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THERMAL ANALYSIS OF CYLINDER HEAD BY USING FINITE ELEMENT ANALYSIS

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ABSTRACT

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.

KEYWORDS: Cylinder Head, I C Engines, Heat Transfer, ANSYS

INTRODUCTION

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.

HEAT TRANSFER IN CYLINDER AND CYLINDERHEAD OF I.C.ENGINES

Introduction

In internal combustion engines, the combustion of fuel takes place and heat energy will be developed. During the process the total heat will not be converted in to work, only a part of the heat energy is converted in to useful work at the crank shaft. The remaining heat will be rejected as follows.

- Heat from the engine boundaries due to radiation, convection and to small extent conduction
- Exhaust heat
- Heat rejected to the coolant

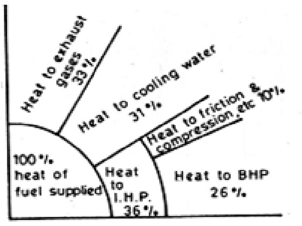

Figure 1: Shows the Typical Distribution of Heat

The energy supplied to the engine (as fuel) is influenced by the physical characteristics of the engine such as

- Engine design
- Type of the fuel used
- Coolant system etc.

In general 30% of the energy supplied is converted in to useful work. About 30% is lost as exhaust and some energy is lost in friction, compression and direct rejection from the engine. Rest of the energy about 30% has to be removed by the cooling system

COMBUSTION CHAMBERS FOR S.I ENGINE

The design of combustion chamber for an S.I engine has an important influence on the engine performance and its knocking tendencies. The design involves the shape of the combustion chamber, the location of the spark plug and location of inlet and exhaust valves.

The important requirements of the S.I Engine combustion chambers are to be provided with high power output at minimum octane requirement, high thermal efficiency and smooth engine operation.

- To design combustion chambers the following objectives are to be considered.
- Smooth engine operation
- High power output and thermal efficiency.

Types of S.I Engine combustion chambers

- T-Head type
- L-Head type
- I- Head type
- F- Head type

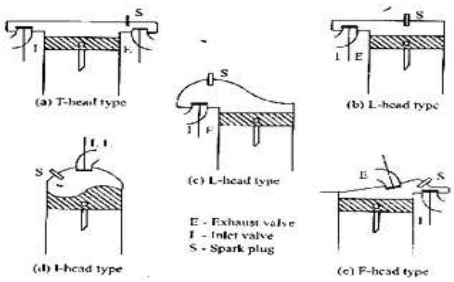

Figure 2: Shows Typical Combustion Chambers for S.I. Engines

AIR COOLING

In this method heat is carried away by the air flowing over and around the engine cylinder. It is used in scooters, motor cycles etc. Here fins are cast on the cylinder head and cylinder barrel which provides additional conductive and radiating surfaces. The fins are arranged in such a way that they are at right angles to the cylinder axis.

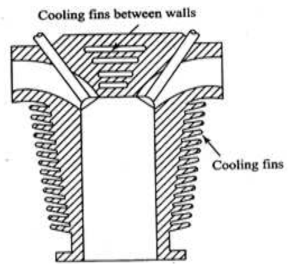

Figure 3: Shows the Cooling Fins of an Engine Cylinder

FINS

In air cooling system fins are most suitable for increasing the heat transfer rate from the cylinder. Fins are extended surfaces. These are placed around the cylinder or cylinder head.

TYPES OF FINS

- Longitudinal Fins

  The fins are made along the length of the body.

- Circumferential Fins

  Circumferential fins are made in the form of discs around the tubes.

- Pin or spines fin

  If the fins are made in the form of cylindrical rods with small diameter are called Pin fins.

The heat dissipating capacity of fins depends up on their cross section and length. At the same time as the heat is gradually dissipated form the fin surface, the temperature of the fin decreases from its root to tip. Hence the fin surface nearer to the tip dissipates heat at a lower rate and is less efficient. On the other hand as the quality of the heat flowing towards the tip gradually decreases, the thickness of the fin can be decreased. The material of the fin is used most efficiently if the drop in temperature from the root to tip is constant per unit length. The rectangular cross section has least temperature drop where as maximum temperature drop for the fin marked ‘a’.

