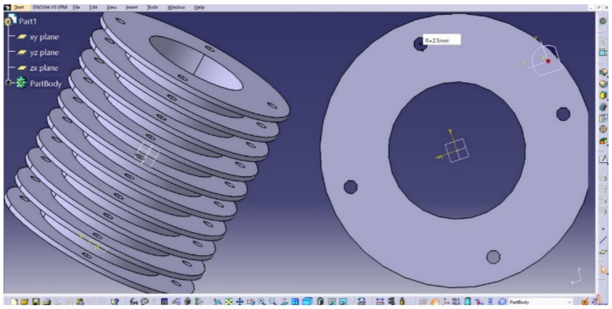

Fig. 1.3 Geometric dimension of the cylindrical block having circular fins with 5 mm circular hole

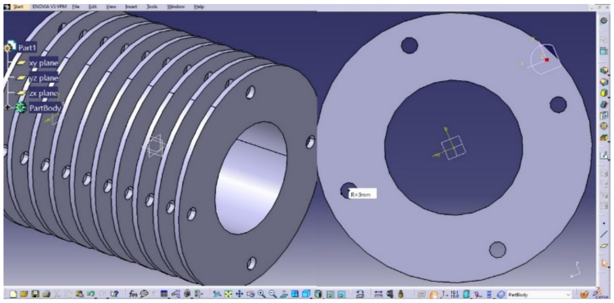

Fig. 1.4 Geometric dimension of the cylindrical block having circular fins with 5 mm circular hole

The engine cylinder considered for analysis is of a 4 stroke 100- cc petrol run motorcycle. The fins considered are uniformly thick, annular fins. The material used for the analysis of the engine cylinder and fins is Aluminium Alloy 6061 (thermal conductivity (k) = 180 Wm^{-1}K^{-1}, specific heat (C$_p$) = 896 Jkg^{-1}K^{-1}, density (q) = 2700 kgm^{-3}). The engine cylinder length is 100 mm with outer and inner radius as 32 mm and 25 mm respectively. The five input parameters along with their dimensions are shown in Table 1. The basic geometry of the engine cylinder and fin array is shown in Fig. 1.

TABLE I
GEOMETRY PARAMETERS

S.N.	Geometrical Parameter	Base paper	Present Study
1.	Inner radius of cylinder block	12.5 mm	12.5 mm
2.	Outer radius of cylinder block	32 mm	32 mm
3.	Fin radius	25 mm	25 mm
4.	Fin thickness	2.5mm, 3mm	2.5mm, 3mm
5.	No. of fins	10	10
6.	Air velocity	20 m/s	20 m/s
7.	No. of hole in fins	-	4
8.	Diameter of hole in fins	-	3mm,4mm,5mm,6mm

TABLE III
PROPERTIES OF THE ALUMINIUM ALLOY 6061

S.N.	Materials properties	symbol	values
1.	Thermal conductivity	**k**	180 Wm-1K-1
2.	Specific Heat	C_P	896 Jkg-1K-1
3.	Density	ρ	2700 kgm-3

C. Meshing of geometry

The ANSYS 22R1 pre-processor stage resulted in the construction of a three-dimensional discretized model. The programmed ANSYS creates a fine mesh, despite the fact that grid types and simulation results are connected. The structure as a whole is discrete in the final volume due to this need. Mesh is made up of ICEM Tetrahedral cells of unit size with triangular frontier faces. In this analysis, a medium fluid curvature is utilized with a mesh metric.

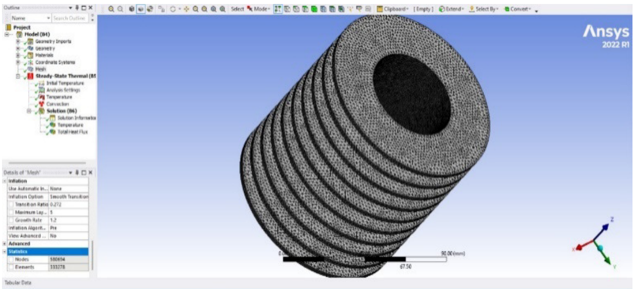

Fig. 1.5. Meshing of cylinder block without hole on fin (2.5 mm).

