Heat Transfer And Efficiency Analysis of Fins in An IC Engine By Using Computational Fluid Dynamics

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Abstract- *The heat transfer processes in an internal combustion engine can be modeled with a variety of methods. Fins are placed on the surface of the cylinder to enhance the amount of heat transfer by convection. For thermal analysis of the engine cylinder fins, it is more beneficial to know the heat dissipation inside the cylinder. An IC Engine block is modified with rectangular fin for the varies fin geometry and the heat transfer rate and heat flux of fins is analyzed and calculated for a specific boundary conditions. As a result, temperature distribution of the cylinder and fin, heat flux through walls was observed. Generally, Heat transfer rate in conduction is directly proportional to thermal conductivity. Gray cast iron has low thermal conductivity hence the heat transfer rate is comparatively very low, considering other metals cast iron can withstand high temperatures & the cost is less compared. So general material like Gray Cast Iron is used in IC Engine cylinder. The components are designed by using SOLIDWORKS and analysis is done in ANSYS.*

Keywords- Convection; IC Engine; Fin; CFD Analysis; Cast Iron; Thermal Conductivity

I. INTRODUCTION

An Internal Combustion Engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high temperature and high pressure gases produced by combustion apply direct force to some component of the engine. This force moves the component over a distance, transforming chemical energy into useful mechanical energy. A cylinder is the central working part of a reciprocating engine or pump, the space in which a piston travel. Multiple cylinders are commonly arranged side by side in a bank, or engine block, which is typically cast from aluminum or cast iron before receiving precision machine work.

Heat losses are a major limiting factor for the efficiency of internal combustion engines. Furthermore, heat transfer phenomena cause thermally induced mechanical stresses compromising the reliability of engine components. The ability to predict heat transfer in engines plays an important role in engine development. Today, predictions are increasingly being done with numerical simulations at an ever earlier stage of engine development. These methods must be based on the understanding of the principles of heat transfer.

1.1 PRINCIPLES OF HEAT TRANSFER

Heat is the transfer of thermal energy. Heat is always transferred from an object of higher heat to one with lower heat. Exchange of heat occurs till body and the surroundings reach at the same temperature. The high-temperature body passes energy to the low-temperature one, eventually achieving thermal equilibrium. The tendency to thermal equilibrium, or even distribution of kinetic energy, is an expression of the second law of thermodynamics, the driving force of heat transfer. According to the second law of thermodynamics, ‘Where there is a temperature difference between objects in proximity, heat transfer between them can never be stopped; it can only be slowed down. Heat is the energy in transit between systems which occurs by virtue of their temperature difference when they communicate.

1.2 MODES OF HEAT TRANSFER

1.2.1 Conduction

Heat conduction, also called diffusion, is the direct microscopic exchanges of kinetic energy of particles (such as molecules) or quasi particles (such as lattice waves) through the boundary between two systems. When an object is at a different temperature from another body or its surroundings, heat flows so that the body and the surroundings reach the same temperature, at which point they are in thermal equilibrium. Such spontaneous heat transfer always occurs from a region of high temperature to another region of lower temperature, as described in the second law of thermodynamics.

Movement of heat through materials;

Fourier's law: $Q = -KA\frac{dT}{dt}$

1.2.2 Convection

Convection is the process of heat transfer in which transfer of heat energy occurs by the mass movement of molecules of the fluids like gases and liquids. Gases and liquids are not a good conductor of heat under normal conditions, but they can easily transfer heat. Heat transfer through convection occurs other through diffusion or advection or both. Convection does not take place in solids, because no movement of its constituent particles occurs. The diffusion of heat occurs in solids, and it is called thermal conduction.

The process in which heat transfer occurs between a surface and a liquid or a fluid that is in contact with the surface is called convection heat transfer. Convection plays a major role while transferring heat from one liquid to another liquid through a barrier. Heat transfer by convection either occurs due to thermal diffusion (motion of fluid molecule) or advection, in which heat is transferred by the bulk motion of heat currents in the fluid. Movement of heat by fluids;
Newton's law of cooling:

$$Q = h_C A(T_\infty - T_W)$$

1.2.3 Radiation

Radiation is the energy transfer in the form of waves through space without any medium other than conduction and convection. Conduction and convection require a medium like solid or gas but radiation only happen in space through electromagnetic waves. The black body is ideal surface for emits radiation at maximum rate, and the radiation transferred by a black body is called black body radiation. Absorptive α is another important property of a plane, is explained as the division of the radiation energy incident on a surface that is received by the surface. The entire radiation incident on it is absorbed by black body. That is, a blackbody is a perfect absorber (α=1) of radiation.

