A Review on Heat Transfer Analysis of Engine Cylinder Block with Different Material Alloys

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Abstract- **When a vehicle or its engine starts the internal combustion engine begins to burn the fuel in its piston chamber or the combustion chamber. In the process of combustion of fuel nearly 70% of the heat is lost into the atmosphere and only around 30% of the total heat generated in the combustion is successfully utilized, a large quantity is required to be passed through the fins of the engine. This heat if not removed adequately and properly in time may cause several problems and even ceasing the engine. Thus to prevent these thermal damages to the engine the heat must be properly removed out of the engine.**

In this review paper an attempt has been made 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 on the basis of previous papers.

For the analysis Finite Element Method has been employed using Ansys Software as a Simulation tool.

Index Terms- **heat transfer rate, finite element methods, piston, cylinder head etc.**

I. INTRODUCTION

1.1 General

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 Oldsmobile in 1902. [1]

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.[3,4]

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. [5,6]

The combustion procedure has the net impact of giving the warmth source to the thermal machine. The way toward changing over thermal energy into mechanical energy has intrinsic thermodynamic impediments, which may be wrongly translated as misfortunes. The genuine thermal misfortune in the combustion chamber is the warmth move through the walls. The combustion procedure achieves temperatures more than 2000K and no customary material is appropriate to fabricate an adiabatic chamber with moving parts.

Today, the main viable option is to utilize metals and control the parts temperature with a suitable cooling framework. This suggests the temperature of the combustion chamber walls is extensively lower than the center. Subsequently, a noteworthy piece of the generated warm is diverted through the cooling framework with no advantage. The warmth exchange between the charge and the walls is commanded by constrained convection [2]. Nevertheless, this is no run of the mill interior stream.The motion of a fluid

fully confined in a closed cavity with changing volume is almost unique to engine technology. [7]

The interactions between the charge and the chamber walls are many and different in nature. To pick up a more profound understanding it is a decent exercise to consider in detachment the warm impacts of the distinctive stream highlights display in motors. The underlying stream force is given amid the acceptance stroke by the cylinder movement. The state of the admission channels prompts certain stream structures (tumble and swirl). With the pressure stroke, these structures are distorted or upset to make a fitting stream field toward the finish of pressure. From that point the combustion process starts. This does not happen at the same time in the whole chamber. In this regard the Otto and the Diesel cycles are very extraordinary. In the Otto cycle the air/fuel charge is premixed, the spark-plug locally initiates the reaction that propagates in all directions until it reaches the wall. [8]

Differently, in modern Diesel engines, at the end of compression, high pressure fuel is injected in the combustion chamber and self-ignites. The high weight gives the liquid fuel a high force, bringing about a heterogeneous responding plane like stream. This in the long run encroaches on the divider with highlights entirely different than some other stream in the motor. [9] For both Diesel and Otto cycles the combustion has the aftereffect of quickly expanding the temperature and, therefore, the weight inside the combustion chamber. The force generated is then changed over into valuable work with the piston motion (power stroke).

Principles of heat transfer

Heat is the transfer of thermal energy. On a mic roscopic level, thermal energy is associated tothe vibrations of atoms and molecules. Hence, it can be s een as a form of kinetic energy. Temperature is ind eed a measure of these vibrations. The heat transf er between two bodies at different temperatures is ind eed an exchange of kinetic energy at a microscopic le vel.

Conduction is the exchange of thermal vitality between regions of issue because of a temperature inclination. Warmth immediately spills out of a region of higher temperature to a region of lower temperature, and decreases temperature contrasts after some time, moving toward thermal harmony.To calculate the heat transfer by conduction the Fourier's law is used

$q = -k\Delta t$ …….. (1.1)

Thermal radiation is electromagnetic radiation emitted from all matter due to its possessing thermal energy which is measured by the temperature of the matter.