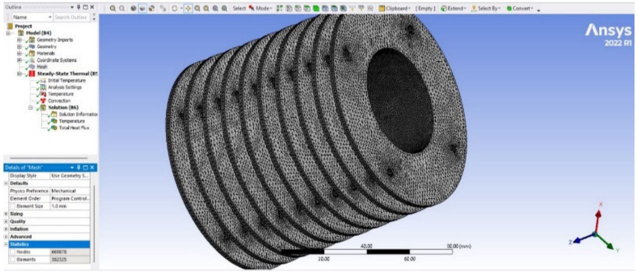

Fig. 1.6. Meshing of cylinder block with hole (3mm) on fin (2.5 mm).

D. Technique

After geometry and meshing are successfully finished, setup comes next. This design is simulated using a velocity formulation-absolute, pressure-based and steady model. We employed the standard, viscous-k, and e models in this. Aluminium is employed as the material for the membrane's entrance and exit sections, while ash-solid graphite, which is made of carbon, is applied for the membrane zone. After the computation was successfully finished, we discovered a pressure difference at the membrane's intake and outflow, and we also used the solution to acquire velocity fluctuated from the inlet to the exit. With the use of this method, additional parameters can be calculated as well, such as mass flow rate.

TABLE IIIII
MESHING DETAIL OF MODEL OF FIN (2.5 MM THICK)

S. No.	Parameters	Without hole on fin	With hole on fin
1	Curvature	On	On
2	Smooth	High	High
3	Number of nodes	580694	669878
4	Number of elements	333278	382325
5	Mesh metric	None	None
6	Meshing type	Tetrahedral	Tetrahedral
7	Element size	1 mm	1 mm
8	Diameter of hole in fin	-	3mm

TABLE IVV
MESHING DETAIL OF MODEL OF FIN (3 MM THICK)

S. No.	Parameters	Without hole on fin	With hole on fin
1	Curvature	On	On
2	Smooth	High	High
3	Number of nodes	392048	698904
4	Number of elements	222514	399387
5	Mesh metric	None	None
6	Meshing type	Tetrahedral	Tetrahedral
7	Element size	1 mm	1 mm
8	Diameter of hole in fin	-	3mm

IV. RESULTS AND DISCUSSIONS

This section is aimed at evaluating the engine cylinder block with modified geometry. The variations in the temperature distribution and heat flux are measured at different modified geometry of cylinder block in order to research the rate of heat transfer

A. Boundary Conditions

The experimental setup used in their study consisted of a set of two engine cylinders upon which fins of thickness 2.5 mm and 3.0 mm were modelled. The numerical analysis was done using the ANSYS software and the thermal model considered was a steady state thermal model (inner cylinder temperature = 285^0C, film co-efficient = 25 $Wmm^{-2}C^{-1}$). The same loads and design specifications were recreated for the numerical analysis conducted in our study for the purpose of validation. The output parameter taken for comparison is the fin tip temperature.

TABLE V
DETAILS OF BOUNDARY CONDITIONS

Detail	Value
Cylinder block	Aluminium Alloy 6061
Thermal model	steady state thermal model
Film co-efficient	25 $Wmm^{-2}C^{-1}$
Inner cylinder temperature	285^0C

B. Analyse the modified fin geometry

Now, we are modified the fin geometry for both the thickness of fin. We are providing the hole of different diameter (3mm, 4mm, 5mm, 6mm) and apply the same criteria as mention the base paper & find out the value of minimum temperature distribution & heat flux with the help of CFD.

- **Using 2.5 mm fin thickness**

In the case first, we are using modified geometry of the engine cylinder having2.5 mm thickness with 3 mm diameter hole on the fin.

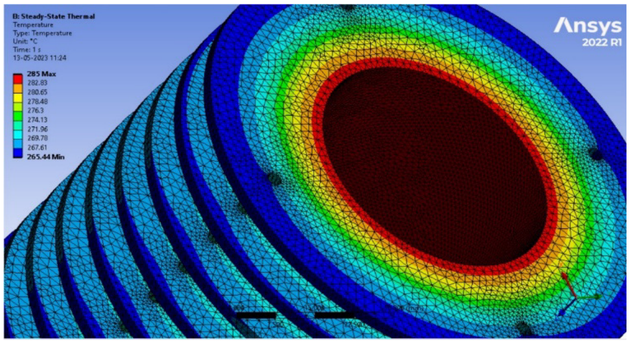

Fig. 1.7 Temperature contour of engine cylinder block with fin thickness 2.5 mm & 3 mm hole on cylinder fin.

With case first, now we are using modified geometry of the engine cylinder with 4 mm diameter hole on the fin and having the same 2.5mm thickness of the fin.