Heat movement by transfer from one body to another:

$$Q = \in \sigma(T_1^4 - T_2^4)$$

1.2.4 Extended Surfaces (Fins)

In the heat transfer study, the surface that extends from an object is known as a fin. Fins are used to increase the rate of heat dissipation from or to the environment by increasing the rate of convection. The total of convection, conduction, or radiation of an object decides the amount of heat it dissipates. It increases with the difference of temperature between the environment and the object, also increasing the convection coefficient of heat transfer, or increasing the surface area. But, increase of the area also causes increased resistance to the heat flow. Hence, coefficient of heat transfer is based on the total area (the base and fin surface area) which comes out to be less than that of the base. There are different types of shape and size fins used in engineering applications to increasing the heat transfer rate.

II. LITERATURE SURVEY

M H Abbood [1] Based on the results for flow around the modified aluminium alloy cylinder for a motorcycle engine created by adding fins around the cylinder made from the same material in different shapes (square, circular, elliptical, air foil), all shapes of fin increase the heat transfer rate from the cylinder to the ambient air. Three different air speeds (12, 18, 25 m/s) and three different heat fluxes (6, 12, 25 KW/m²) were examined. By changing the shape of the fin, the weight of the fin body is reduced, increasing efficiency.
Prof. Ravindra Mohan [2] During this paper we've got designed a cylinder fin body used n a 100cc Hero Honda motorbike and 3D modeling software package CATIA version 5.0 and used material for fin body is metallic element alloy fins and internal core with gray forged iron. We have a tendency to are commutation with metallic element alloy 6063 for entire body. the form of the fin is rectangular; we've got modified the form with circular geometry formed.

Dr. Pradeep Patil [7]It was found that higher air velocities around the extended surfaces increase the heat transfer. The variation in vehicle speed significantly changes heat transfer rate. As a consequence, fin efficiency also varies with vehicle speed. The physical dimensions of fin also impact the fin efficiency. It was found that the fin efficiency/heat transfer rate increases when air velocity was increased from 11.11 m/s to 16.667 m/s. The flow pattern of air is governed by physical geometry of fins.

Prof. Arvind S. Sorathiya [11] The summary of the present review study are as Heat release from the cylinder did not improve when the cylinder had more fins and too narrow a fin pitch at lower wind velocities, because it is difficult for the air flow into the narrower space between fins, so temperature between them increased.Heat transfer rate and heat transfer coefficient can be increased with the wind velocity. Based on review study cylinder heat transfer rate also increase by changing the various types of geometry of fins mounted on it. That can be analyzed by CFD and validate results by conducting experimental work.

III. PROBLEM DESCRIPTION AND OBJECTIVE

However almost all modern motorcycle engines use liquid-cooling except for motorbike engines. Because it is more difficult for air–cooling than liquid–cooling to uniformly cool an engine cylinder.

In order to permit the development of design data for more effective cooling fin. An experimental model cylinder for an air -cooled engine is considered and it is processed for heat transfer process followed by the combustion. Thus, the rate of heat dissipation, rate of cooling, efficiency, effectiveness and thermal conductivity of the fins are determined by using CFD analysis. Air cooled engines are more likely to overheat. High on wearing in engines when it gets cooled suddenly. In order to permit the development of design data for more effective cooling fin. The fin geometry is modified for the required boundary conditions and it is analyzed by using CFD Ansys software.

The main objective of this project is to compare the thermal properties of the fins in Air-cooled IC engine with different atmospheric conditions and closed chamber IC engine by using CFD Analysis.

Stage 1: To analyze the Temperature distribution and Heat flux of the fins.
Stage 2: To analyze the Temperature distribution and Heat flux of fins by changing fin properties.
Stage 3: To compare the thermal properties of fins with various conditions.