$q = \varepsilon\sigma AT^4$ …….. (1.2)

Epsilon is the emissivity of the material and sigma the Stefan-Boltzmann constant. In the engine, radiation occurs in two places:

- Between the burning gas and the cylinder wall
- Between the block and the air
- Between the block and the other surfaces in the engine bay

Convection is another heat transfer mechanism that requires a medium. It occurs by means of the molecules movement within fluids. It takes place in two different ways: diffusion and advection. The first is the random Brownian motion of individual particles and the second is the heat and matter transported by the bulk motion of fluid. [10]

For the cooling system the convective heat transfer occurs, for example, in the cooling pipes when there is a temperature different between the wall surface temperature and the temperature of the coolant. The fluid in this case forms a thermal boundary layer where the convection takes place. Near the pipe surface the fluid velocity is low, and diffusion dominates. When moving away from the surface bulk motion starts to play the major role.

The convection can be classified to forced and natural. Forced convection occurs when a fluid flow is affected by external means. In the event of coolant pipes it is influenced by the pump, along these lines the convection heat transfer here can be thought to be constrained. Then again natural convection happens when there is no external effects on the heat transfer. [12]

Heat sources in a internal combustion engine

There are several processes within a internal combustion engine which generates heat. The combustion of the fuel converts to work as the expansion of the gases causes the motion of the piston. This combustion can be divided into radiation and convection terms. The radiation is released in the moment of combustion while the convection is

related to the gas flow. As the piston moves, the piston skirts and the piston rings slide along the cylinder liner lubricated by oil. This motion in turn creates friction between the faces. The friction of the piston ring assembly can be determined by tribology [2].

II- LITERATURE REVIEW

The previous study by the researchers are as:

"Thermal Analysis of cylinder block with fins for different materials using ANSYS", 2016, Obula Reddy Kummitha, B.V.R. Reddy, Materials Today: Proceedings 4 (2017) 8142–8148

In this paper an attempt has been made to find out the thermal analysis of cylinder block with fins for different materials by using ANSYS, and the results has been analyzed to find out the best material that gives the better heat transfer rate and consists of light weight.

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

Balances are the stretched out surfaces which help to dissipate heat produced in the engine yet these broadened surface length are restricted which constrain the rate of heat dispersal. Different automobile enterprises work to build this heat dissemination rate by which engine effectiveness can be expanded. In this paper we endeavor to expand the heat scattering rate through these broadened surfaces by expanding engine blade tip thickness around 3mm and furthermore giving openings of 50mm, 75mm, and 100mm The 3D displaying of engine with various space sizes keeping balance size and number of balance same planned on Solidworks and the investigation on the ANSYS relentless state. For this examination work we utilize Bajaj Caliber so we can recheck the outcome with past research comes about. We are contrasting its execution and others come about by utilizing distinctive material, for example, Aluminum Alloy 6061, Aluminum Alloy C443 and Aluminum Alloy 2014 which having higher thermal conductivities. Consequence of these different examination demonstrates that the engine utilizing Aluminum 2014 keeping the space width 75mm have high thermal heat dissemination rate as others openings width of others materials.

"Effect of solution heat treatment on residual stress in Al alloy engine blocks using neutron diffraction", 2017, A. Lombardi, D. Sediako, A. Machin, C. Ravindran, R. MacKay, Materials Science & Engineering A 697 (2017) 238–247

The results indicated that solutionizing at 470 °C caused a gradual relief of tensile residual strain up to approximately 5 h, where strain was completely relieved. At 500 °C, the strain relieved more rapidly, which resulted in complete relief in under 0.5 h. Cooling to ambient temperature caused the partial re-development of tensile residual stress throughout the cylinder depth due to thermo-mechanical mismatch, however the magnitude was lower than for the as-cast condition.

