CFD Analysis of Engine Cylinder Block Fins with Holes

Prof. Amol Kumar Tripathi[1], Dharmendra Kumar Dixit[2]
[1]*Rewa Institute of Technology, Professor, REWA, MP, INDIA*
[2]*Rewa Institute of Technology, M.Tech Scholar, REWA, MP, INDIA*

Abstract- **The energy is transit is termed Heat and Heat is a form of energy. The molecules of a substance are in parallel motion. The mean kinetic energy per molecule of the substance is proportional to its absolute temperature. The transmission of energy from one region to another as a result of temperature gradient. In heat transfer the driving potential is temperature difference. The aim of this study to optimized the better design for engine cylinder block for maximum heat transfer. In this work the model of engine cylinder block has been design in ANSYS 14.5 and opted the various shape of holes in the engine cylinder block fin. The designed model has been meshed and the transient analysis of engine cylinder block done for 120 seconds. The temperature distribution, heat flux and directional heat flux have been analysed by ANSYS and make a comparison between them.**

Index Terms- Heat flux, temperature distribution, directional heat flux, heat transfer, ANSYS, Transient analysis, fins.

1. INTRODUCTION

Heat is something which appears at the boundary when a system changes its state due to a difference in temperature between the system and its surrounding. Heat transfer which is defined as the transmission of energy from one region to another as a result of temperature gradient takes place by the fallowing three modes conduction, convection and radiation. Heat transmission in majority of real situations, occurs as a result of combination of these modes of heat transfer.

Conduction: Conduction is the transfer of heat one part of the substance to another part of the same substance, or one substance to another in physical contact with it, without appreciable displacement of molecules forming the substance.

Convection: Convection is the transfer of heat within a fluid by mixing of one portion of the fluid with another. Convection is possible only in a fluid medium and is directly linked with the transport of medium itself. This mode is basically conduction in a very thin fluid layer at the surface and then mixing caused by the flow.

Radiation: Radiation is the transfer of heat through space or matter by means other than conduction and convection. Radiation heat is thought of as electromagnetic waves or quanta an emanation of the same nature as light and radio waves.

2. 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.

Mulukuntla Vidya Sagar, Nalla Suresh [2017] The main aim of the this project was to analyse the thermal properties like Directional Heat Flux, Total Heat Flux and Temperature Distribution by varying Geometry (Circular, Rectangular), material (Aluminium Alloy, Magnesium Alloy) and thickness of Fin (3mm,2mm) of an approximately square cylinder model prepared in SOLIDWORKS-2013 which is imported into ANSYS WORKBENCH-2016 for Transient Thermal analysis with an Average Internal Temperature and Stagnant Air-Simplified case as Cooling medium on Outer surface with reasonable Film Transfer Coefficient as Boundary Conditions.

Pulkit Agarwal etc. [2017] simulated the heat transfer in motor cycle engine fan using CFD analysis. It is observed that ambient temperature reduces to the very low value; it results in over cooling and poor efficiency of the engine. They have concluded that over cooling also affects the engine efficiency because over cooling excess fuel consumption occurs.

Hardik D. Rathod, et. al..[2016] have numerically analyses different types of fin for their heat transfer rates between 60 km/hr to 100 km/hr and found better heat transfer rates for waving shaped fin than straight one.

J.C. Sanders et.al.[2015] carried out the cooling tests on two cylinders, one with original steel fins and one with 1-inch spiral copper fins brazed on the barrel. The copper fins improved the overall heat transfer coefficient from the barrel to the air 115 per cent. They also concluded that in the range of practical fins dimensions, copper fins having the same weight as the original steel fins will give at least 1.8 times the overall heat transfer of the original steel fins.

Bassam A and K Abu Hijleh [2013] investigated the problem of cross-flow forced convection heat transfer from a horizontal cylinder with multiple, equally spaced, high conductivity permeable fins on its outer surface numerically. Permeable fins provided much higher heat transfer rates compared to the more traditional solid fins for a similar cylinder configuration.