IV. MATERIAL SELECTION AND PROPERTIES

Engine blocks are normally cast from either a cast iron or an aluminium alloy. The aluminium block is much lighter in weight, and has better heat transfer to the coolant, but iron blocks retain some advantages such as durability and better clearances from heat expansion. Hence, Most engines have cylinders liners made of cast iron. Some cylinder liners or cylinders are also coated with high resistance to wear materials such as nickel, silicon carbide, boron nitride, etc depending on the application. Generally, the temperature inside an IC engine cylinder ranges from 600 to 2000ºC. Grey cast iron is the first and most material used for manufacturing of engine blocks. Though the other alloys also contain many similarities with low weight, it is still used in the manufacturing of diesel engine blocks because their internal stresses are higher.

Grey cast iron is characterized by its graphitic microstructure, which causes fractures of the material to have a grey appearance. It is the most commonly used cast iron and the most widely used cast material based on weight. Most cast irons have a chemical composition of 2.5–4.0% carbon, 1–3% silicon, and the remainder iron. Grey cast iron has less tensile strength and shock resistance than steel, but its compressive strength is comparable to low- and medium-carbon steel. These mechanical properties are controlled by the size and shape of the graphite flakes present in the microstructure and can be characterized according to the guidelines given by the ASTM.

The important properties of grey cast iron are given as

It posses excellent compressive strengths.

It also has good torsional and shear strengths.

It has good corrosion resistance, which may be attributed to high silicon content.

It has excellent fluidity and hence it can be cast into any complex shapes.

It posses good wear resistance in adhesive wear conditions and this is due to presence of graphite flakes which provide self lubrications.

It exhibits excellent Machinability because graphite acts to break up the chips and lubricate contact surfaces.

It also has outstanding sound and vibration damping capacity, this is again due to the fact that graphite flakes absorbs transmitted energy.

V. GEOMETRY GENERATION

Solid works is a 3D mechanical CAD program that runs on Microsoft Windows which was developed by Solid Works Corporation. Solid works provides a full range of integrated modeling, simulation, visualization; communication and validation tools that product designers need to develop better products faster and at lower cost.

Solid works enable the design engineer to:

Precisely turn creative concepts into 3D designs
Create the most ergonomic designs possible

Produce design in iterations in less time
Reduce prototyping time and cost

Solid works mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows TM graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent.

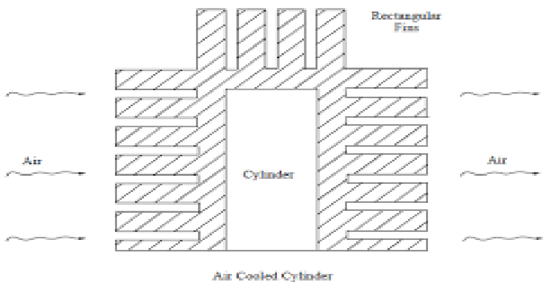

Fig 1: 2D Configuration of Fins

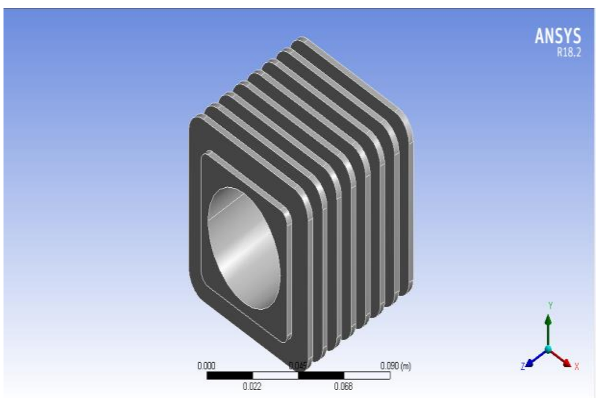

Fig 2: 3D Modeling of Engine Block – Model 1.

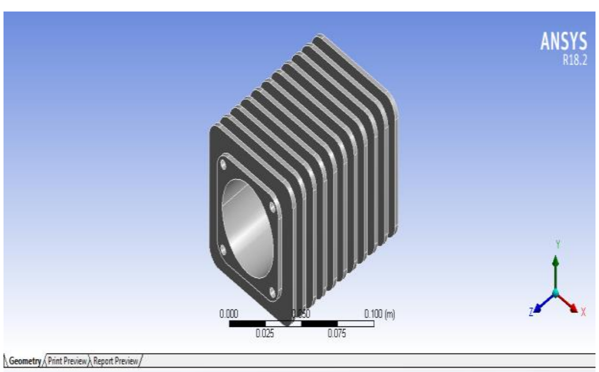

Fig 3: 3D Modeling of Engine Block – Model 2.

