Thermal Performance Improvement of Single Cylinder IC Engine

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***Abstract*--The calculation of engine heat transfer rate is very difficult due to complex design of engine geometry and periodic flow of air-fuel mixture during the engine operation for entire cycles. Various studies indicate that about 25 % of the fuel energy is converted into useful work and the remaining 75% is transferred from the engine to the environment.**

The main objective of the paper is to enhance the heat transfer rate from existing engine cylinder block by changing its design of fin with new material. CAD models have been created with the help of CATIA software and then transient thermal analysis were performed using ANSYS at ambient temperatures for summer season (45^{o}C) for actual as well as proposed design of IC engine to optimize geometrical parameters and enhance heat transfer rate. It has been observed from the results of transient thermal analysis the proposed design of engine cylinder block has better performance and heat transfer rate as compared to actual design of engine cylinder block.

***Keywords*-- Heat transfer rate, Internal Combustion engine, Transient thermal analysis Engine design, etc.**

I. INTRODUCTION

The Internal Combustion Engine (ICE) has been a part of society since the early 19th century. Although the fuel was different (petroleum was not commercially produced until the 1850s) the concept was the same. The first combustion engines were mainly used in industrial applications, but were later introduced into vehicles now capable of moving by themselves. The first modern car was designed and produced by Karl Benz in 1885, it was called the Motorwagen and ≈25 of them were sold between 1888 and 1893. In the following years more and more car manufacturers entered the market and started building, designing, and selling cars. The first car produced in an affordable way was Ransom Olds mobile in 1902.

An engine is a device that converts thermal energy into mechanical work. The thermal energy is created by the combustion of air fuel blend inside the cylinder by methods for a start delivered by the start plug. Since it utilizes thermal energy it is called as thermal engines. It is a wellspring of energy for some applications.

The cylinder head closes one side of the cylinder. They are normally given a role as a solitary piece and are rushed to the highest point of the cylinder. Between the cylinder and the cylinder head, gasket is given Gasket is given with a specific end goal to go about as fixing (to prevent gases escaping during the expansion stroke) and furthermore to decrease stun.

A. Engine Cylinder and Combustion Chamber

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result in seizing or welding of same that is chances of piston seizure, chances of piston ring, compression ring, oil ring etc. can be affected. Excess temperature can also damage the cylinder material. So this temperature must be reduced to about 150- 200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence 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.

To avoid overheating, and the consequent ill effects, the heat transferred to an engine component (after a certain level) must be removed as quickly as possible and be conveyed to the atmosphere. It will be proper to say the cooling system as a temperature regulation system. It should be remembered that abstraction of heat from the working medium by way of cooling the engine components is a direct thermodynamic loss.

The rate of heat transfer depends upon the wind velocity, geometry of engine surface, external surface area and the ambient temperature. In this work analysis is done on engine block fins considering temperature inside by means of conduction and convection, air velocity is not consider in this work. Motorbikes engines are normally designed for operating at a particular atmosphere temperature, however cooling beyond optimum limit is also not considered because it can reduce overall efficiency. Thus it may be observed that only sufficient cooling is desirable.

Air-cooled engines generally use individual cases for the cylinders to facilitate cooling. Inline motorcycle engines are an exception, having two-, three-, four-, or even six-cylinder air-cooled units in a common block. Water-cooled engines with only a few cylinders may also use individual cylinder cases, though this makes the cooling system more complex. The Ducati motorcycle company, which for years used air-cooled motors with individual cylinder cases, retained the basic design of their V-twin engine while adapting it to water-cooling.

B. Natural Air Cooling

In normal cause, larger parts of an engine remain exposed to the atmospheric air. When the vehicles run, the air at certain relative velocity impinges upon the engine, and sweeps away its heat. The heat carried-away by the air is due to natural convection, therefore this method is known as Natural air-cooling. Engines mounted on 2-wheelers are mostly cooled by natural air. As the heat dissipation is a function of frontal cross-sectional area of the engine, therefore there exists a need to enlarge this area. An engine with enlarge area will becomes bulky and in turn will also reduce the power by weight ratio. Hence, as an alternative arrangement, fins are constructed to enhance the frontal cross-sectional area of the engine. Fins (or ribs) are sharp projections provided on the surfaces of cylinder block and cylinder head. They increase the outer contact area between a cylinder and the air. Fins are, generally, casted integrally with the cylinder. They may also be mounted on the cylinder.

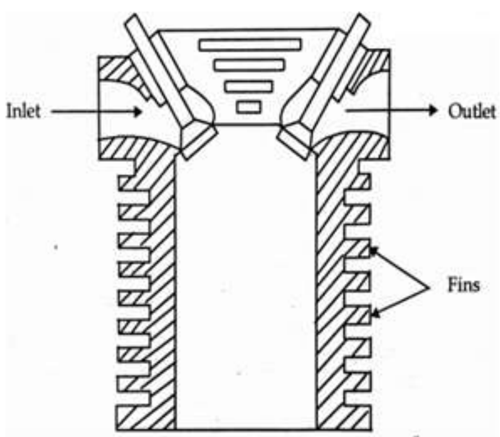

Fig. 1 Natural air cooling

C. Fins

A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, radiation of an object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the Heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to the object, however, increases the surface area and can sometimes be economical solution to heat transfer problems. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples.

Fig. 2 Automobile Fin

The temperature distribution within an SI engine is extremely important for proper engine operation to maximize the thermal efficiency of an engine; it has to be operated at specific thermal condition. This condition is controlled by cooling process of fins that tends to remove the heat that is highly critical in keeping an engine and engine lubricant from thermal failure and thermal effects. Actually Fins are provided because, they provide a channel for cooling the engine whenever it gets hot. Fins doesn't let the engine to burn out. The fins provided on the engine cylinder depends on the capacity of the engine. Higher the capacity of the engine, more number of fins provided on the surface of the engine block.

II. LITERATURE REVIEW

Mahendra Kr Ahirwar et. al. [1] studied and compared with 100 cc Hero Honda Motorcycle fins and analyze the thermal properties by varying geometry, material and thickness. In this paper author has designed a cylinder fin body used n a 100cc Hero Honda motorbike and 3D modelling software package CATIA over 5.0 and used material for fin body is metallic element alloy fins and internal core with gray forged iron. The projected style of IC engine has higher performance and heat transfer rate from the heating zone within the IC engine that's why the results of present work is additional focus on it and additionally projected replacement of recent style.

Ravi Gupta et. al. [2] attempted to find out the best material in respect of finest heat transfer rate through it for cooling as primary consideration, Safe working of Engine, High strength , Light in weight and also Lower Cost that is used for cylinder block. By observing the results it is identified that the grey cast iron and Structural Steel are giving the better heat distribution and maximum temperature difference. Al MMC shows the highest strength while Mg alloy shows the lowest strength while the other materials showing moderate strength.

Mulukuntla Vidya Sagar et. al. [3] analysed 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. The results shows, By using circular fin with material Aluminum Alloy is better since heat transfer rate of the fin is more. By using circular fins the weight of the fin body reduces compared to existing rectangular engine cylinder fin.

Pulkit Sagar et. al. [4] analysed the heat transfer rate by varying the shape and surface roughness of fins. As from the above analysis in NASTRAN 2015 it is clear that the Heat flow in convex geometry is more as compared to other geometry. It is clear that if we use convex fin we can actually increase heat transfer rate and make component using less material. analysis of body concludes that as we change the geometry of the body the heat transfer increases for the body of same area and volume. It also concludes that change in geometry can increase and decrease the specific heat, applied heat flow, heat flux etc.

Devendra J. Waghulde et. al. [5] Finite element analysis and experimental investigation on the thermal behaviour of cylinder with different fins of varying fin thickness, geometry and material is carried out. FEA and Experimental results analysis shows that the temperature distribution is maximum for the cylinder with rectangular fin of 3.5 mm fin thickness for aluminium alloy 6061 and minimum for triangular fin of 2.5 mm thickness for aluminium alloy 6061.

Pushkar Bhanudas Patil et. al. [6] find out the effect of fin height on two-wheeler engine cylinder for temperature distribution. Then Steady State Thermal Analysis done on the implemented geometries with variable heights of fins using ANSYS AIM 18.1. Results obtained from the finite element analysis are in close approximation with results of experimental method. FEA and Experimental results analysis shows that the temperature distribution is maximum for the cylinder with rectangular fin of 7 mm fin Height for aluminium alloy 6061 and minimum for triangular fin of 3 mm Height for aluminium alloy 6061.

Sandeep Kumar et. al. [7] performed Transient thermal analyses for actual and proposed design of engine cylinder in order to optimize geometrical parameters and enhanced heat transfer from the IC engine. In the present work transient thermal analysis is performed on ANSYS on actual design and also on two different geometrical designs at ambient temperature 25^{o}C indicates the maximum temperature is 650 ^{o}C and minimum temperature is 74.739 ^{o}C, Maximum Total heat flux generated is 29.665 W/mm^2 and minimum heat flux generated is 0.00353 W/mm^2 .