J. Ghorbanian • M. Ahmadi [2012] In order to look at this issue, authors zero in on wide-ranging experimental and analytical study to investigate temperature fields in cylinder head and block of a recently developed turbocharged bi-fuel engine. A bi-fuel turbocharged engine (CNG and gasoline) were equipped with more than 40 sets of thermocouples and a comprehensive thermal survey was carried out on the fired engine in the various conditions.

2.1 Importance of Present Investigation: About 35% of heat generated in engine cylinder is lost to the cooling medium. In case of air cooling larger heat transfer area is needed. This can be possible by providing fins on cylinder block. So it demands an urgent need to carry out research work to find out the viable-effective fin design for fast removal of heat. Very less research work has been carried out on fins. It is found that heat transfer rate through fins can be augmented by changing fins geometry, materials, fins parameter like thickness, pitch and wind velocity etc. Therefore, there will be wide importance of the research to be carried out in area of fins geometry effect on heat transfer rate.

2.2 Summary of Literature Review: Lots of research has been done for the increment in heat transfer rates of heat exchange but very less research work has been carried out in the case of engine cylinder fins with holes. A majority of research done in the past was on straight fins thickness, pitch and materials. The gap identified is to check effect of fins geometry on heat transfer.

3. METHODOLOGY

In this study we have analyse the heat transfer in engine cylinder block by introducing the holes in fins of cylinder block. The investigation has performed with the Transient Thermal Analysis by using ANSYS 14.5 and utilized the Heat flux, Directional Heat flux and Temperature distribution. The analysis has done by introducing the hole in the cylinder fin.

3.1DISCRETIZATION OF GOVERNING EQUATIONS

3.1.1 Finite-Difference Method

The finite-difference method is the oldest of the methods for the numerical solution of partial differential equations. At each nodal point of the grid used to describe the fluid-flow domain, the Taylor series expansions are used to generate finite difference approximations to the partial derivatives of the governing equations.

3.1.2 Finite-Volume Method

The finite-volume method discretizes the integral form of the conservation equations directly in physical space. The computational domain is subdivided into a finite number of contiguous control volumes, where the resulting statements express the exact conservation of relevant properties for each of the control volumes.

3.1.3 Finite-Element Method

Both the finite-element and finite-volume methods are suitable for irregular computational domains, meaning that they can accommodate complex geometries.

Nevertheless, one distinguishing feature of the finite-element method is that the governing equations are first approximated by multiplication with the so called shape functions before they are integrated over the entire computational domain. For the domain that is divided into a set of finite elements, the generic variable ϕ can be approximated by

$$\varphi = \sum_{j=1}^{n} \phi_j \psi_j(x, y, z) \quad \text{................................ I)}$$

Where n represents the number of discrete nodal unknowns ϕ_j and $\psi_j(x, y, z)$ are the shape functions.

For the consideration of linear shape functions, they can be constructed simply from the values at the corners of the elements. As a general guide, the use of linear shape functions generates solutions of about the same accuracy as those of the second-order finite-difference method. This approximation is then substituted into the integral of the weighted residual over the computation domain that is taken to be equal to zero,

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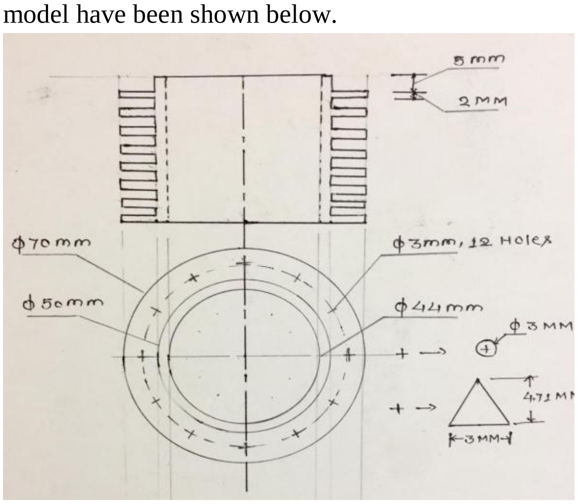
$\iiint W_m(x, y, z) R dx\, dy\, dz = 0$ .... II)

In order to generate a system of algebraic equations for ϕ_j, which normally can be solved via numerical methods. In (Eq.II) R is referred to as the equation residual, while W_m represents the weight functions.