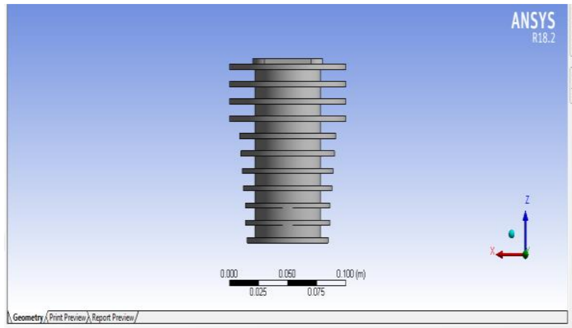

Fig4: 3D Modeling of Engine Block – Model 3.

5.1 MESHING

For CFD analysis by Fluent software, the model was first prepared and meshed in the Gambit and a mesh file was generated which is then reopened in fluent for the analysis where the element type and the boundary conditions were applied.

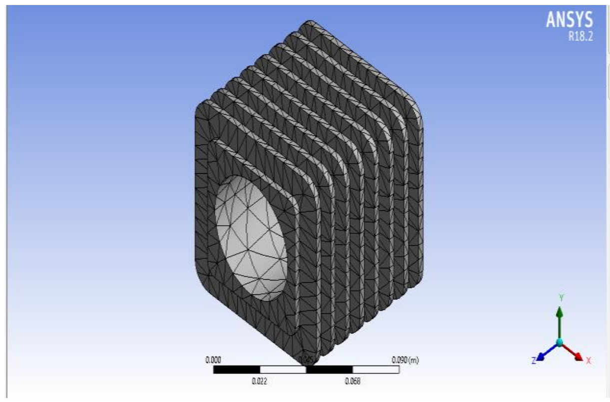

Fig 5: Meshing Generation for Model 1

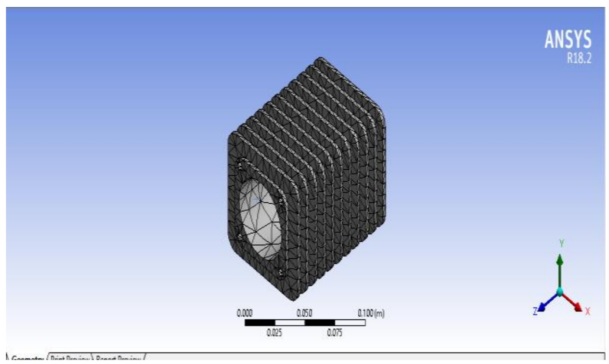

Fig 6: Meshing Generation for Model 2

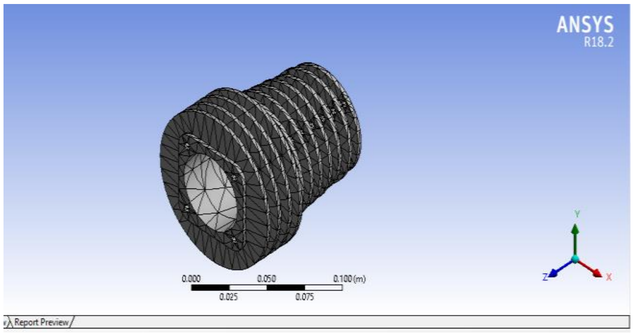

Fig 7: Meshing Generation for Model 3

VI. CFD ANALYSIS

Analysis of structure was done with the help of ANSYS. Global coordinate system was used with 28470 nodes and 15311 elements. Following results was obtained after simulation.