Tensile residual stress in the cylinder bore region is a significant problem associated with Al engine blocks containing cast-in gray iron cylinder liners as it can result in cylinder distortion or engine block fracture. These issues can lead to significant environmental (emissions) and economic (recalls) problems for automotive OEMs. in this examination, in-situ and ex-situ neutron diffraction was utilized to quantify the adjustment in residual strain in the cylinder bridge as an element of time during arrangement heat treatment and guide to the pressure profiles following heat treatment. A heating system, consisting of coiled tubular heaters in the cylinder bores and strip heaters along the front and side faces of the engine block, was designed and built to heat the blocks to the solution temperatures

"Thermal and hydraulic performance of a compact plate finned tube air-fuel heat exchanger for aero-engine", 2017, Jie Wen, Haoran Huang, Haiwang Li, Guoqiang Xu, Yanchen Fu, Applied Thermal Engineering

The ***article displays*** a novel reduced plate finned-tube air-fuel heat exchanger which is planned by means of utilizing logarithmic mean temperature difference method (LMTD) and both thermal and hydraulic performance of the heat exchanger are tentatively explored. Worldwide, because of the harsh working condition, both flying industry and aerospace industry office are in seriously need of minimized heat exchanger with light weight and high proficiency. In this paper, the plan, make and trial of a model, plate finned tube heat exchanger are

displayed. The stainless-steel heat exchanger weights 1.207 kg and by utilizing the fuel RP-3 as the coolant, it can cool the high-temperature air from high weight compressor in flying machine motor in an extremely constrained space. The investigation of stream protection in air-fuel stream permits deciding the stream grating element. Exploratory estimations of heat exchange for the heat exchanger are likewise ascertained. Furthermore, got estimations of heat exchange coefficient demonstrate a few differences with writing connections. In view of these differences, an exact connection for the outside heat exchange of minimal finned tube heat exchanger is set up, which will be useful for the analysts to outline comparable heat exchangers. *"Design, Analysis and Optimization of Four Stroke S.I. Engine Piston using Finite Element Analysis in ANSYS software",* 2016, Ankit Kumar Pandey, Prof. Sandeep Jain, Dr. Lokesh Bajpai, International Journal of Advance Engineering and Research Development Volume 3, Issue 9, September -2016

The aim of this paper is to design, analysis and optimization of four stroke S.I. engine piston, which is strong and lightweight using finite element analysis with the help of ANSYS Software. Solid Model of piston has been made utilizing ANSYS 16.2 Geometric module and Thermo-Mechanical (Static Structural Analysis + Steady-State Thermal Analysis) analysis is done to break down burdens, add up to twisting and factor of wellbeing appropriation in different parts of the piston to know the impact because of gas pressure and thermal varieties utilizing ANSYS 16.2.

"Design, Analysis and Optimization of Four Stroke S.I. Engine Piston using Finite Element Analysis in ANSYS software", 2016, Ankit Kumar Pandey, Prof. Sandeep Jain, Dr. Lokesh Bajpai, International Journal of Advance Engineering and Research Development

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"Thermal Analysis of a Diesel Piston and Cylinder Liner using the Inverse Heat Conduction Method", 2015, Martin Gonera, Olle Sandin, Chalmers University Of Technology

The *results* from the *validations* was that, for the intended engine load case span, the piston thermal analysis gave accurate results in terms of the piston structure temperature field and its surface heat flux. Consequently, the authors of this Master's thesis considers this thermal analysis model to generate results of high applicability and believe that the developed method of conducting a thermal analysis of a diesel piston is suitable. The procedure of mapping the element heat fluxes per unit area onto the cylinder liner was validated by reapplying the extracted thermal load onto the piston surface. The results indicated excellent resemblance to the original analysis results. As such, the element heat flux per unit area mapping methodology was considered to be feasible.

"Numerical modeling of subcooled nucleate low boiling in engine cooling systems", 2014, Fredrik Ohrby, Master's thesis in the Applied Mechanics programme

An arrangement of picked models have been assessed in Matlab and in the commercial CFD code Star-CCM+. An articulation to foresee the nearness of boiling has effectively been executed into the product and when connected to a motor cooling coat, boiling is anticipated to happen in those regions where it is normal. The heat transfer effects are evaluated utilizing the Chen connection together with the Dry-spot demonstrate with promising outcomes yet convergence issues show up for the Dry-spot display at high divider temperatures.