4. MODEL DESCRIPTION

In this study the model of cylinder block has designed in design modular by using Ansys 14.5. Finite element method has used for transient thermal analysis of cylinder block the various geometry model have been shown below.



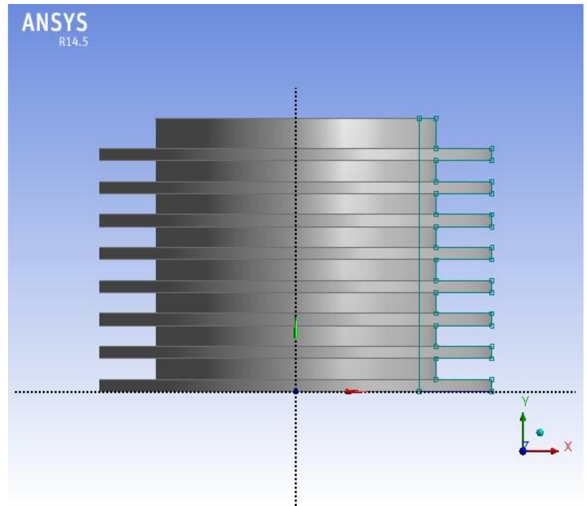


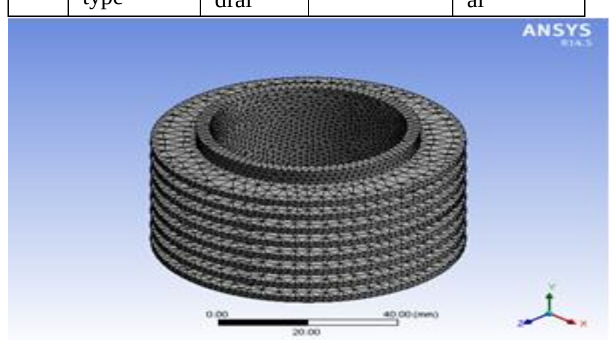
Figure 1 sketch geometry & model of cylinder block

4.1 Meshing

By, default, a coarse mesh is generated by ANSYS software. Mesh contains mixed cells per unit area (ICEM Tetrahedral cells) having triangular faces at the boundaries. The meshing that has used in this transient thermal analysis is none mesh metric with medium smooth curvature. The mesh type generated tetrahedral meshing as shown in figure.

Table 1 Meshing detail of various models

S. No	Parameters	Without hole	With circular hole	With triangular hole
1	Curvature	On	On	On
2	Smooth	Medium	Medium	Medium
3	Number of nodes	22361	36864	29751
4	Number of elements	10938	18093	14576
5	Mesh metric	None	None	None
6	Meshing type	Tetrahedral	Tetrahedral	Tetrahedral



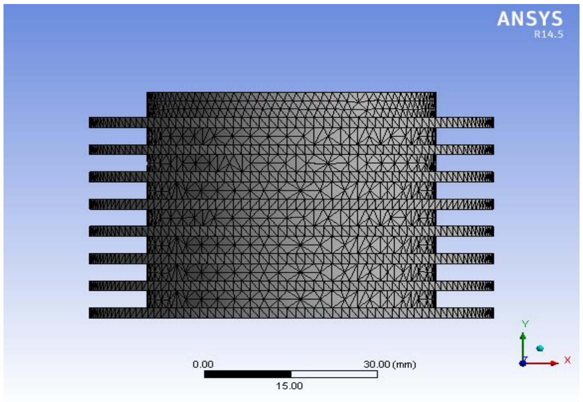


Fig. 2 meshing of circular fin cylinder block without hole

4.2 Boundary conditions

A different part of the cylindrical block having circular fins with holes is selected and the names are given to them so that boundary conditions can be applied.