Divyank Dubey et. al. [8] increased the heat dissipation rate through extended surfaces by increasing engine fin tip thickness to 3mm and also providing slots of 50mm, 75mm, and 100mm The 3D modeling of engine with different slot sizes keeping fin size and number of fin same designed on Solidworks and the analysis on the ANSYS steady state. Comparing its performance by using different material such as Aluminum Alloy 6061, Aluminum Alloy C443 and Aluminum Alloy 2014 .

- The minimum surface provided for 75mm for fin surface temperature.
- Aluminum 2014 having 75mm slotted fin engine with thick tip fin have maximum heat transfer.

Deepak Tekhre et. al. [9] used Computational fluid dynamics to determine thermal stresses and temperature distribution through the fins. .Project is based on designing more efficient cooling fins for a 150 cc (Honda Unicorn) bike engine by improvising the design and the material of the fin. Where the modelling of the fin is performed on Creo modelling software and the CFD analysis is performed on ANSYS 15.0 Workbench software. As the hole area increases the fin efficiency also increases. the reduction in minimum temperature of the engine by implementing the material from AL 6063 to Aluminium Nitride (ALN) which is showing better and more efficient results than AL 6063. It has been seen that the implementation results in reduction in minimum temperature of the engine up to 20% in Aluminium nitride after improvising from Aluminium 6063. It is clear from CFD analysis that, to achieve better cooling results Aluminium Nitride is a better option than Aluminium 6063 alloy material.

N. Arul et. al. [10] attachedrectangular, circular and pin fins to circular rod separately. Then, these three models were subjected to experimental, analytical and computational analysis. In experimental analysis three models were heated to 100^{0}C then they were allowed for natural convection at room temperature. The temperature distributions were measured and viewed using thermocouple. In analytical method, the amount of heat transfer is calculated and plotted graphically. In computational analysis, these three models were analyzed ANSYS 14.0. Using the CFD software the fluid analysis is done with existing design. The dimensions of the cylinder length, cylinder thickness, cylinder inner and outer diameter are initialized by us to a certain value corresponding to the existing available design.

Praveen Choudhary et. al. [11] In this article, Unsteady analysis of heated inclined fin-plate at an angle of 45º is carried out using ANSYS FLUENT 15.Numerical analysis of unsteady natural convection in the square enclosure is performed. The study is conducted to see the effect of Rayleigh number, aspect ratio, fin position and orientation on convection flow field and temperature field. For a specified position the value of Nusselt number increases with the increasing value of Rayleigh number. Value of Nusselt depends on the orientation of plate. Maximum heat transfer is achieved for Ra 106

Obula Reddy Kummitha et. al. [12] performed thermal analysis on cylinder block with various alloys to find out the best material which gives the best heat transfer rate through it and keep the engine in safe working condition and also consists of high strength with light weight.aluminium alloys are also considered for thermal analysis and compared all the results for best one. From all the above nodal temperature contours and from column charts, it is to be concluded that A380 had the better heat transfer rate along with more strength as compared with other considered alloys.

Aju Joseph et. al. [13] In this research, Fin heat sinks are a great deal to increase heat transfer in applications such as cooling of electronic components, heat exchangers ,engines etc and can sometimes be an economical solution to heat transfer problems. Perforated heat sink gives higher heat transfer rate compared to solid fin heat sink by varying the different parameter like shape of fin, diameter of Perforations ,number of Perforations higher heat transfer rate can be accomplished. This review reveals that convective heat transfer from fin depends on various factors as geometrical parameters, operating parameters, fin material used, fin array in orientation, number of fins etc. But geometrical parameters affect most. As there are limitations to increase the size of fin array in order to increase surface area due to limitations on proposed length and width of fin array, optimal fin spacing found most important factor to enhance convective heat transfer. Instead of only going for natural convection or forced convection, mixed convection was also proposed for better enhancement in convective heat transfer as mixed convection enhanced natural convection.

A Sathishkumar et. al. [14] the engine fins with different materials such as Aluminium 6061, A2014, C443. The various geometries of fins used are angular, curved and circular instead of rectangular fins. The observations from the present research work are, Aluminium Alloy 2014 showing 17 % higher temperature distribution compared to that of Aluminium Alloy 204 due to its material composition and higher thermal conductivity. All the materials are showing linear distribution of temperature along the length of fins and the circular fins increase the efficiency of the engine by reducing the weight of the engine. Also, observed that the engine with curved fins is shown better efficiency due to its less weight

Rahul Gupta et. al. [15] The main purpose of using these cooling fins is to cool the engine cylinder by air. The main aim of the project is to analyze the thermal properties by varying geometry, material of cylinder fins. In present work, a cylinder fin body is modeled with the help of Solid Works 2010 software and transient thermal analysis is done by using ANSYS 14.5. These fins are used for air cooling systems for two wheelers. In present study, Aluminum alloy and Magnesium alloy are used and IJSER compared with G. Babu and M. Lava Kumar results. The various parameters (i.e., shape and geometry of the fin) are considered in the study, shape (Rectangular, Circular and Triangular), and thickness (3 mm) by changing the shape of the fin to triangular shaped, the weight of the fin body reduces thereby increasing the heat transfer rate and efficiency of the fin. The weight of the fin body is also reduced when Magnesium alloy is used. By using triangular fins the weight of the fin body reduces compare to existing engine cylinder fins.

L. Natrayan et. al. [16] analyzed the thermal properties by varying geometry of cylinder fins using Ansys work bench. The 3D model of the geometries are created using SOLIDWORKS 2016 and its thermal properties are analyzed using Ansys workbench R 2016 Material used for manufacturing cylinder fin body is Aluminium Alloy AA 6061 which has thermal conductivity of 160 – 170 W/mk. presently analysis is carried out for cylinder fins using this material. Wavy fin shaped cylinder block can be used for increasing the heat transfer from the fins by creating turbulence for upcoming air. It is found that the curved fins provide better result when compared with all the other geometries.

Joel Hemanth [17] compared solid rectangular aluminum fin and the same rectangular fin with different perforations (2, 4, 8 and 10) were analytically, experimentally and its validity through finite element analysis for its temperature distribution along the length. From the present research it is observed that the mathematical and FEA for a solid rectangular fin without perforations are converging within ±1˚C and rectangular fin with 10 perforations are converging within ±2˚C and hence the validity.

Ravi Gupta[18] find the best suitable material among the eight selected alloys for the application of Engine cylinder block used for Vespa Scooters on the basis of various parameters i.eHeat dissipation capability, strength, economy etc. It is observed that the distribution of temperature through the material is high for the grey cast iron with about 140.69 ˚C temperature difference and minimum for A 380 material about 34.24 ˚C temperature difference. Also the value of Total Heat Flux is higher for Structural Steel and lower for Mg Alloy , Cast iron and structural steel material cylinder block shows higher weight and Mg allow material shows the lower weight. Cast iron and structural steel are the best material that satisfies the above desirable properties except that it has a low thermal conductivity and it is a comparatively heavy material.

Devendra J. Waghulde[19]analyzed the effect of material geometry and type of material used in two wheeler engine cylinder fins on temperature distribution and heat flux. For this purpose, fins with two types of geometries rectangular, triangular geometry in variable thickness such as 2.5mm, 3mm and 3.5mm has been used. The study shows that the temperature distribution is maximum for the cylinder with rectangular fin of 3.5 mm fin thickness for aluminium alloy 2014 and minimum for triangular fin of 2.5 mm thickness for aluminium alloy 2024. It also shows that the total heat flux is maximum for the cylinder with rectangular fin of 2.5 mm fin thickness for aluminium alloy 2014 and minimum for triangular fin of 3.5 mm fin thickness for aluminium alloy

2024 and directional heat flux is maximum for the cylinder with rectangular fin of 2.5 mm fin thickness for aluminium alloy 2014.

III. METHODOLOGY

A. Mathematical Analysis

The heat transfer analysis takes place the following assumptions:

1. Conductive heat transfer in the IC engine fins is one dimensional and is along the x- direction
2. Heat losses by the convection from the sides of the heat sink at constant ambient temperature T_∞.
3. The heat sink in the steady state condition.