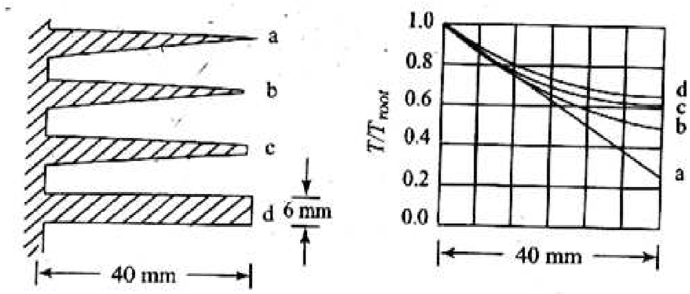

Figure 4: A Comparison of the Fins Different Cross Section as Shown in Figure

Fins are usually given a taper of 3 to 5 decreasing order to give sufficient drop to the pattern. The tip is made 0.5 to 1.25mm thick and a clearance of 2.5 to 5mm is allowed at the root. The fins are made 25to50mm long. Too close spacing of the fins results in small quantity of heat dissipation.

TASKS IN A THERMAL ANALYSIS

The procedure for doing a thermal analysis involves three main tasks:

- Build the model.
- Apply loads and obtain the solution.
- Review the results.

CREATING MODEL GEOMETRY

There is no single procedure for building model geometry; the tasks you must perform to create it vary greatly, depending on the size and shape of the structure you wish to model. Therefore, the next few paragraphs provide only a generic overview of the tasks typically required to build model geometry. For more detailed information about modeling and meshing procedures and techniques, see the *ANSYS Modeling and Meshing Guide*.

The first step in creating geometry is to build a solid model of the item you are analyzing. You can use either predefined geometric shapes such as circles and rectangles (known within ANSYS as *primitives*), or you can manually define nodes and elements for your model. The 2-D primitives are called *areas*, and 3-D primitives are called *volumes*.

Model dimensions are based on a global coordinate system. By default, the global coordinate system is Cartesian, with X, Y, and Z axes; however, you can choose a different coordinate system if you wish. Modeling also uses a working plane - a movable reference plane used to locate and orient modeling entities. You can turn on the working plane grid to serve as a "drawing tablet" for your model.

You can tie together, or sculpt, the modeling entities you create via Boolean operations, For example, you can add two areas together to create a new, single area that includes all parts of the original areas. Similarly, you can overlay an area with a second area, then subtract the second area from the first; doing so creates a new, single area with the overlapping portion of area 2 removed from area 1.

SOLID87 ELEMENT DESCRIPTION

SOLID87 is well suited to model irregular meshes (such as produced from various CAD/CAM systems). The element has one degree of freedom, temperature, at each node.

The element is applicable to a 3-D, steady-state or transient thermal analysis. See SOLID87 in the *ANSYS, Inc. Theory Reference* for more details about this element. If the model containing this element is also to be analyzed structurally, the element should be replaced by the equivalent structural element (such as SOLID92). A 20-node thermal solid element, SOLID90, is also available.

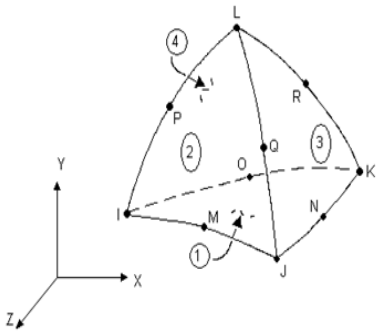

Figure 5: SOLID87 Geometry

SOLID87 Input Data

The geometry, node locations, and the coordinate system for this element are shown in Figure 5, "SOLID87 Geometry".

Orthotropic material directions correspond to the element coordinate directions. The element coordinate system orientation is as described in Coordinate Systems. Specific heat and density are ignored for steady-state solutions. Properties not input default as described in Linear Material Properties.

Element loads are described in Node and Element Loads. Convection or heat flux (but not both) and radiation may be input as surface loads at the element faces as shown by the circled numbers on Figure 5: "SOLID87 Geometry". Heat generation rates may be input as element body loads at the nodes. If the node I heat generation rate HG (I) is input, and all others are unspecified, they default to HG (I). If all corner node heat generation rates are specified, each midside node heat generation rate defaults to the average heat generation rate of its adjacent corner nodes.