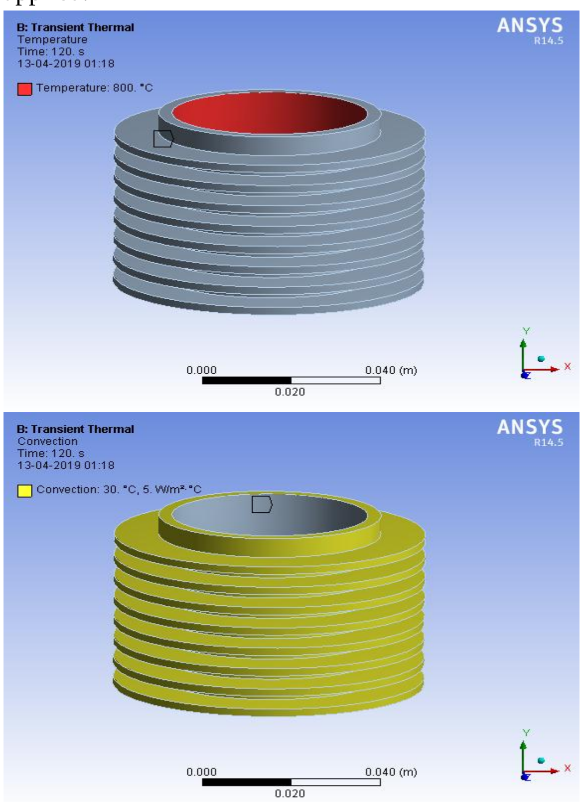


Fig 3 Boundary condition of engine cylinder block

5. RESULTS AND DISCUSSIONS

After applying all boundary condition we have obtained the fallowing results which are shown in figure:

5.1 Contours for circular fin without holes

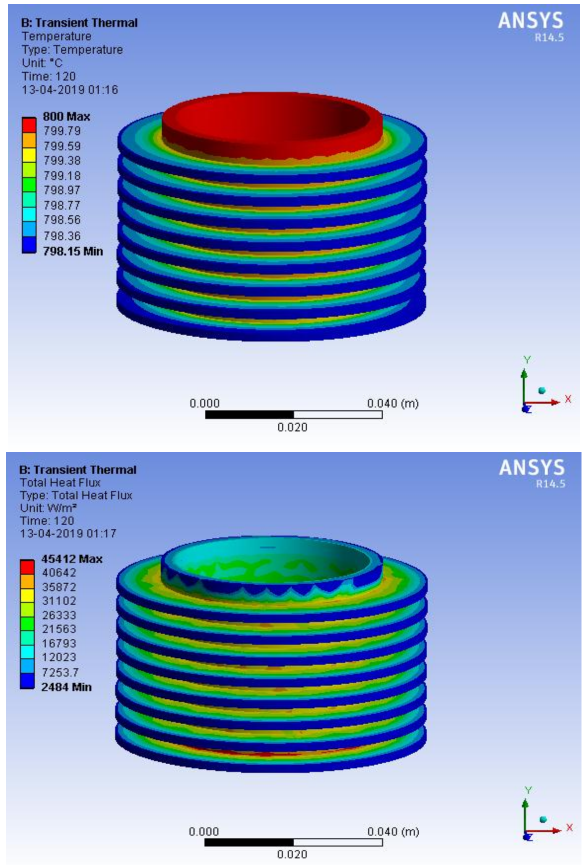


Figure 4 Temperature & total heat flux contour of cylindrical block having circular fin without hole.