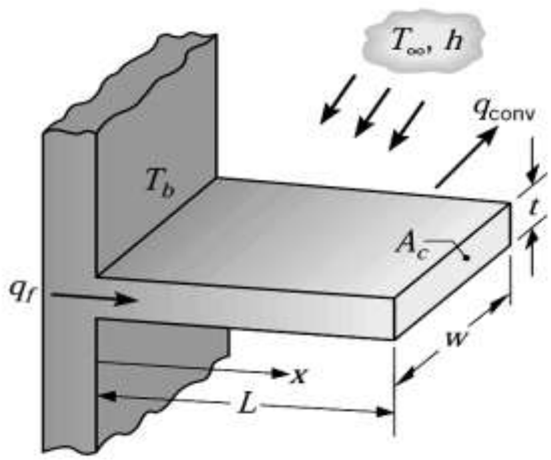

Fig.3 Theoretical information of fin geometry

Heat in to the left face = Heat out from the right face + Heat loss by convection

Case I: The fin of infinite length:

$$Q_{Fin} = \sqrt{hPkA}(T_0 - T_\infty)$$

Case II: Fin Insulated at the tip

$$Q_{Fin} = \sqrt{hPkA}(T_0 - T_\infty)\tanh(ml)$$

Case III: The finite length of the fin

$$Q_{Fin} = \sqrt{hPkA}(T_0 - T_\infty)\left[\frac{\tanh(ml) + \frac{h}{km}}{1 + \frac{h}{km}\tanh(ml)}\right]$$

B. Finite Element Analysis

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed

C. Assumptions

The following assumptions are made to perform thermal analysis of cylinder block.

- Symmetric flow and identical heat transfer throughout the heat sink
- Isothermal boundary condition is applied for the base and fins..

IV. EXPERIMENTAL WORK

A. Transient Thermal Analysis for the actual design of engine block

1) CAD Geometry

In the present work The CAD geometry of cylinder block is created with the help of CATIA software then imported in ANSYS workbench for further analysis. A three dimensional view of cylinder block is shown in figure 4.

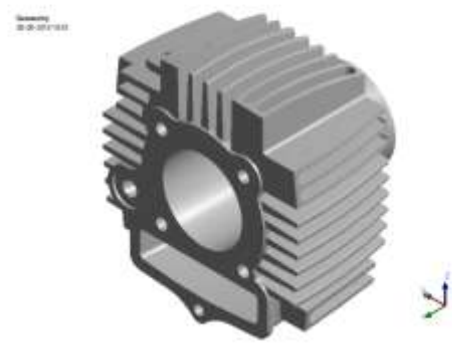

Fig.4 CAD geometry of Actual engine cylinder block

Meshing:

After completing the CAD geometry of engine cylinder block is imported in ANSYS workbench for further transient thermal analysis. The mesh created in this work is shown in figure No. 5. The total Node is generated 792792 & Total Number of elements is 458302.

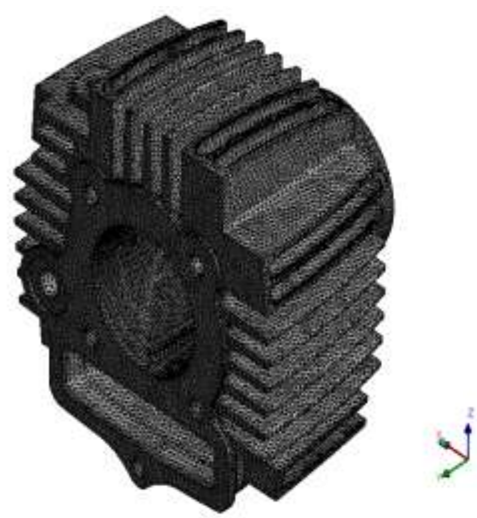

Fig.5 Meshing of Actual engine cylinder block

2) Defining Material Properties

There are thousands of materials available in the ANSYS environment and if required library is not available in ANSYS directory the new material directory can be created as per requirement. For the present work cast iron used as a material of cylinder block. The material properties of the present case are as: Density: 7200 kg m^{-3}, Isotropic thermal conductivity: 83 w/m ^{o}C, Specific Heat: 165J/kg ^{o}C.

3) Boundary condition

a. The maximum temperature generated on inside the cylinder block is taken as 650^{o}C (John B.LHeywood "*Engine Heat transfer*").
b. The ambient temperature assumed as 45^{o}C for summer season.
c. The value of Isotropic thermal conductivity of the material is taken as 83 W/m ^{o}C.
d. Since this cylinder block of an IC engine moved in open space that is why it is assumed that in this open space, the normal air temperature available and its convective coefficient value for the present work is taken as 100 W/m^2.
e. The Quasi Linear Thermal Transient Solution solver is used for transient thermal analysis.

4) Temperature distribution of actual design of engine block for CI

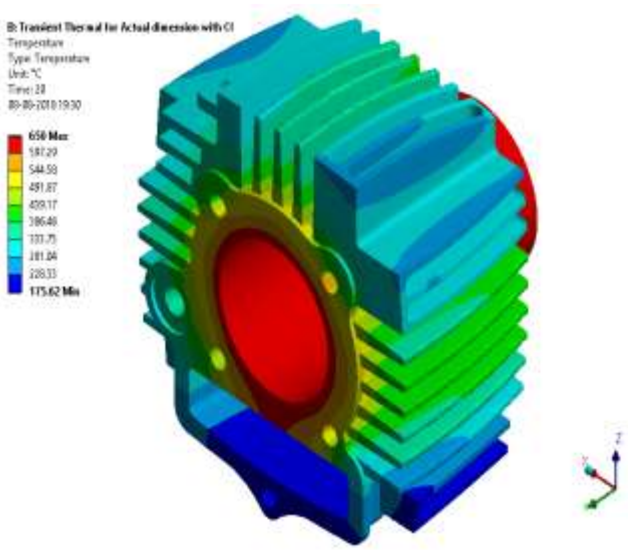

Fig. 6 Temperature distribution over cylinder block for CI

Transient thermal analysis where performed on actual design of engine block at 45^{o}C atmospheric temperature. The temperature distribution over the entire body of engine block is shown in figure No. 6 with different color contours. The maximum temperature is 650 ^{o}C and minimum temperature is 175.62 ^{o}C.

5) Total Heat flux of actual design of engine block for CI

Transient thermal analysis where performed on actual design of engine block at 45^{o}C atmospheric temperature. The total heat flux generated in the engine cylinder is 9.08e6 W/m^2 as shown in Figure No. 7.

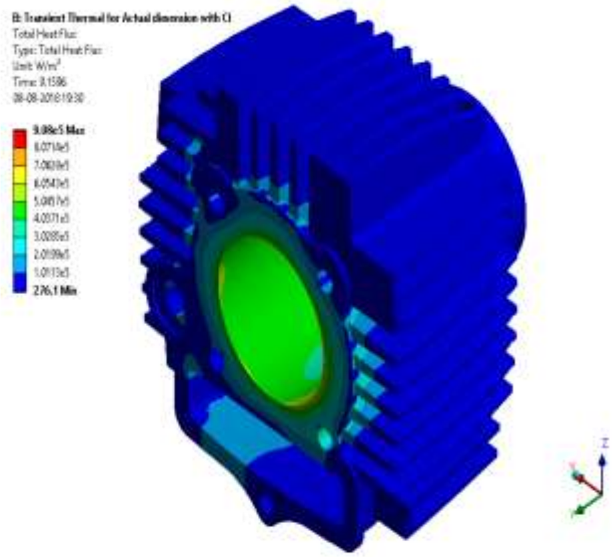

Fig. 7 Total Heat flux of actual design of engine block for CI

B. Transient Thermal Analysis on actual design of engine block for aluminium alloy

For the transient thermal analysis on actual design of engine block for aluminium alloy same CAD geometry and meshing are used as for transient thermal analysis of actual design of engine block of cast iron.

1) Material properties

For the present work another material aluminium alloy is used in place of cast iron. The material properties of aluminium alloy are as: Density: 2700 kg m^{-3}, Isotropic thermal conductivity: 190 W/m-K, Specific Heat: 0.880 J/g-°C.

2) Boundary condition

a. The maximum temperature generated on inside the cylinder block is taken as 650^{o}C (John B.L Heywood "*Engine Heat transfer*").
b. The ambient temperature assumed as 45^{o}C for summer season.
c. The value of Isotropic thermal conductivity of the material is taken as 190 W/m ^{o}C.
d. Since this cylinder block of an IC engine moved in open space that is why it is assumed that in this open space, the normal air temperature available and its convective coefficient value for the present work is taken as 100 W/m^2.
e. The Quasi Linear Thermal Transient Solution solver is used for transient thermal analysis.

3) Temperature distribution of actual design of engine block for Al Alloy

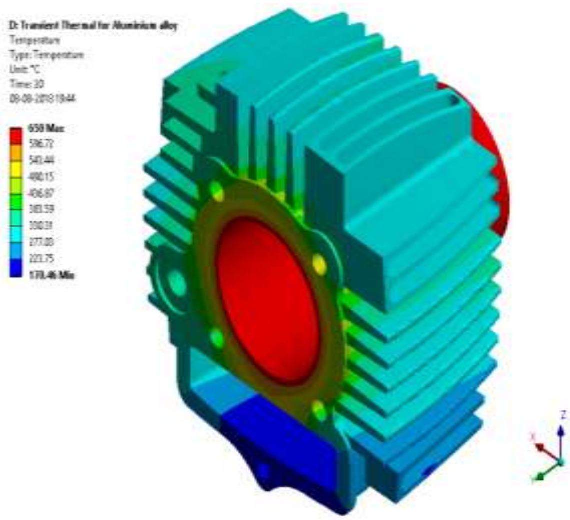

Fig.8 Temperature distribution of actual design of engine block for Al Alloy

The transient thermal analysis is performed on actual design of engine block for aluminium alloy and result indicates the temperature distribution over the entire body of engine block as shown in figure No. 8 with different color contours. The maximum temperature is 650°C and minimum temperature is 170.46°C.