A summary of the element input is given in "SOLID87 Input Summary". A general description of element input is given in Element Input.

SOLID87 INPUT SUMMARY

Nodes

I, J, K, L, M, N, O, P, Q, R

Degrees of Freedom

TEMP

Real Constants

None

Material Properties

KXX, KYY, KZZ, DENS, C, ENTH

Surface Loads

Convection or Heat Flux (but not both) and Radiation (using Lab = RDSF) --

Face 1 (J-I-K), face 2 (I-J-L), face 3 (J-K-L), face 4 (K-I-L)

Body Loads

Heat Generations --

HG(I), HG(J), HG(K), HG(L), HG(M), HG(N), HG(O), HG(P), HG(Q), HG(R)

SOLID87 ASSUMPTIONS AND RESTRICTIONS

- The element must not have a zero volume.
- Elements may be numbered either as shown in Figure 87.1: "SOLID87 Geometry" or may have node L below the IJK plane.
- An edge with a removed mid side node implies that the temperature varies linearly, rather than parabolic ally, along that edge.
- See Quadratic Elements (Mid side Nodes) in the *ANSYS Modeling and Meshing Guide* for more information about the use of mid side nodes.
- The specific heat and enthalpy are evaluated at each integration point to allow for abrupt changes (such as melting) within a coarse grid of elements.
- A free surface of the element (i.e., not adjacent to another element and not subjected to a boundary constraint) is assumed to be adiabatic.

THERMAL ANALYSIS OF CYLINDER HEAD BY F.E.M

Finite element analysis of cylinder head for steady state heat transfer analysis consists of two broad stages.

- creation of cylinder head Geometry
- Finite element modeling

As the shape of the cylinder head is complex, ANSYS software do not have the capability to model such complexities. Software, AutoCAD is used to generate 3D model.

GEOMETRIC MODELLING OF CYLINDER HEAD

The single-cylinder IC engine cylinder head is modeled in AutoCAD software.

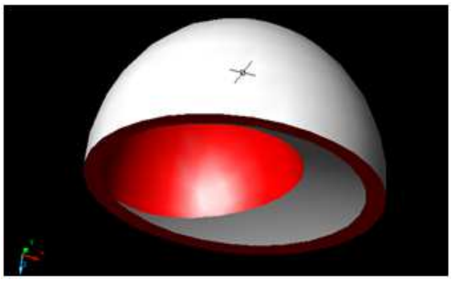

Figure 6: Shows the 3D Model

RESULTS AND CONCLUSIONS

Cylinder head with and without fins have been modeled using AutoCAD software. Thus developed models are exported to ANSYS as SAT files. General purposing Finite Element Analysis software ANSYS has been used to make Static analysis of cylinder head.

Temperature distribution of the cylinder head at steady state conditions, thermal gradients, thermal fluxes along x, y and z directions can be viewed. Results can also be plotted so that the temperature distributions, thermal fluxes and gradients at desired element or area can be viewed.

Following are the results which are obtained from thermal Analysis of cylinder head at steady state conditions with and without fins.