A technique has likewise been made to show the nearness of basic lm boiling and when connected to the motor cooling coat, boiling is shown chiefly in the barrel head around the fumes ports. Before incorporating the created strategies in the standard investigation of the motor cooling coat, additionally work is expected to enhance and approve the estimations of the heat transfer and to settle the convergence issues.

"Thermal Analysis of Engine Cylinder Fin by Varying Its Geometry and Material", 2014, P. Sai Chaitanya, B. Suneela Rani, K. Vijaya Kumar

The Engine cylinder is one of the real automobile parts, which is subjected to high temperature varieties and thermal burdens. With a specific end goal to cool the cylinder, fins are given on the surface of the cylinder to build the rate of heat transfer. By doing thermal investigation on the engine cylinder fins, it is useful to know the heat scattering inside the cylinder. We realize that, by expanding the surface territory we can build the heat dispersal rate, so designing such a vast complex engine is exceptionally troublesome. The primary point of the present paper is to break down the thermal properties by shifting geometry, material and thickness of cylinder fins utilizing ansys work seat.

Transient thermal investigation decides temperatures and other thermal amounts that change after some time. The variety of temperature dispersion after some time is of enthusiasm for some applications, for example, in cooling. The exact thermal reenactment could allow critical design parameters to be distinguished for enhanced life. By and by Material utilized for assembling cylinder balance body is Aluminum Alloy A204 which has thermal conductivity of 110-150W/mk. By and by examination is done for cylinder fins utilizing this material and furthermore utilizing Aluminum alloy 6061 which have higher thermal conductivities.

"Failure analysis of an aircraft engine cylinder head", 2013, Branimir Krstic , Bosko Rasuo, Dragan Trifkovic , Igor Radisavljevic , Zoran Rajic, Mirko Dinulovic, Engineering Failure Analysis 32 (2013) 1–15

The piston engine of the preparation airplane broke down amid the flight because of the cracking of its barrel head (CH), which is made from an aluminum throwing amalgam. In light of the fractographic examination of the mating break surfaces, the trademark ratchet and shoreline marks were watched demonstrating the event of fatigue disappointment. The crack was started from numerous sources situated on the internal flange fillet on the fumes side of the CH. The metallography examination has demonstrated that the fatigue was advanced from preexisting material imperfection because of a lifted nearness of shrinkage pores at the crack start zone and was in all likelihood connected with the assembling procedure of throwing. The finite element (FE) strategy, used to decide the pressure condition of the CH subjected to gas pressure, additionally confirmed that the crack inception was situated and no more pressure region.

III- RESEARCH METHODOLOGY

3.1 Finite-Element Analysis

Mechanical components as simple bars, beams, and so on., can be examined easily by basic methods of mechanics that give closed-frame solutions. Genuine com-ponents, be that as it may, are once in a while so simple, and the designer is compelled to less powerful approximations of closed-frame solutions, experimentation, or numerical methods.

There are a large number of numerical techniques used in building applications for which the digital PC is extremely useful. In mechanical design, where PC aided design (CAD) software is intensely utilized, the analysis strategy that integrates well with CAD is finite-element analysis (FEA). The mathematical theory and applications of the technique are vast. There is also various business FEA software packages that are accessible, such as ANSYS, NASTRAN, Algor, and so on. A heat transfer analysis can be performed on a structural component including the impacts of heat conduction, convection, or potentially radiation. After the heat transfer analysis is finished, a similar model can be utilized to decide the subsequent thermal burdens .

3.2 CFD Principles

The plain idea of CFD is to divide a great composite flow in smaller simpler flows, and to define them with practicable mathematical expressions. The way out of this system of equations is then a description of the great composite flow. In practice the finite volume method is applied to the equations leading the flow. The equations become then discrete rather that continuous and are solved using numerical discretization methods. The geometrical discretization of the entire flow is called mesh or grid and it is composed of cells or elements, which are the control volumes.