Total Heat flux of actual design of engine block for Al alloy:

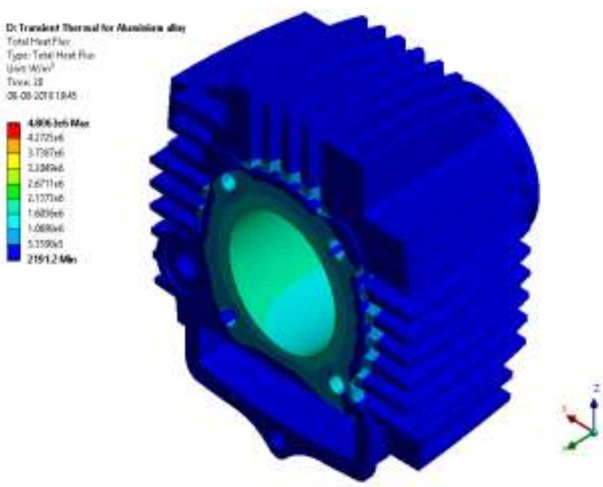

Fig. 9Total Heat flux of actual design of engine block for Al alloy

The transient thermal analysis is performed on actual design of engine block for aluminium alloy and result indicates the total heat flux generated inside the engine block as shown in figure No. 9 with different color contours. The maximum total heat flux generated in the engine cylinder is 4.8063e6 W/m^2.

C. Transient Thermal Analysis for proposed design-1 using cast iron

1) *CAD geometry*

The new CAD geometry of proposed design-1 of engine block is created with the help of CATIA software then imported in ANSYS workbench for further analysis. A three dimensional view of proposed design-1 of engine block is shown in figure No. 10.

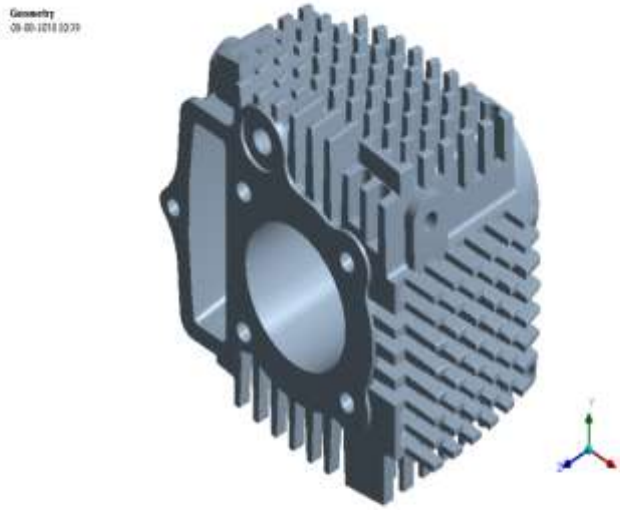

Fig. 10 CAD geometry of proposed design-1 of engine cylinder block

2) *Meshing*

Fig. 11 Meshing of proposed design-1 of engine cylinder block

After completing the CAD geometry of engine cylinder block is imported in ANSYS workbench for further transient thermal analysis. The mesh created in this work is shown in figure No. 11. The total Node is generated 803957 & Total Number of elements is 455264.

3) *Defining Material Properties & Boundary condition*

The material property and boundary conditions remain same as actual design of engine cylinder block.

4) *Temperature distribution of proposed design-1 of enginecylinder block for CI*

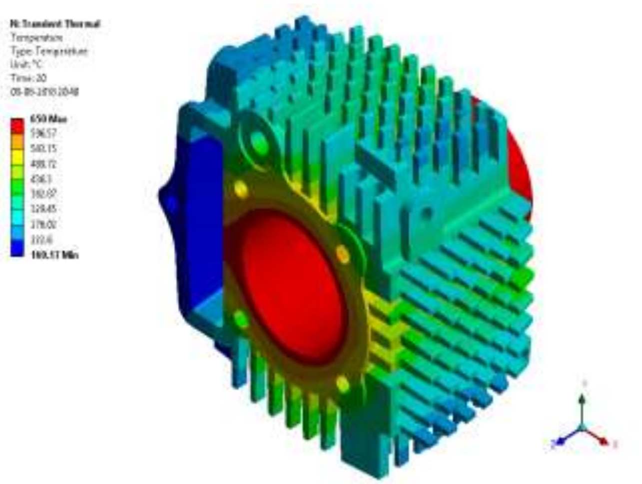

Fig. 12 Temperature distribution over cylinder block of proposed design-1 for CI

Transient thermal analysis where performed on engine cylinder block of proposed design-1 for CI at 45^{o}C atmospheric temperature. The temperature distribution over the entire body of engine block is shown in figure No. 12 with different color contours. The maximum temperature is 650 ^{o}C and minimum temperature is 169.17 ^{o}C.

5) *Total Heat flux of proposed design-1 of engine cylinder block for CI*

The total heat flux generated in the engine cylinder is 7.0734e6 W/m^2 as shown in Figure No. 13.

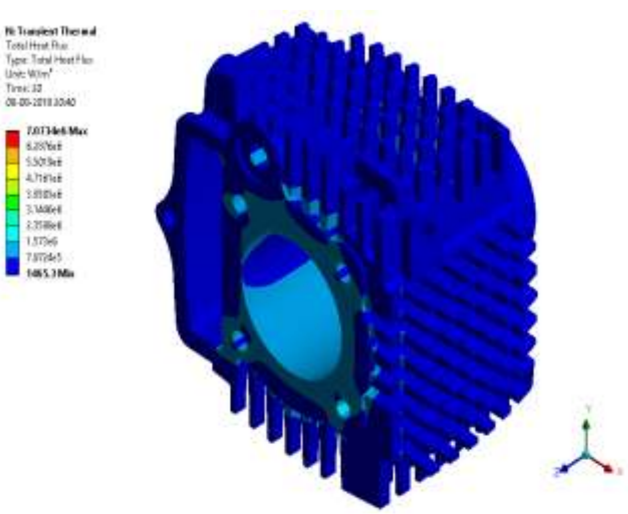

Fig. 13 Total Heat flux of proposed design-1of engine block for CI

6) *Temperature distribution of proposed design-1 of engine block for Al alloy*

Transient thermal analysis where performed on proposed design-1of engine block for Al at 45^{o}C atmospheric temperature. The temperature distribution over the entire body of engine block is shown in figure No. 14 with different color contours. The maximum temperature is 650 ^{o}C and minimum temperature is 155.88 ^{o}C.

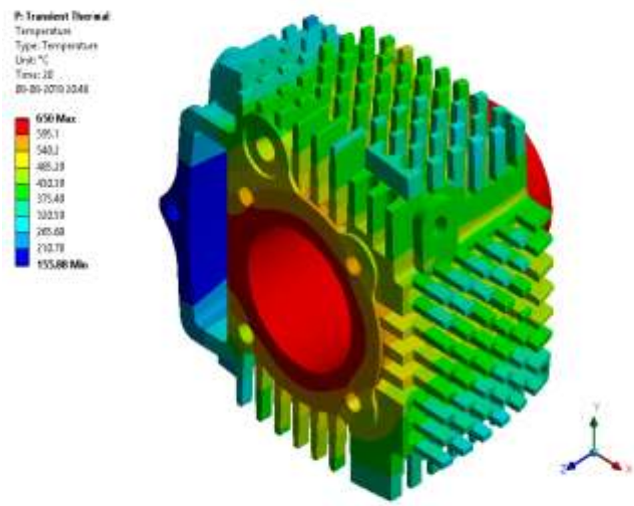

Fig. 14Temperature distribution of proposed design-1of engine block for Al alloy

7) *Total Heat flux of proposed design-1of engine block for Al alloy*

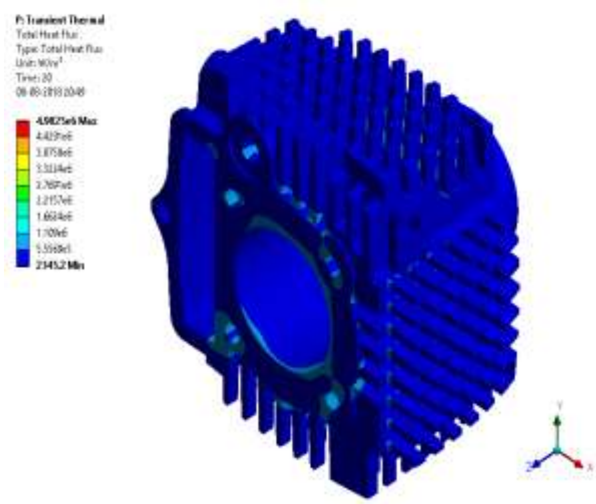

Fig. 15 Total Heat flux of proposed design-1of engine block for Al alloy

The total heat flux generated in the proposed design-1of engine cylinder is 4.9825e5 W/m^2 as shown in Figure No. 15.