5.2 Contours for circular fin with circular holes

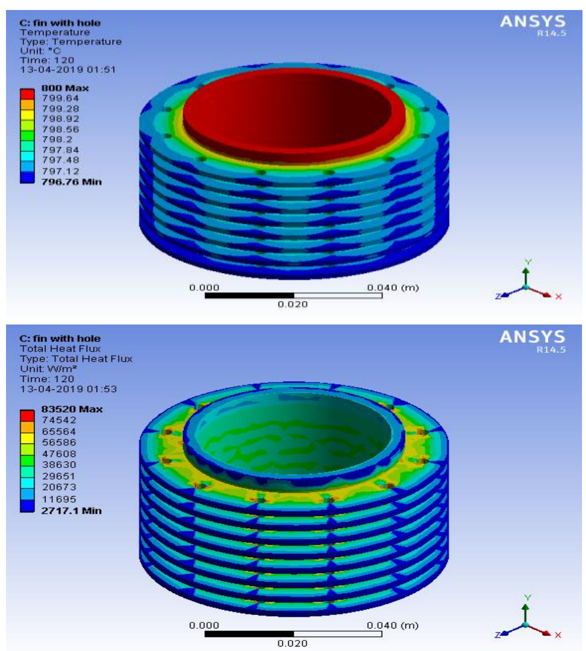


Figure 5 Temperature & total Heat Flux contour of cylindrical block having circular fin with circular hole.

5.2 Contours for circular fin with Triangular holes

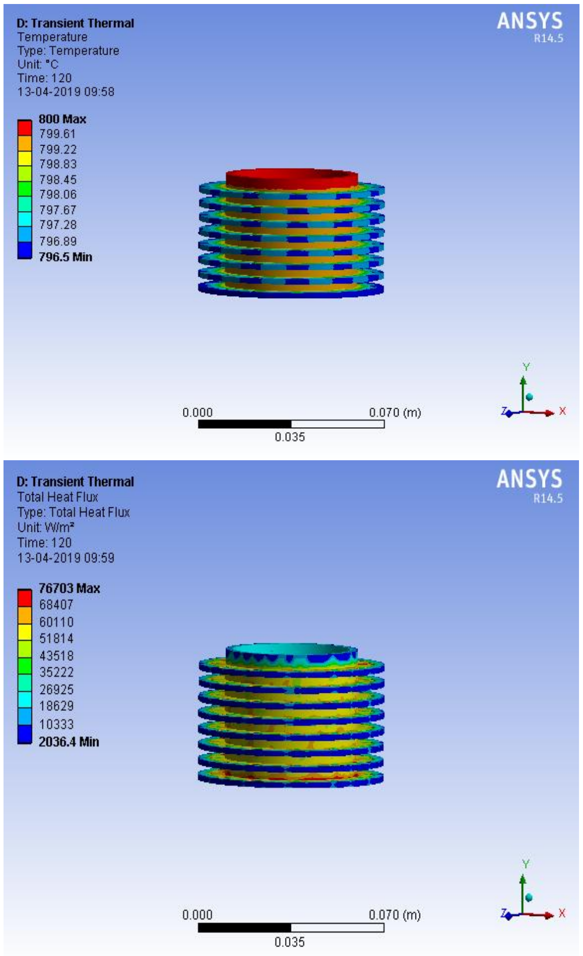
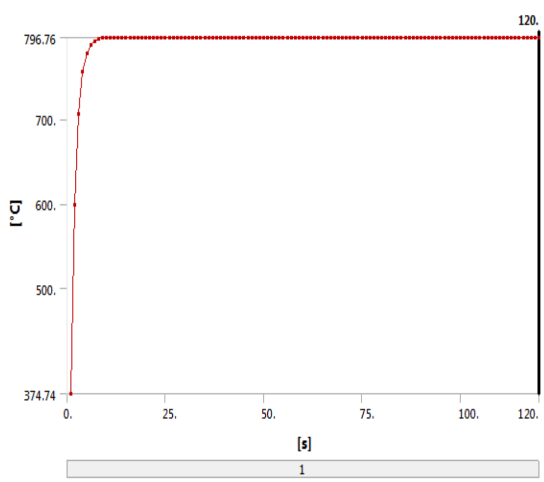


Figure 6 Temperature & Total Heat Flux contour of cylindrical block having circular fin with triangular hole