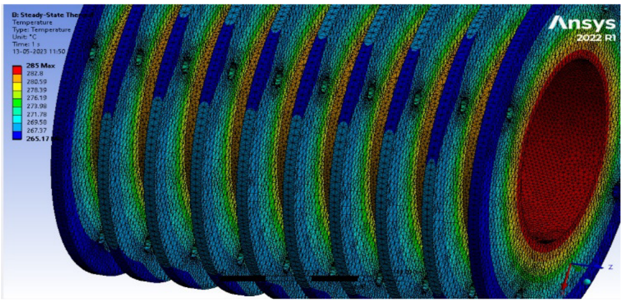

Fig. 1.8. Temperature contour of engine cylinder block with fin thickness 2.5 mm & 4 mm hole on cylinder fin.

With case first, now we are using modified geometry of the engine cylinder with 5mm diameter hole on the fin and having the same 2.5mm thickness of the fin.

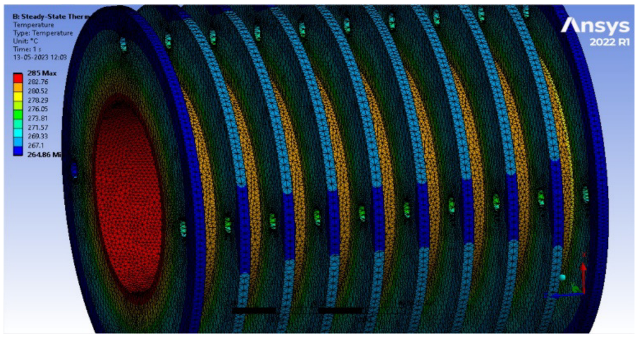

Fig. 1.9. Temperature contour of engine cylinder block with fin thickness 2.5 mm & 5 mm hole on cylinder fin

- **Using 3 mm fin thickness**

In the case second, we are using modified geometry of the engine cylinder having 3mm thickness with 3 mm diameter hole on the fin.

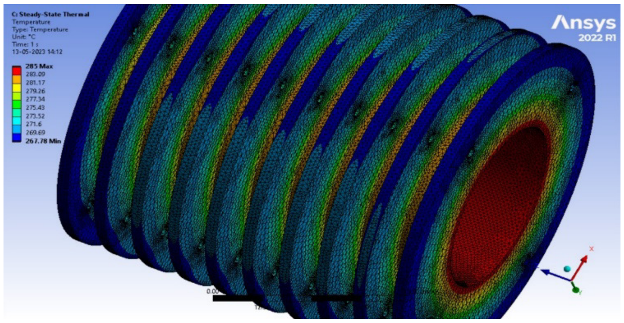

Fig. 1.10 Temperature contour of engine cylinder block with fin thickness 3 mm & 3 mm hole on cylinder fin

With case second, now we are using modified geometry of the engine cylinder with 4 mm diameter hole on the fin and having the same 3 mm thickness of the fin.

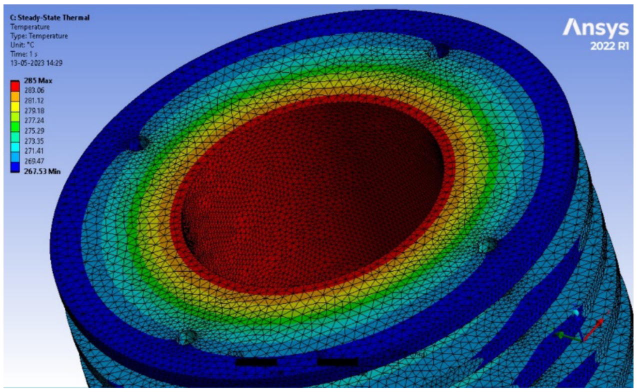

Fig. 1.11 Temperature contour of engine cylinder block with fin thickness 3 mm & 4 mm hole on cylinder fin

With case second, now we are using modified geometry of the engine cylinder with 5 mm diameter hole on the fin and having the same 3 mm thickness of the fin.