D. Transient Thermal Analysis for proposed design of engine block with inter-cooling arrangement using cast iron

1) CAD geometry

The new CAD geometry of proposed design-2 of engine block with inter-cooling arrangement is created with the help of CATIA software then imported in ANSYS workbench for further analysis. A three dimensional view of proposed design of engine block with inter-cooling arrangement is shown in figure No. 16.

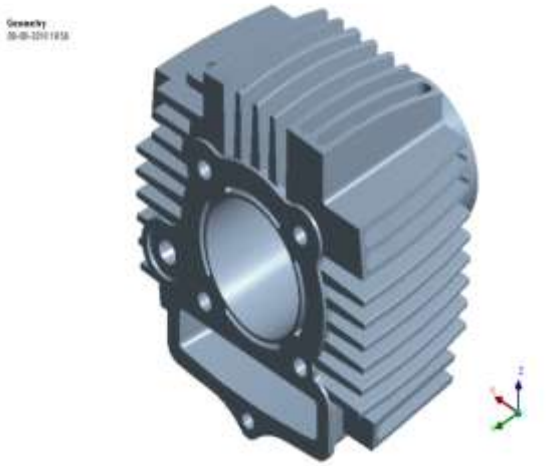

Fig.16 CAD geometry of proposed design with water jacket

2) Meshing

After completing the CAD geometry of proposed design of engine block with inter-cooling arrangement is imported in ANSYS workbench for further transient thermal analysis. The mesh created in this work is shown in figure No. 17. The total Node is generated 972853 & Total Number of elements is 560322.

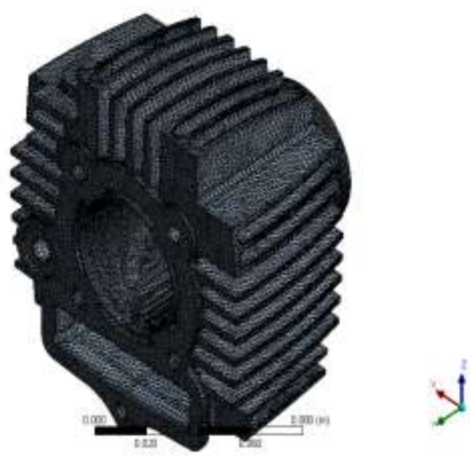

Fig. 17 Meshing of proposed design -2 with water jacket

3) Defining Material Properties & Boundary condition

The material property and boundary conditions remain same as actual design of engine cylinder block.

4) Temperature distribution of proposed design-2 of engine block for CI

The transient thermal analysis where performed on new proposed design-2 of engine block with water jacket at 45°C atmospheric temperature. The temperature distribution over the entire body of engine block is shown in figure No. 18 with different color contours. The maximum temperature is 650°C and minimum temperature is 156.26°C.

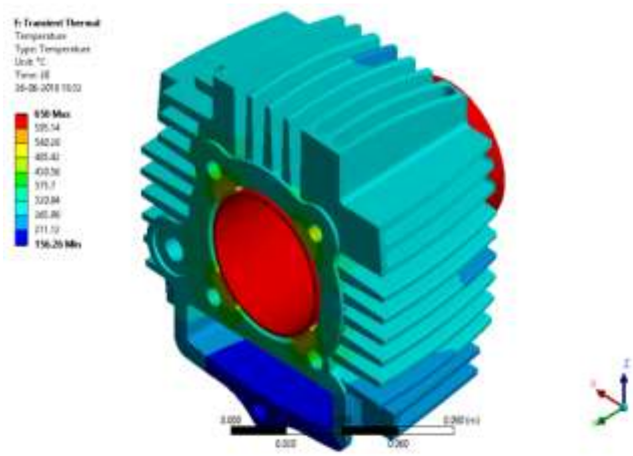

Fig. 18 Temperature distribution over of proposed design-2 of engine block for CI

5) Total Heat flux of new proposed design-2 of engine block for CI

The total heat flux generated in the engine cylinder is 5.2096e6 W/m^2 for the new proposed design of engine block with water jacket as shown in figure No. 19 with different color contours.

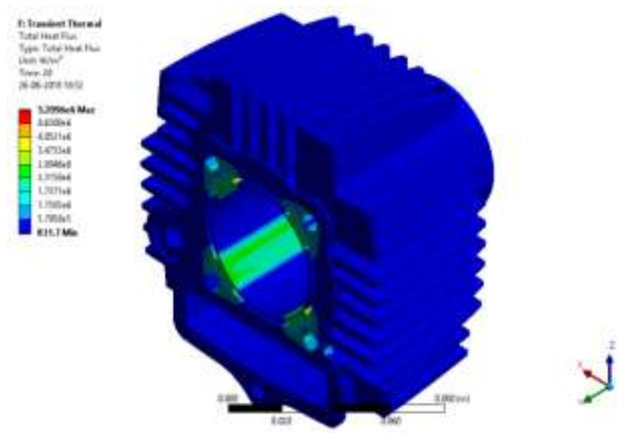

Fig. 19 Total Heat flux of new proposed design-2 of engine block for CI

E. Transient Thermal Analysis on proposed design-2 of engine block with for Al alloy

For the transient thermal analysis on actual design of engine block for Al alloy same CAD geometry and meshing are used as for transient thermal analysis of actual design of engine block of cast iron.

1) Temperature distribution of proposed design-2 of engine block for Al Alloy

The transient thermal analysis where performed on proposed design-2 of engine block with water jacket at 45°C atmospheric temperature. The temperature distribution over the entire body of engine block is shown in figure No.20 with different color contours. The maximum temperature is 650°C and minimum temperature is 119.21°C.

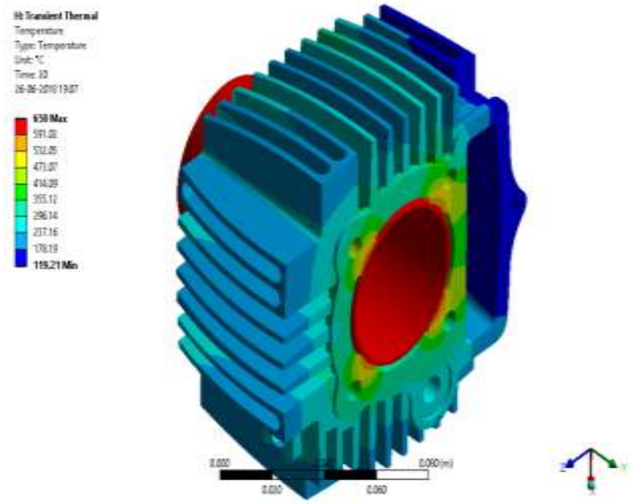

Fig. 20 Temperature distribution of proposed design-2 at engine block for Al Alloy

2) Total Heat flux of proposed design-2 of engine block for Al alloy

The total heat flux generated in the engine cylinder is 6.3621e6 W/m^2 for the new proposed design-2 of engine block with water jacket as shown in figure No. 21 with different color contours.

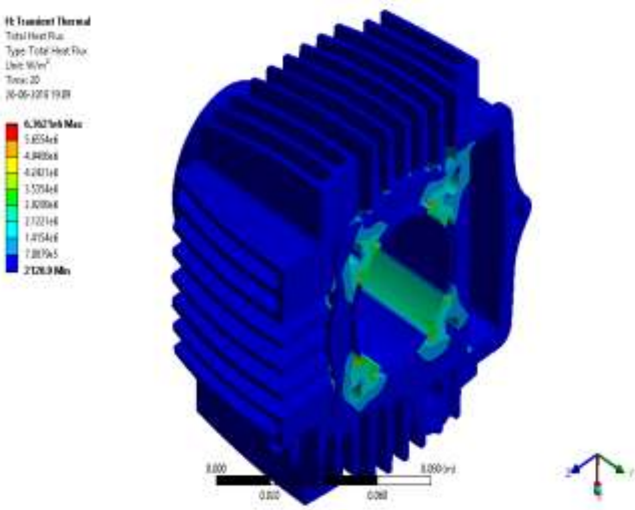

Fig. 21 Total Heat flux of proposed design-2 at engine block for Al Alloy

F. Transient Thermal Analysis for proposed design-3 of engine block for CI

1) CAD geometry

The new CAD geometry of proposed design-3 of engine block having discontinuous fins with inter cooling arrangement is created with the help of CATIA software then imported in ANSYS workbench for further analysis. A three dimensional view of proposed design of engine block with inter-cooling arrangement is shown in figure No. 22.

