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THERMAL ANALYSIS OF THREE CYLINDER ENGINE HEAD AND PERFORMANCE OPTIMISATION

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Abstract: The internal combustion engine is a rich source of examples of almost every conceivable type of heat transfer. There are a wide range of temperatures and heat fluxes in the various components of the internal combustion engine. Internal combustion engines come in many sizes, from small model airplane engines with o 0.25 (6 mm) bore and stroke to large stationary engines with a 12" (300 mm). About 25 % of the air/fuel mixture energy is converted to work, and the remaining 75% must be transferred from the engine to the environment. The heat transfer paths are many, and include many different modes of heat transfer.

In this module, we will discuss the heat transfer processes in the engine components, then consider the engine parameters and variables which affect the heat transfer processes. Maximnum amount of heat is transferred târough the cylinder head In this project we have tafen efforts to analyze the heat transfer through the cylinder head of three cylinder S.I. engine. CAE is extensively used for simulation.

Heat transfer is analyzed for different rates of coolant flow and a optimized coolant flow rate is suggested.

Keywords: *Cylinder Head, Thermal Analyis, Heat Transfer.*

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I.INTRODUCTION TO CYLINDER HEADS

1.1 CYLINDER HEADS:

As an appreciable amount of heat is transferred through the I. C. engine which effects the engine performance, it is therefore essential to look forward to analyze the modes of heat transfer and temperature variations in the engine components.

About 35% of the total chemical energy that enters an engine in the fuel it converted to crankshaft work, & about 30% of the fuel energy is carried array from the engine in the exhaust flow in the form of enthalpy & chemical energy. This leaves about one third of the total energy that must be dissipated to the surrounding by some mode of heat transfer. Temperatures within the combustion of an engine reach values on the order 2700 K & up. Materials in the engine cannot tolerate this kind of temperature & would quickly fail if proper heat transfer did not occur. Removing heat is highly critical in keeping an engine & engine lubricant away from thermal failure. On the other hand it is desirable to operate an engine as hot as possible to maximize thermal efficiency. - [Willard Pulkrabek Engineering Fundamtation of I. C. engine Second Edition.]

It must be remembered that the reliability of an engine depends not so much, it is true on the proportion of the total heat converted into useful work, but rather upon the proportion of the total heat which is not so converted & which is left over to make trouble. [Harry Ricardo, High speed combustion Engine 1923]

Internal combustion engines at best can transform about 25 to 35% of chemical energy in the fuel into mechanical energy. About 35% of heat generated is lost into the surrounding of combustion space. Remainder being dissipated through exhaust & radiation from the engine.

It should be remembered that abstraction of heat from the working medium by the way of cooling the engine components is a direct thermodynamic loss.

High pressure fuel injection systems such as common rail system & electronically controlled unit injector [EUI] systems have been widely applied modern heavy duty diesel engines. They are shown to be very effective for achieving high power density with high fuel efficiency & low exhaust gas emissions. However the increased peak combustion pressure gives additional structural & thermal load to engine structure. Thus proper material selection & thermal analysis of engine components are essential in order to meet the durability, requirements of heavy duty CI engines adopting high pressure injection systems.

1.2 OBJECTIVE OF WORK:

Temperature of burned gases in the cylinder of an internal combustion engine may reach upto ten times of surface temperature and leads to great heat fluxes emitted to the chamber walls during the combustion period. Maximum metal temperatures for the inside of combustion chamber space are limited to much lower values by a number of considerations & hence cooling for the engine becomes essential. In regions of high heat flux, thermal stresses must be kept below levels that would cause fatigue cracking (less than about 400°C for cast iron & 300°C for aluminium alloys). The gas side surface of cylinder wall must also be kept low to prevent deterioration of the lubrication oil film. Heat transfer effects the engine performance, efficiency & emissions.

It should always be remembered that abstraction of heat from the working medium by the way of cooling the engine components is a direct thermodynamic loss.

For a given mass of fuel within the cylinder, higher heat transfer by extra cooling will lower the average combustion gas temperature & pressure which in turn reduce the work per cycle transferred to the piston. Thus specific power & efficiency are reduced.