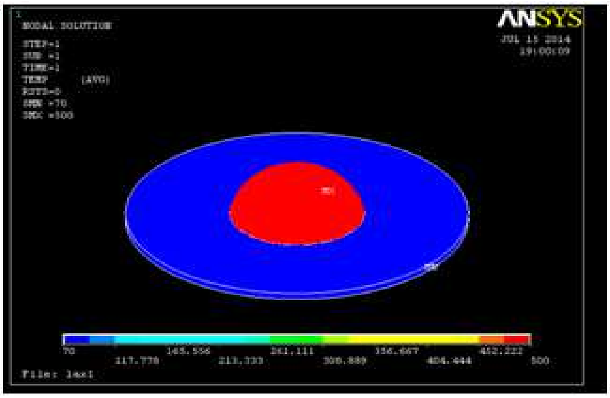

Figure 7: Temperature Distribution of Cylinder Head without Fins

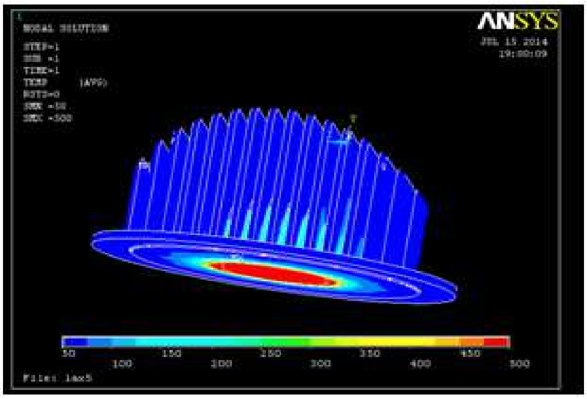

Figure 8: Temperature Distribution of Cylinder Head with Fins

Figure 7 shows the temperature distribution of cylinder head without fins. In figure the flow of temperature varies from 500 degrees centigrade at the combustion chamber to 70 degrees centigrade on free surface.

Figure 8: shows the temperature distribution of cylinder head with fins. Due to fins the minimum temperature is reduced to 50 degrees centigrade on fins.

Results such obtained can also be plotted in terms of temperature nodal solution per node.

Some of the solutions such obtained are listed below.

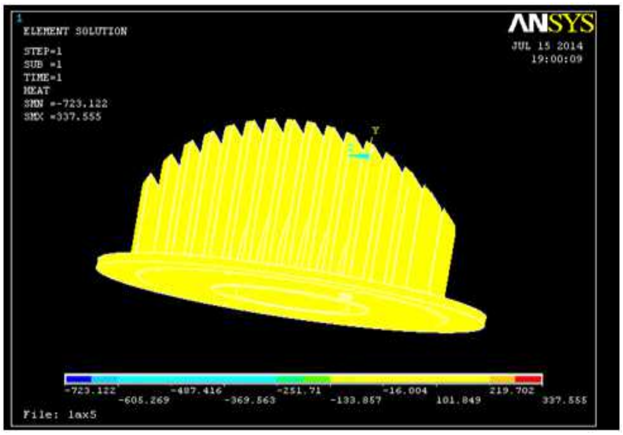

Figure 9: Heat Flow of Diagram Cylinder Head with Fins

Figure 9 shows flow of heat in cylinder head and it varies from maximum 37.555) w/mm^2 to (minimum) zero on insulated surfaces.

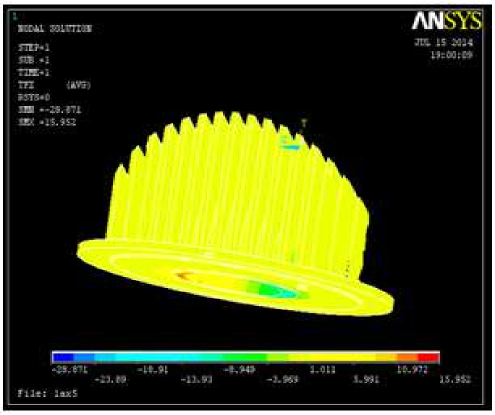

Figure 10: Thermal Flux in Z – Direction of Cylinder Head with Fins.

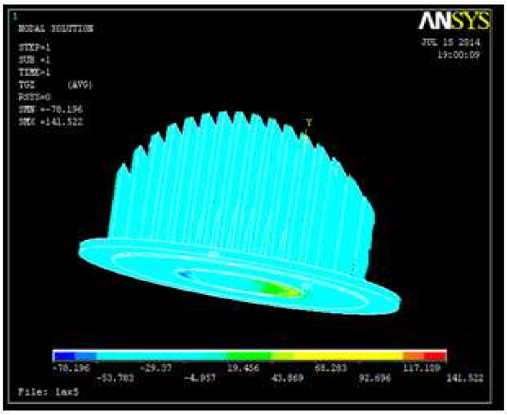

Figure 11: Thermal Gradient of Cylinder Head in Z Direction

Figure 10 shows the flow of heat per unit area. The flow of heat is varying in different directions and in different ranges, where the difference in z-direction exists from maximum (15.952) to minimum (-28.871).

SCOPE FOR FUTURE WORK

Changing the cross section and orientation of fins on the cylinder head will yield better results such as increase in the heat transfer rate from the cylinder head and increase thermal efficiency of cylinder head.

Verification of results can be obtained by test set up on an engine can be taken up as future work.

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