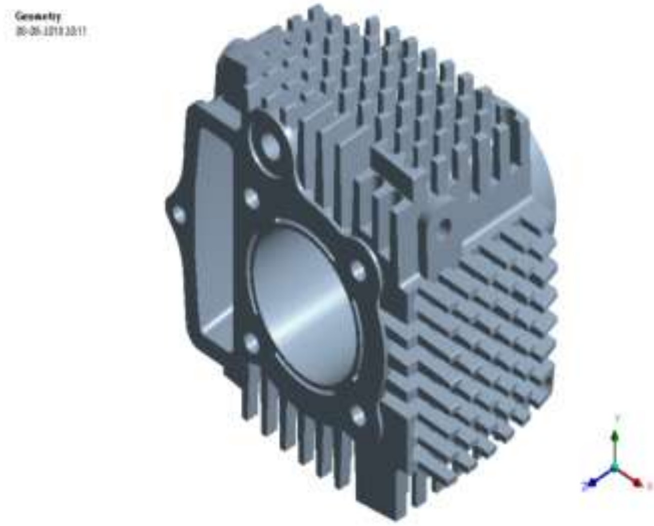

Fig. 22 CAD geometry of proposed design with water jacket

2) Meshing

After completing the CAD geometry of proposed design-3 of engine block having discontinuous fins with inter cooling arrangement is imported in ANSYS workbench for further transient thermal analysis. The mesh created in this work is shown in figure No. 23. The total Node is generated 938346 & Total Number of elements is 531983.

Fig. 23 Meshing of proposed design-3 of engine block

3) Defining Material Properties & Boundary condition

The material property and boundary conditions for proposed design-3 of engine block having discontinuous fins with inter cooling arrangement remain same as actual design of engine cylinder block.

4) Temperature distribution of proposed design-3 of engine block for CI

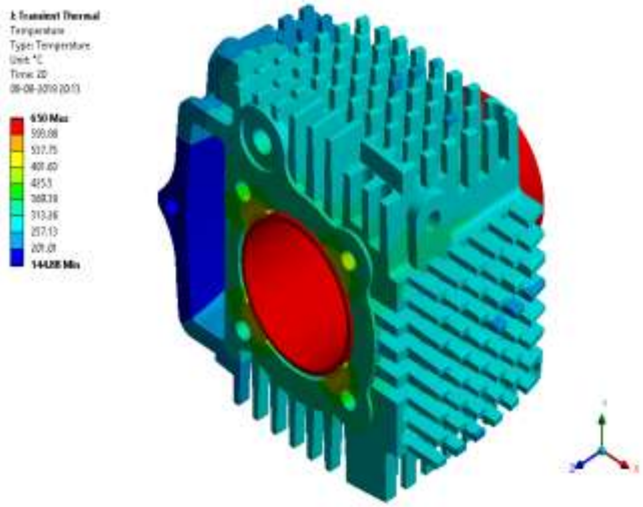

Fig. 24 Temperature distribution on proposed design-3 at engine cylinder block for CI

The transient thermal analysis performed on proposed design-3 of engine block having discontinuous fins with inter cooling arrangement at 45°C atmospheric temperature. The temperature distribution over the entire body of engine block is shown in figure No. 24 with different color contours. The maximum temperature is 650°C and minimum temperature is 144.88°C.

5) *Total Heat flux of proposed design-3 of engine cylinder block for CI*

The total heat flux generated in the engine cylinder is 5.3838e6 W/m^2 for the new proposed design of engine block with water jacket as shown in figure No. 25 with different color contours.

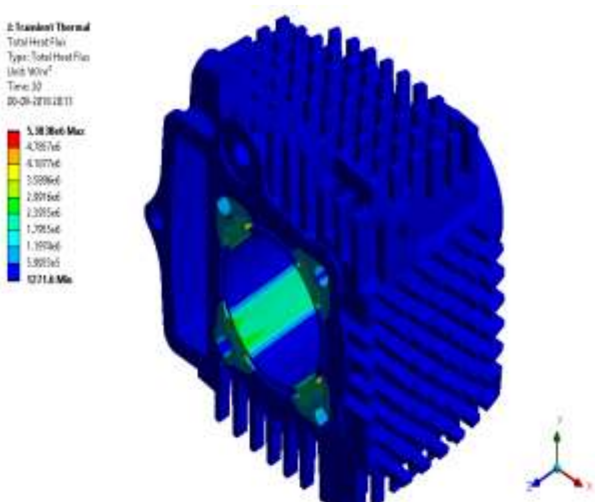

Fig. 25 Total Heat flux for proposed design-3 of engine cylinder block for CI

6) *Temperature distribution of proposed design-3 of engine cylinder block for Al alloy:*

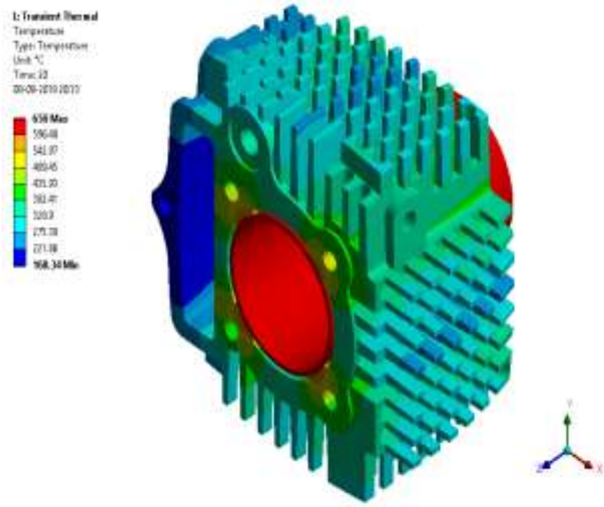

Fig. 26 Temperature distribution of proposed design-3 at engine block for Al Alloy

The transient thermal analysis performed on proposed design-3 of engine block having discontinuous fins with inter cooling arrangement for Al alloy at 45°C atmospheric temperature. The temperature distribution over the entire body of engine block is shown in figure No. 26 with different color contours. The maximum temperature is 650°C and minimum temperature is 168.34°C.

7) *Total Heat flux of proposed design-3 of engine cylinder block for Al alloy:*

The total heat flux generated in proposed design-3 of engine block having discontinuous fins with inter cooling arrangement is 5.932e6 W/m^2 as shown in figure no. 27 with different color contours.

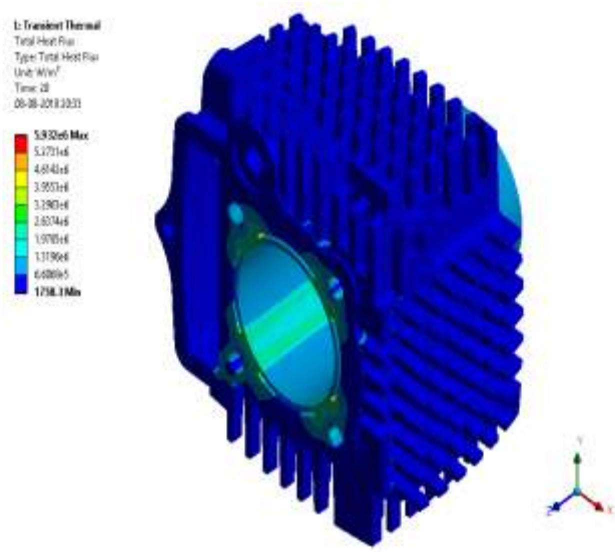

Fig. 27Total Heat flux of proposed design-3 of engine cylinder block for Al alloy

V. RESULT AND DISCUSSION

The transient thermal analysis ware performed using ANSYS workbench based on finite volume method for actual and proposed design with and without inter cooling arrangement and also for two different materials such as cast iron and Al alloy. The results obtained from the above parameters have been discussed in this chapter with the help of various tabulated and graphical representations.