Various thermal efficient super alloys are been invented & used for I.C. engine component, but it is not possible to achieve all the mechanical, chemical & thermal properties from same material. The engine components are not directly exposed to elevated temperatures & thus are relieved from heavy thermal stresses increasing the working life. Also this reduces the amount of cooling required and results in power saving of the engine. As can be seen, it is very important to predict the magnitude of heat transfer in designing engines. Hence it is the objective in this analysis to study temperatures distribution overs the cylinder head & optimize it's cooling.

II.LITERATURE SURVEY

2.1 LITERATURE REVIEWS:

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Cylinder head is a critical part of an I C engines cylinder head is used to seal the working ends of the cylinder and accommodates combustion chamber in its cavity, spark plug and valves. The heat generated in combustion chamber is highly dynamic and allows very little time (few micro seconds) to transfer the heat if not distributed will lead to squeezing of piston due to overheating. Hence an effective waste heat distribution through cylinder head plays a very important role in smooth function of I C engine.

Heat Transfer through cylinder head consists of conduction through walls and convective heat transfer due to surrounding air flow. As the shape of cylinder head is complex and temperature within the combustion chamber is still fairly unknown. Conventional methods of evaluating heat transfer are very complex. This project aims at evaluating heat transfer through cylinder head using finite element analysis. Geometrical models of Cylinder head with and without fins are developed in Auto CAD software .Thus developed models are exported to ANSYS software, and finite element model for thermal analysis done in ANSYS. Effect of fins on heat transfer through cylinder is evaluated.

Cylinder head is the very important part in the automobiles. The top of cylinder is covered by a separate cast piece known as the cylinder head. The cylinder head is bolted to the top of cylinder block. It contains combustion chamber, spark plug, and sometimes valves are mounted on it. It incorporates passages for flow of cooling air. The main purpose of cylinder head is to seal the working ends of the cylinder and not to permit entry and exit of the gasses on over head valve engines. The inside cavity of head is called the combustion chamber in to which the mixture is compressed for firing. Its shape controls the direction and rate of combustion. So the performance of an I.C engine depends on the effective utilization of heat liberated during the combustion. Heat generated during the combustion is converted to mechanical power on to the crankshaft and part of it is wasted as heat losses through exhaust gases and heat transfers to the surroundings. This project aims to determine the heat transfer through the cylinder head for various configurations that is without fins and with fin.

III.HEAT TRANSFER THROUGH CYLINDER HEAD

3.1 HEAT TRANSFER:

Heat transfer is that science which predicts the rate of energy transfer taking place between material bodies is a result of temperature difference between them. The study of heat transfer has become an increasingly intense concern in modern technology in the earth science, in organic metabolism in environmental Engineering. The study of heat transfer is carried out for the following purpose-

i. To estimate the rate of flow of energy as heat through the boundary of the system under study. (Both under steady and transient conditions)
ii. To determine the temperature field under steady and transient condition.

In almost every branch of engineering, heat transfer problems are encountered which cannot be solved by thermodynamics reasoning alone, but requires an analysis based on heat transfer principles. The areas covered under the discipline of heat transfer are-

1) Design of thermal and nuclear power plants.
2) Internal combustion engines.
3) Refrigeration and air conditioning units.
4) Design of cooling systems for electronics motors, generators and transformers.
5) Heating and cooling of fluids etc. in chemical operations.
6) Construction of dams and structures; minimization of building heat loss using improved insulation techniques.
7) Thermal control of space vehicles.
8) Heat treatment of metals.
9) Dispersion of atmospheric pollutants.

3.2 HEAT TRANSFER MECHANISM

Heat transfer, which is defined as the transmission of energy from one region to another as a result of temperature gradient takes place by the following three modes:

1) Conduction.
2) Convection.
3) Radiation.

Heat transmission, in majority of real situations, occurs as a result of combinations of three modes of heat transfer. Heat always flows in the direction of lower temperature.

The above three modes are similar in that a temperature differential must exist and the heat exchange is in the direction of decrease in temperature, each method however has different controlling laws.