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by conditions. With high speed super computers,

In the present work, certain assumptions have been made to simplify the geometry and to carry out simulation with minimum computational power. A rectangular fins and annular fins are introduced on the cylinder surface to increase the rate of temperature distribution towards the external fins which helps in increasing the rate of cooling. In total, nine fins are taken on a cylinder block for heat dissipation process. The number of fins will be increased for better heat transfer rate.
As an object for modeling, a engine model is chosen with dimensions of 70 mm and 110 mm of cylinder length, 50 mm of cylinder bore and 70 mm length of fins. It was assumed that the cylinder block are identical presents a concept of a model of Engine cylinder block with fins, the cylinder block is equipped with internal surfaces and external surfaces. Processes which occur during fuel cell operation can be divided into three steps: Heat generation on engine block during Combustion process, Heat distribution from the internal surfaces to the external surfaces by mode of conduction, and the heat dissipation to the surroundings by mode of convection process.

VII. RESULTS AND DISCUSSION

Fluent software contains the broad, physical modeling capabilities needed to model flow, turbulence, heat transfer and reactions for industrial applications. Fluent spans an expansive range, including special models, with capabilities to model in-cylinder combustion, aero-acoustics, turbo machinery and multiphase systems.Fluent also offers highly scalable, high-performance computing (HPC) to help solve complex, large-model computational fluid dynamics (CFD) simulations quickly and cost-effectively.

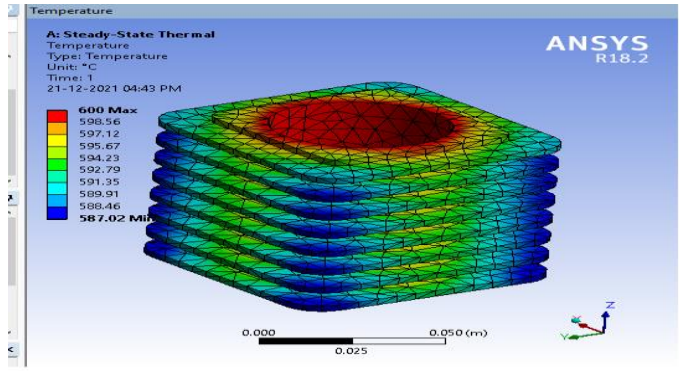

Fig 8: Temperature Distribution on Engine Block for Model 1

The figu re 8 depicts the temperature range from the internal surface cylinder bore to the external surface fins where the temperature is maximum at the internal surfaces and the temperature is minimum in the external surfaces.

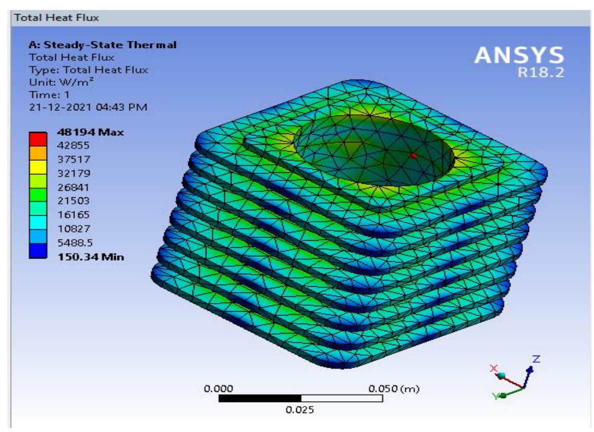

Fig 9: Heat Flux on the Engine blocks for Model 1

The Figure 9 describes the Heat Flux from the internal to external surfaces fins where the heat flow or heat density is maximum in the flow region of the engine block. When the temperature is maximum the heat flow is also increased as shown above.

- After simulation was done, we found deviation in theoretically calculated value and simulated result.
- ANSYS value of heat flux = 48194 W/ m^2.

- Obtained value of heat flux = 140033.64 W/m^2.

VIII. CONCLUSION

The analysis for the geometry of fin was carried out using ANSYS CFD. The simulations have been carried on the engine head internal surfaces to the external surfaces. The geometry of the engine heads was described earlier in the previous chapter with the objective of increasing the heat transfer rate of the fins.

Analysis of heat transfer through fins of engine was done. Temperature distribution of cylinder and fins, heat flux through walls was observed with the help of ANSYS. Generally, Heat transfer rate in conduction is directly proportional to thermal conductivity. Grey cast iron has low thermal conductivity hence the heat transfer rate is comparatively very low, considering other metals cast iron can withstand high temperatures & the cost is less compared. So, it is mainly used in I. C Engine cylinder.

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