A. Results of actual and proposed design of IC engine cylinder block

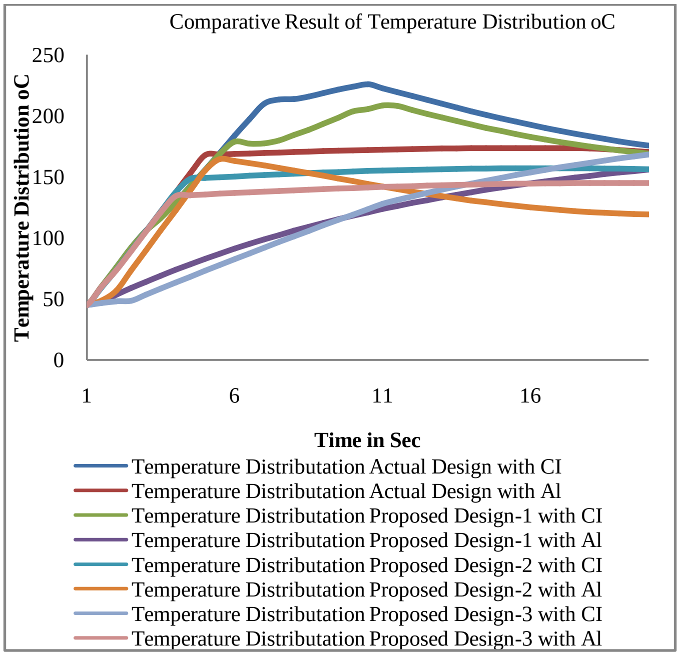

Fig. 28Comparative Result of Temperature Distribution °C

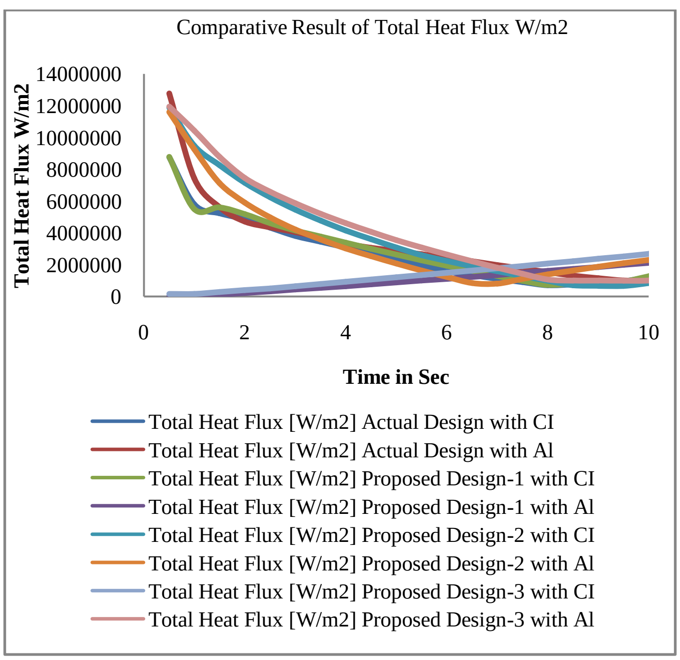

Fig. 29Comparative Result of Total Heat Flux W/m^2

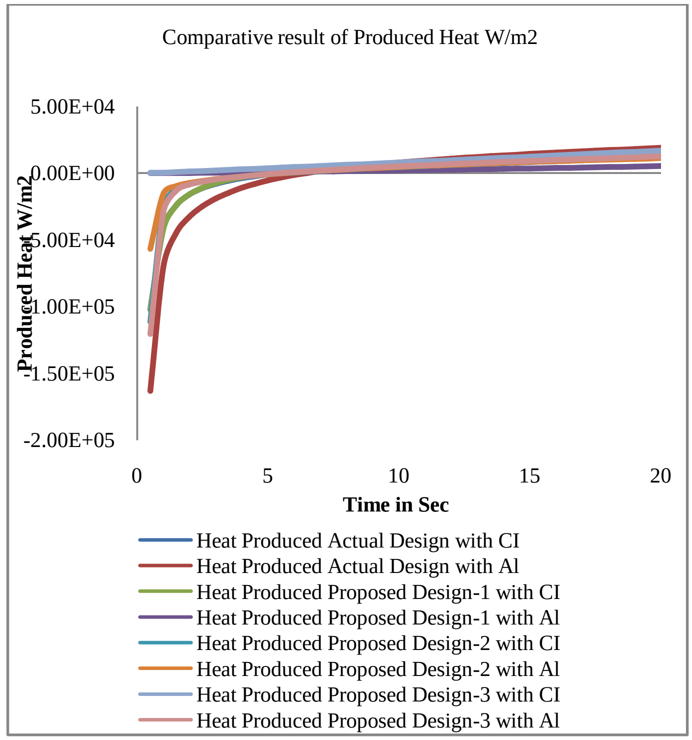

Fig. 30Comparative result of Produced HeatW/m^2

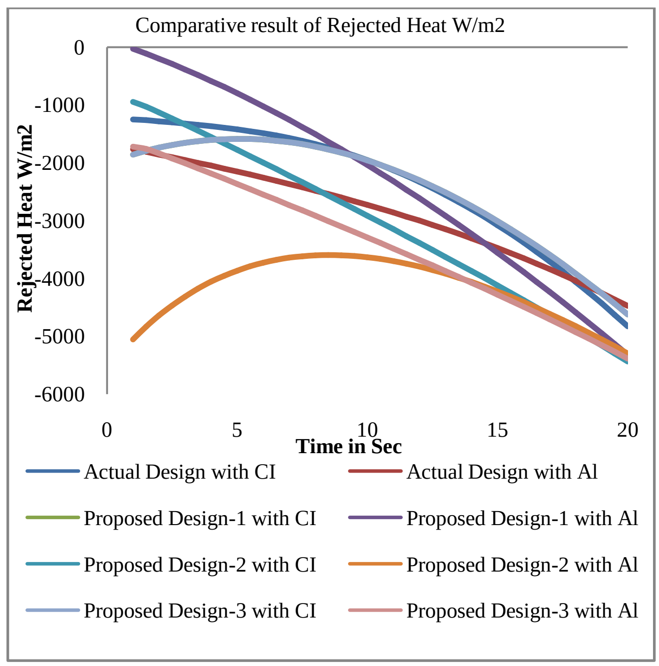

Fig. 31Comparative result of Rejected Heat W/m^2

B. Comparative results of Temperature Distribution

TABLE I

COMPARATIVE RESULTS OF TEMPERATURE DISTRIBUTION

Design of Cylinder block	Temperature Distribution (°C)	Total Heat Flux (W/m^2)
Actual design with CI	175.62	9.08E+05

Actual design with Al alloy	170.46	4.81E+06
Proposed design-1 with CI	169.17	7.07E+06
Proposed design-1 with Al alloy	155.88	4.98E+06
Proposed design-2 with CI	156.26	5.21E+06
Proposed design-2 with Al alloy	119.21	6.36E+06
Proposed design-3 with CI	168.34	5.93E+06
Proposed design-3 with Al alloy	144.88	5.38E+06

It has been observed that the proposed design of engine cylinder block using aluminum alloy for inter-cooling arrangements has better performance and heat dissipation from the heating zone in the IC engine that is why this present work more concentrate on it and also proposed.

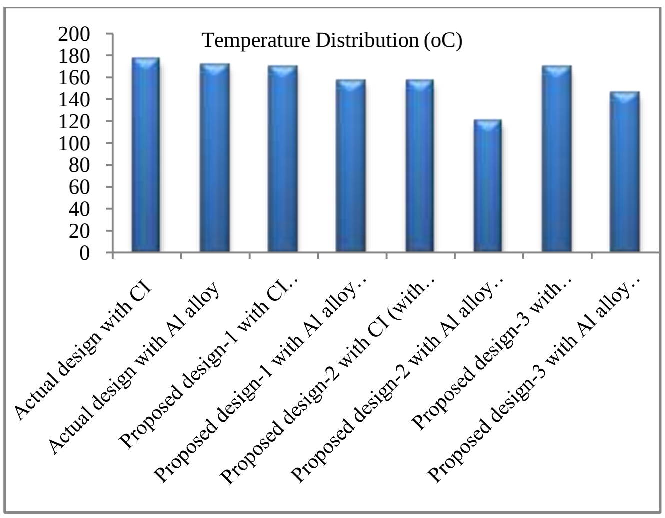

Fig. 32: Comparative Result of temperatures

VI. Conclusion

Mathematical and transient thermal analysis were performed in order to optimize geometrical parameters for heat transfer from Actual engine cylinder block and proposed design of cylinder block.

The following points have been identified in the form of conclusive statements which are as follows.

1. The result of transient thermal analysis of Actual design engine cylinder block for cast iron as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 175.62^{o}C, total heat flux generated is 9.08e6 W/m^2.
2. The result of transient thermal analysis of Actual design engine cylinder block for Al alloy as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 170.46^{o}C, total heat flux generated is 4.8063e6 W/m^2.
3. The result of transient thermal analysis of proposed design-1 of engine cylinder block having discontinuous fins for CI as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 169.17^{o}C, total heat flux generated is 7.0734e6 W/m^2.
4. The result of transient thermal analysis of proposed design-1 of engine cylinder block having discontinuous fins for Al alloy as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 155.88^{o}C, total heat flux generated is 4.9825e5 W/m^2.
5. The result of transient thermal analysis of proposed design-2 of engine cylinder block having inter-cooling arrangement for CI as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 156.26^{o}C, total heat flux generated is 5.2096e6 W/m^2.
6. The result of transient thermal analysis of proposed design-2 of engine cylinder block having inter-cooling arrangement for Al alloy as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 119.21^{o}C, total heat flux generated is 6.3621e6 W/m^2.
7. The result of transient thermal analysis of proposed design-3 of engine cylinder block having discontinuous fins with inter-cooling arrangement for CI as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 144.88^{o}C, total heat flux generated is 5.3838e6 W/m^2.
8. The result of transient thermal analysis of proposed design-3 of engine cylinder block having discontinuous fins with inter-cooling arrangement for Al alloy as a material at 45^{o}C atmospheric temperature indicates the temperature distribution over the cylinder block the maximum temperature is 650^{o}C and minimum temperature is 168.34^{o}C, total heat flux generated is 5.932e6 W/m^2.