CONDUCTION

Conduction heat transfer is energy transport due to molecular motion and interaction. Conduction heat transfer through solids is due to molecular vibration. Fourier determined that Q/A, the heat transfer per unit area (W/m2) is proportional to the temperature gradient dT/dx. The constant of proportionality is called the material thermal conductivity k. figure shows the heat transfer through conduction.

Fourier equation: Q/A = -k (dT/ dx)

The thermal conductivity k depends on the material and somewhat on the temperature of the material. The various materials in engines have the following thermal conductivities (W/m K):

1) Copper ………… 400
2) Aluminum……….240
3) Cast Iron…………80
4) Water……………0.61
6) Air……………..0.026

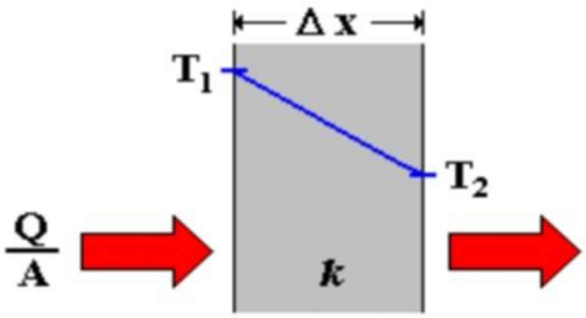


Fig. 3.1: Conduction

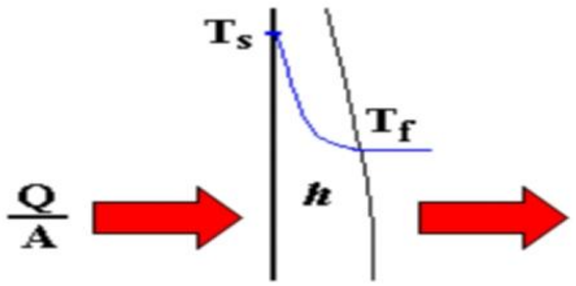


Fig. 3.2 Convection

CONVECTION:

Convection heat transfer is energy transport due to bulk fluid motion. Convection heat transfer through gases and liquids from a solid boundary results from the fluid motion along the surface. Newton determined that the heat transfer area, Q/A, is proportional to the fluid solid temperature difference Ts –Tf the temperature difference usually occurs across a thin layer of fluid adjacent to the solid surface. This thin fluid layer is called a boundary layer. The constant of proportionality is called the heat transfer coefficient, h. figure shows the heat transfer through convection.

Newton's Equation:

Q/A = h (Ts –Tf)

The heat transfer coefficient depends on the type of fluid and the fluid velocity. The heat flux, depending on the area of interest, is the local or area averaged. The various types of convection heat transfer are usually categorized into the following areas:

Convection Type	**Description**	**Typical value of 'h'**
Natural convection	Fluid motion induced by density differences.	10 (gas) 100 (liquid)
Forced convection	Fluid motion induced by pressure differences from a fan or pump.	100 (gas) 1000 (liquid)
Boiling	Fluid motion induced by a change of phase from liquid to vapor.	20,000
Condensation	Fluid motion induced by a change of phase from vapor to liquid.	20,000

RADIATION:

Radiation heat transfer is energy transfer due to emission of electromagnetic waves from a surface or volume. The radiation does not require a heat transfer medium, and can occur in a vacuum. The heat transfer by radiation is proportional to the fourth power of the absolute material temperature. The proportionality constant 'б' is the Stefan Boltzman constant equal to 6.67* 10 –8 W/ m2k4. The radiation heat transfer also depends on the material properties represents 'ϵ' , the emissivity of the material. figure shows the heat transfer through the radiation.

Q/A = ϵ б T4

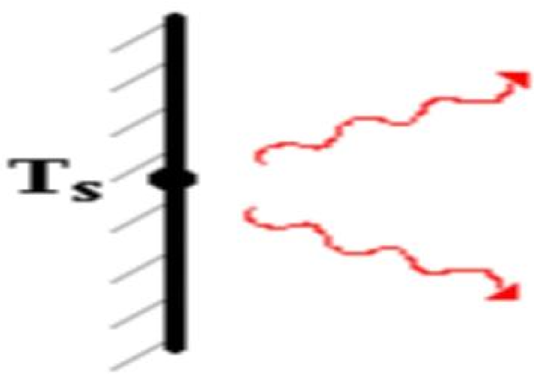


Fig. .3.3: Radiation

3.3: EFFECTS OF OVERHEATING OF ENGINE PARTS

Some time due to following operation conditions, heat generation within the engine cylinder may be excessive:

Extremely high-speed operation.