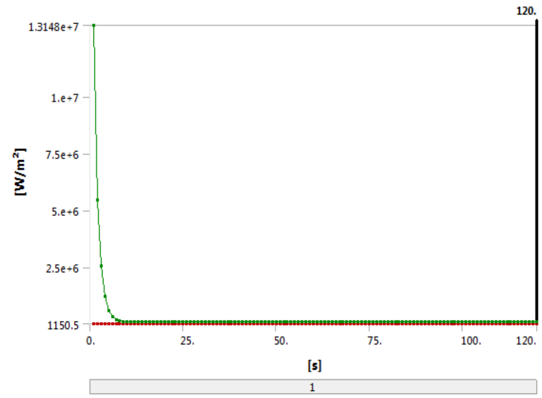
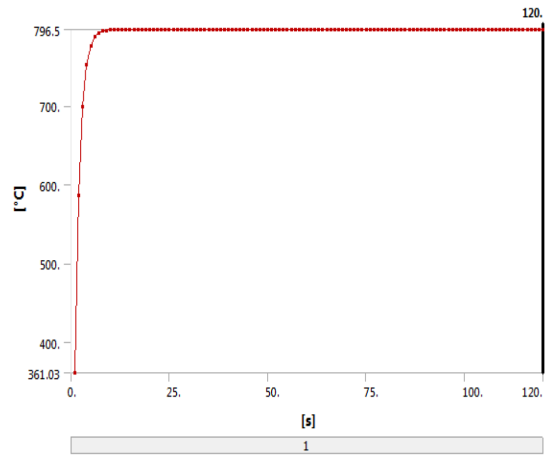


Figure 7 Temperature & Total Heat Flux distribution of cylindrical block having circular fin with circular hole



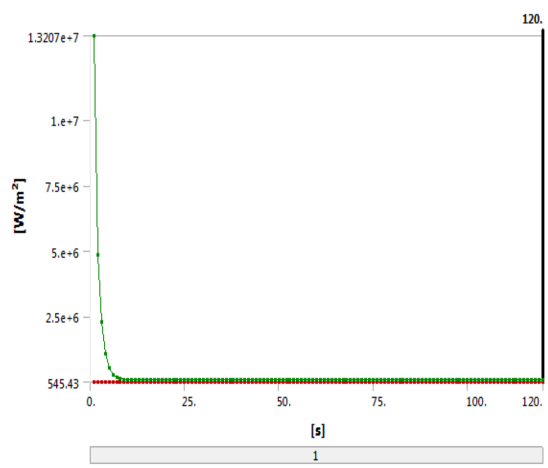


Figure 8 Temperature distribution & Total Heat Flux of cylindrical block having circular fin with triangular hole.

Table 2 Comparison of Temperature Distribution

Time(in s)	Maximum Temperature (in °C)		
	Without hole	With circular hole	Triangular hole

At 1 seconds	384.01	374.74	361.03
At 2 seconds	605.69	598.18	585.81
At 3 seconds	711.65	706.86	698.84
At 4 seconds	759.56	756.43	751.72
At 5 seconds	780.97	778.71	776.03
At 6 seconds	790.51	788.69	787.15
At 7 seconds	794.75	793.15	792.23
At 8 seconds	796.64	795.15	794.55
At 9 seconds	797.48	796.04	795.61
At10seconds	797.86	796.44	796.1

CONCLUSIONS

From the above results this can be observed that by introducing hole in the circular fin the heat transfer would be increase. By introducing circular hole in the fin the heat transfer through fin increased but by triangular hole of equal area the heat transfer will improved also. Due to the complexity of design parameter in triangular holes the better design shape that can be obtained easily is circular fin with circular hole which can obtain a better temperature at outer surface of cylinder block in 10 seconds 796.44°C. In the previous study the temperature of outer surface 797.85 °C which is higher than current study outer temperature. The temperature drop is increasing by providing holes in the fins which result in higher heat transfer and rate of heat transfer. Total heat flux also increases in the circular fin with circular hole cylinder block the maximum heat flux obtain is 83520 w/m^2 and minimum heat flux is 2717.1 w/m^2. The directional heat flux is also increasing in circular fin with circular hole cylinder block.

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