To summarize the proposed design of engine cylinder block using aluminum alloy for inter-cooling arrangements has better performance and heat dissipation from the heating zone in the IC engine that is why this present work more concentrate on it and also proposed.

References

[1] Mahendra Kumar Ahirwar, Ravindra Mohan and. Jagdish Prasad, “I.C. Engine Cylinder Fins Transient Thermal Analysis By Using ANSYS Software” International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 02 | Feb-2018, e-ISSN: 2395-0056.

[2] Ravi Gupta and K.K. Jain, “Heat Transfer Analysis of Engine Cylinder Block with Different Material Alloys”, International Jo Urnal Of Innovative Research In Technology, IJIRT 145437, © March 2018 | IJIRT | Volume 4 Issue 10 | Issn: 2349-6002.

[3] Mulukuntla Vidya Sagar and Nalla Suresh, “Thermal Analysis of Engine Cylinder with Fins by using ANSYS Workbench”, International Journal of Engineering Research & Technology (IJERT), Vol. 6 Issue 06, June – 2017, ISSN: 2278-0181.

[4] Pulkit Sagar, Puneet Teotia, Akash Deep Sahlot and H.C Thakur, “Heat transfer analysis and optimization of engine fins of varying geometry”, Materials Today: Proceedings 4 (2017) 8558–8564.

[5] Devendra J. Waghulde, V H Patil and T. A. Koli, “Effect of geometry, material and thickness of fin on engine cylinder fins”, International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 07 | July -2017, e-ISSN: 2395-0056.

[6] Pushkar Bhanudas Patil and Dr. M. K. Chopra, “Effect of Fins Height on Two Wheeler Engine Cylinder”, IJSART- Volume 3 Issue 9 – SEPTEMBER 2017, ISSN [ONLINE]: 2395-1052.

[7] Sandeep Kumar and Nitin Dubey, “Investigation and Thermal Analysis of Heat Dissipation Rate of Single Cylinder SI Engine”, International Journal of Engineering Development and Research © 2017 IJEDR | Volume 5, Issue 2 | ISSN: 2321-9939.

[8] Divyank Dubey, Dinesh Singh, Abhishek yadav, Satyajeet pal and Harishchandra Thakur, “Thermal Analysis of Engine Cylinder having thick tip fin with varying slot sizes and material”, Materials Today: Proceedings 4 (2017) 7636–7642.

[9] Deepak Tekhre and Jagdeesh Saini, “Design Modification And Thermal Analysis of IC Engine Fin”, International Refereed Journal of Engineering and Science (IRJES) ISSN (Online) 2319-183X, (Print) 2319-1821 Volume 6, Issue 11 (November 2017), PP. 11-15.

[10] N. Arul, G. Srinivasan, K. Sriram, M. Vignesh and S.Vijayaraj “Experimental and Computational Analysis of Various Types of Fins”, International Journal For Research In Mechanical & Civil Engineering, Volume-3 | Issue-4 | April,2017 | Paper-4, ISSN: 2208-2727.

[11] Praveen Choudhary, Satyendra Kumar Pankaj, Mukul Tomar and Dr Harish Chandra Thakur, “Unsteady Analysis of Heated Inclined Fin-plate Placed Inside Square Enclosure”, 2017 2nd International Conference for Convergence in Technology (I2CT), 978-1-5090-4307-1/17/$31.00 ©2017 IEEE.

[12] Obula Reddy Kummitha and B. V. R. Reddy, “Thermal Analysis of cylinder block with fins for different materials using ANSYS”, Materials Today: Proceedings 4 (2017) 8142–8148.

[13] Aju Joseph, Amal Dev C George, Aneesh K, FibinShafi, Jijo Joseph and Arunraj A, “Heat Transfer Enhancement Perforations: A Review”, International Journal of Innovative Research in Science, Engineering and Technology, (An ISO 3297: 2007 Certified Organization), Vol. 6, Issue 1, January 2017, ISSN(Online) : 2319-8753.

[14] A Sathishkumar, MD KathirKaman, S Ponsankar and C Balasuthagar, “Design and thermal analysis on engine cylinder fins by modifying its material and geometry”, Journal of Chemical and Pharmaceutical Sciences, JCPS Volume 9 Issue 4, October - December 2016, ISSN: 0974-2115.

[15] Rahul Gupta, Rajneesh Kumar and Prateek Kumar Verma, “Heat Transfer Analysis of Engine Cylinder Fins Having Triangular Shape”, International Journal of Scientific & Engineering Research, Volume 7, Issue 5, May-2016, ISSN 2229-5518.

[16] L. Natrayan, G.Selvaraj, N.Alagirisamy and M.S.Santhosh, “Thermal Analysis of Engine Fins with Different Geometries”, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 5, May 2016, ISSN(Online) : 2319-8753.

[17] Shubham Shrivastava and Shikar Upadhyay, “Thermal Analysis of IC Engine Cylinder Block with Fins Perpendicular to the Axis of Piston Movement”, International Journal of Mechanical and Industrial Technology, Vol. 3, Issue 2, pp: (139-149), Month: October 2015 - March 2016, ISSN 2348-7593 (Online).

[18] Pinja Laaksonen, Timo Hyppänen and TeroTynjälä, “Effects Of Fin Parameters On Gas-Side Heat Transfer Performance Of H-Type Finned Tube Bundle In a Waste Heat Recovery Boiler”, 2015.

[19] Sachin Kumar Gupta, Harishchandra Thakur and Divyank Dubey “Required of Cooling System in IC Engines”, HCTL Open International Journal of Technology Innovations and Research (IJTIR) http://ijtir.hctl.org Volume 14, April 2015 e-ISSN: 2321-1814, ISBN (Print): 978-1-62951-946-3.

[20] PandugaEeshwar Prasad, Y. Dilip Kumar and Dr. P. H. V. SeshaTalpa Sai “Thermal Analyis Of Engine By Changing Fluid And Thickness Of Fins”, International Journal Of Emerging Trends In Technology And Science, Volume-06, Issue-01, November-2015, (ISSN: 2348-0246(online)).

[21] Sampath SS, Sawan Shetty and ChithiraiPon Selvan M, “Estimation of Heat Dissipation from Plate with Multiple Tapered and Rectangular Fins”, European Journal of Advances in Engineering and Technology, 2015, 2(5): 123-128, ISSN: 2394 - 658X.

[22] Subodh Kumar Sharma, P. K. Saini and N. K. Samria, “Experimental Thermal Analysis of Diesel Engine Piston and Cylinder Wall”, Hindawi Publishing Corporation Journal of EngineeringVolume 2015, Article ID 178652, 10 pages.

[23] Mr. Mehul S. Pate and Mr. N.M.Vora “The rmal Analysis of IC Engine cylinde r fins array using CFD”, International Journal of Advance Engineer ing and Research Development (IJAERD) Volume 1,Issue 5,May 2014, e-ISSN: 2348 - 4470 , print-ISSN:2348-6406.

[24] . Sai Chaitanya, B. Suneela Rani and K. Vijaya Kumar, “Thermal Analysis of Engine Cylinder Fin by Varying Its Geometry and Material”, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 6 Ver. I (Nov- Dec. 2014), PP 37-44.

[25] Pradeep Mani Tripathi, Satya Prakash, Rahul Singh and Satish Kumar Dwivedi, “Thermal Analysis on Cylinder Head of SI Engine Using FEM”, International Journal of Scientific Engineering and Research (IJSER), ISSN (Online): 2347-3878 Volume 2 Issue 4, April 2014.

[26] J. Krishneveni, G. Sowmya& U. Sudhakar, “Thermal Analysis of Cylinder Head by Using FiniteElement Analysis”, International Journal of Mechanical Engineering (IJME) ISSN(P): 2319-2240; ISSN(E): 2319-2259 Vol. 3, Issue 6, Nov 2014, 11-20.

[27] Mr. N. Phani Raja Rao and Mr. T. Vishnu Vardhan, “Thermal Analysis Of Engine Cylinder Fins By Varying Its Geometry And Material”, International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 8, August – 2013, ISSN: 2278-0181.