Unusually engine being overloaded.

Late valve timing.

Engine hot spots or overheating.

The heat flow to the various part of the engine will tend to over heat them, unless cooled properly. Overheating may cause the following problems:

Evaporation of lubricating oil that lubricates the cylinder and cylinder wall. High temperature cause the lubricating oil film to break down i.e. the oil film fails to stick to the surfaces and the lubricating oil also losses its lubricating properties. This will result in metal-to-metal contact of the piston and the cylinder and may cause piston seizure.

Setting up of the thermal stresses in the cylinder head and the piston. This may lead to cracking of the cylinder head and piston.

Sticking of piston rings in the ring grooves. This is due to carbonization of the lubricating oil. Ring sticking will result in insufficient sealing of the cylinder, increased blow by of the gases and loss of thermal efficiency.

Burning of piston crown.

Burning and warping of (exhaust) valves.

Reduction in volumetric efficiency. This is due to excess heating of the incoming charge. Heating reduces charging weight by way of reducing charge density. Reduction in the charge weight will lower the power output of the engine.

3.4 OPTIMUM COOLING

To prevent overheating and the consequent ill effects, the heat transferred to an engine component must be removed as quickly as possible and be conveyed to the atmosphere. Some parts of the engine may melt from the heating of the burning gases, if no cooling system is provided. It will be correct to say the cooling system as a temperature regulation system.

It should be remembered that, abstraction of heat from the working medium by the way of cooling the engine components is a direct thermodynamic loss. Excessive cooling result in the following:

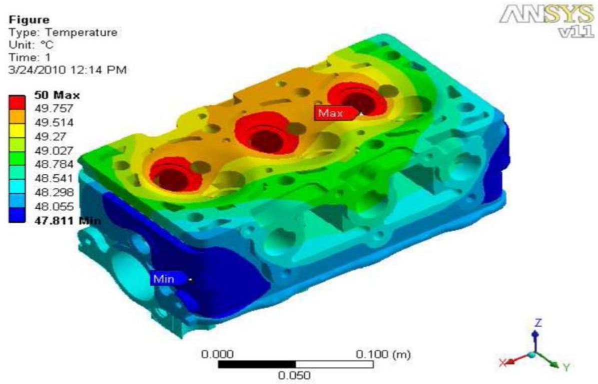
1) Reduction in thermal efficiency.
2) Increase corrosion in the engine parts.
3) Reduced mechanical efficiency.
4) Improper vaporization of the fuel. This leads to wastage of fuel and dilution of the crank case oil by the un-vaporized fuel.
5) Hence, if high thermal efficiency is desired, the quantity of heat abstracted shall not be more than the necessary to prevent overheating.

IV.RESULT AND DISCUSSION

RESULT AND CONCLUSION:

The CAE softwares are nowadays widely used for simulation as the result achieved are quite close and approximate to the real condition. Various software were used in the project. Modeling was done with CATIA V5. Meshing was done with the thermal analysis was done with ANSYS WORKBENCH 2014.0.

To obtain the optimum condition of temperature we take three cases:



CASE I: Coolant flow rate of 80 GPM

This is a thermal mapping of cylinder head for 50˚ C. the cooling rate required for this temp. is 80 GPM at this state cylinder head get overcooled**.**

Max. temp. = 50˚ C

Min temp. = 47.81˚ C

Max Heat Flux = 12332 W/m²

V.CONCLUSION:

The Three Cylinder Head S.I. engine in conventional mode is suggested to be operated at a flow rate of 63 GPM where the max. temp. 72˚ C. at the exhaust valve region. On reducing flow rate to 49 GPM the max temperature at the exhaust valve region goes to 90˚ C. where the cylinder head get overheated and for increasing the flow rate up to 80 GPM the temperature in the vicinity of exhaust valve reduces to 50˚ C. where cylinder head is overcooled.

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