CFD stands for Computational Fluid Dynamics but in the context of this work it is important to explicitly state that the approach can be directly extended to solids. For stationary solids it is not necessary to solve the momentum and continuity equations. Only the energy equation for conduction needs to be solved.

3.3 Geometry Modeling

The existed Vespa scooter cylinder block was considered for the study of thermal analysis. This model was generated with the help of AutoCAD modeling package as shown in Figure 3.1 and 3.2.

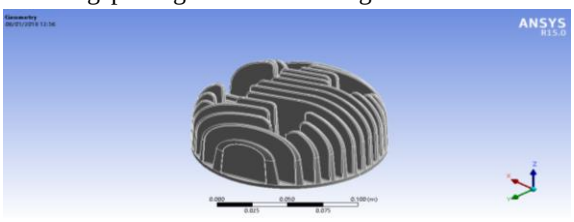

Figure 3.1 Geometry of Vespa Scooter Cylinder block

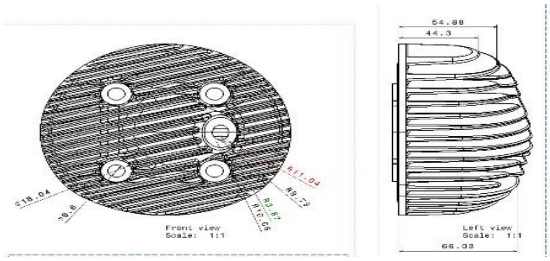

Figure 3.2 (a) Side View and Front View of the Drawing

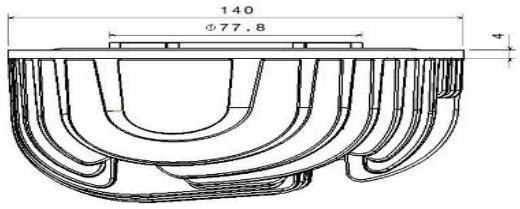

Figure 3.2 (b) Top View of the Drawing

Figure 3.2 AutoCAD generated drawing of Cylinder block

Table 3.1 Properties of Cylinder Block

Property	Value
Volume	4.0093× 10^{-4} m^3

The properties of these materials are given in table 3.2.

Table 3.2 Properties of material used for the study [Obula Reddy Kummitha, B.V.R. Reddy]

Material	Tensile strength (Mpa)	youngs moduls (Gpa)	density (kg/m^3)	specific heat (j/kg.k)	thermal conducivity (W/m.k)
A356	234	48	2670	963	151
A360	303	71	2630	963	113
A380	324	75	2760	963	109
Al metal matrix alloys (Al-MMC)	345	80	2760	963	109
Mg Alloy	230	45	1810	1050	72
Aluminium Alloy 6061	310	73	2700	1256	167
Grey Cast Iron	255	54	7200	45	46
Structural Steel	250	46	7850	434	60.5

IV- CONCLUSION

The conclusion of present study based on the previous papers, to find out the best suitable material which gives the

- Finest heat transfer rate through it for cooling as primary consideration
- Safe working of Engine
- Having high strength
- Light in weight and also
- Lower Cost

Following conclusions have been made

- ✓ By observing the results it is to be identified that the grey cast iron and Structural Steel are giving the better heat distribution and maximum temperature difference
- ✓ 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.
- ✓ Cylinder blocks are subjected to high strengths due to combustion of fuel; hence strength is also one more important parameter needs to be considered for the selection of material. Al MMC shows the highest strength while Mg alloy shows the lowest strength while the other materials showing moderate strength.
- ✓ Cost of raw materials which is one of the important consideration for selecting the material for the cylinder block manufacturing of economical vehicles in developing countries. Apart of all the other materials Grey cast iron and Structural steels are more economical.

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