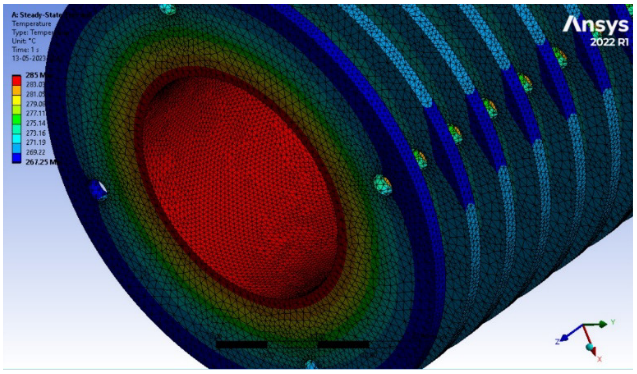

Fig. 1.12 Temperature contour of engine cylinder block with fin thickness 3 mm & 5 mm hole on cylinder fin

C. Effect of the modified geometry of fin on the engine cylinder

It is evident from the numerical findings and experimental evidence that the minimum temperature distribution tendencies are qualitatively consistent. As a result, we use different diameter of hole (3mm, 4mm, 5mm, 6mm) on the both of the engine cylinder model (2.5 mm & 3mm thickness of fin) analyze the impact of the temperature variation at tip of the fin section. The boundary conditions used in this study weresame. Chapter 5 makes reference to the material characteristics of engine cylinder for determining the impact of heat distribution on the fin.

TABLE VI
MESHING DETAIL OF MODEL OF FIN (3 MM THICK)

S.No.	Modified geometry	Temperature Distribution at the tip of the fin	
		2.5 mm	**3 mm**
1	No. modification	265.93	268.26
2	3 mm diameter	265.44	267.78
3	4 mm diameter	265.17	267.53
4	5 mm diameter	264.86	267.25
5	6 mm diameter	264.50	266.92

Table VI Shows the values of Heat distribution or minimum temperature value calculated from the CFD modeling using modified geometry of fin having various diameter of hole.

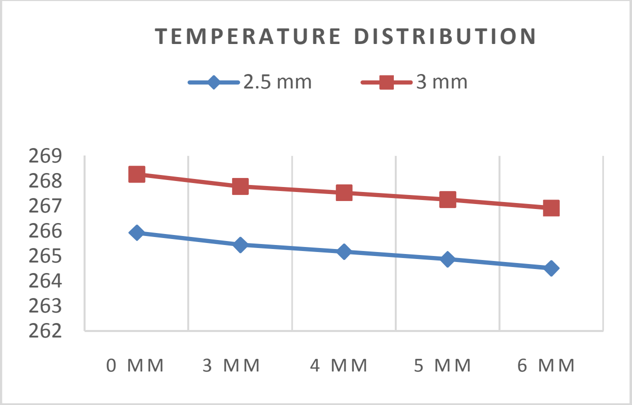

Fig. 1.13. Comparison of Temperature distribution at the tip of the fin in engine cylinder block of both (2.5 & 3 mm) fin thickness with modified geometry.

V. CONCLUSIONS

After going CFD analysis through the comparison charts shown in the above, we can see that the results are quite encouraging. From the CFD analysis by using properties and boundary conditions the following conclusions are made:

- As shown in the above graph(Figure 6.23) increasing the fin thickness does not have much effect on the heat distribution.
- On modifying the fin, we can see that the temperature at the tip of the fin is lower indicating that the temperature distribution is more than without modification.
- In this analysis, we observe the difference of temperature found in the tip of fin on different holes having fin thickness of 2.5 mm is 0.49^0C, 0.27^0C, 0.31^0C, 0.36^0C respectively. And similarly,the temperaturedifference found in the tip of fin on different holes having fin thickness of 3 mm is 0.48^0C, 0.25^0C, 0.28^0C, 0.33^0Crespectively
- When we observe the difference of temperature distribution on different holes of fin thickness of 2.5 mm, we understand that the temperature difference first increases up to 3 mm, then this difference starts decreasing and so on when If we look at the temperature distribution difference of 3 mm fin thickness, then we understand that the temperature difference first increases up to 4 mm, then this difference starts decreasing
- In this analysis the heat distribution percentage for 2.5 mm fin thickness is found to be 0.184%, 0.101%, 0.116%, 0.135%, respectively. And similarly, the heat distribution percentage of 3 mm fin thickness is found to be 0.178%, 0.0933%, 0.104%, 0.123%, respectively.
- When we see the temperature distribution in percentage of 2.5 mm fin thickness, we understand that the percentage differencestarts decreasing and after a time it starts increasing, Similarly, when we see the difference in temperature distribution of fin thickness of 3 mm in percentage, then the percentage difference of temperature is less at first and then this difference starts increasing.
- From the above analysis it is known that the best temperature distribution over the fin is observed at 4 mm and 5 mm hole in both the cases, after 5 mm the temperature distribution starts decreasing.

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