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Heat Flux and Temperature Distribution Analysis of I C Engine Cylinder Head Using ANSYS

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Abstract: **A Cylinder head is the closed and often detachable end of a cylinder located in an internal combustion engine. It is typically found on the top portion of the engine block. The cylinder head contains such parts as valves, valve seats, guides, springs and rocker arm supports. The main objective of our project is to design the cylinder head by using standard formulae and modeling by using the SOLIDWORKS software. The steady state thermal analysis is carried by using ANSYS software. In this project we are analyzing the various thermal properties for various geometrical shapes of the cylinder head (Rectangle and Circular) and further correlating the numerical values of the cylinder heads with the finite element values.**

Keywords: **Cylinder head, I C Engine, heat flux and Temperature etc.**

1. INTRODUCTION

Amit V. Paratwar, D.B Hulwan [1] Engine heat transfer and cooling is always been a crucial area of interest for improvement of engine performance.CFD methods and tools used today provide clearer and more detailed data on temperature, flow and pressure variation. Aim and objective of the present study is to carry heat transfer as well as flow analysis of existing cooling jacket of 6-cylinder turbo after-cooled medium duty diesel engine and then investigate the factors affecting cooling performance to optimize the said parameters through steady state CFD analysis and validate them with experimental results. Marcel Diviš , Radek Tichánek and Miroslav Španiel, [2] This paper documents the research carried out by Josef Božek Research Center of Engine and Automotive Engineering dealing with extended numerical stress/deformation analyses of engines parts loaded by heat and mechanical forces. It contains closed description of C/28 series diesel engine head FE model and discussion of tunning heat transfer analysis and results. The head model consisting of several parts allows describing contactinteraction in both thermal and mechanical analysis.

P.N.Shrirao,Dr. Rajeshkumar SambheI [3] In this study, thermal analysis is investigated on a conventional (uncoated) cylinder head of diesel engine, made of cast iron in previous stage. Then the thermal analysis is performed on cylinder head, coated with 3Al2O3 .2SiO2 (mullite) (Al2O3 = 60%, SiO2= 40%) material by means of using a commercial code, namely **ANSYS**. Finally, the temperature distributions are compared with each other. Heat transfer models have been developed for cylinder head with and without thermal insulation coating, which is incorporated in the simulated program. Gas wall heat transfer calculations are based on Annand's heat transfer model for IC engines. The effect of coating on the thermal behavior of the cylinder head is investigated using finite element analysis. It has been shown that the maximum surface temperature of the coated cylinder head with low thermal conductivity mullite material is improved approximately by 22-38%.

J. Krishnaveni et al [4] 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 ishighly 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. M. Fadaei et al [5] The results of a thermo-mechanical analysis of a natural gas, internal combustion engine cylinder head are presented in this paper. The results are pertinent to the evaluation of overheating damage in critical areas. The three-dimensional geometries of the cylinder head and the water jacket were modeled by means of a computer-aided engineering tool. Commercial finite element and computational fluid dynamics codes were used to compute details of mechanical stress in the head and flow details in the cylinder and cooling jacket, respectively. A six-cylinder, four-stroke diesel engine and a spark-ignition natural gas engine were modeled over a range of speeds at full load. Computed results, such as maximum allowable cylinder pressure, output power, BMEP and BSFC, were validated by experimented data in the diesel engine model. The results were in good agreement with experimental data. The results show high stresses at the valve bridge. Cylinder head temperatures and comparison of output power with high stress measurements, often exceeding the elastic limit, were found at the valve bridge.

II ANALYZING THERMAL PHENOMENA

A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities of interest are: The temperature distributions, The amount of heat lost or gained, Thermal gradients and Thermal fluxes. Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate thermal stresses (that is, stresses caused by thermal expansions or contractions).

2.1 ANSYS Supports Two Types Of Thermal Analysis

A steady-state thermal analysis determines the temperature distribution and other thermal quantities under steady-state loading conditions. A steady-state loading condition is a situation where heat storage effects varying over a period of time can be ignored. A transient thermal analysis determines the temperature distribution and other thermal quantities under conditions that vary over a period of time

2.2 Coupled-Field Analysis

Some types of coupled-field analyses, such as thermal-structural and magnetic-thermal analyses, can represent thermal effects coupled with other phenomena. A coupled-field analysis can use matrix-coupled ANSYS elements, or sequential load-vector coupling between separate simulations of each phenomenon.

2.3 Steady-State Thermal Analysis

The ANSYS Multiphysics, ANSYS Mechanical, ANSYS FLOTRAN, and ANSYS Professional products support steady-state thermal analysis. A steady-state thermal analysis calculates the effects of steady thermal loads on a system or component. Engineer/analysts often perform a steady-state analysis before performing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis, performed after all transient effects have diminished. Thermal simulations play an important role in the design of many engineering applications, including internal combustion engines, turbines, heat exchangers, piping systems, and electronic components. In many cases, engineers follow a thermal analysis with a stress analysis to calculate thermal stresses (that is, stresses caused by thermal expansions or contractions).

III MATERIAL & METHODS

3.1 Material Properties Used

Thermal Conductivity = 167 W/m K Specific Heat = 896 J/kg K Density = 2700 kg/m^3 Viscosity = 17.95x10^{-6} m^2/s Film Coefficient = 1.5 w/m^2 k

3.2 Solid70 Element Description

SOLID70 has a 3-D thermal conduction capability. The element has eight nodes with a single degree of freedom, temperature, at each node. The element is applicable to a 3-D, steady-state or transient thermal analysis. The element also can compensate for mass transport heat flow from a constant velocity field. If the model containing the conducting solid element is also to be analyzed structurally, the element should be replaced by an equivalent structural element (such as SOLID45). With this option, the thermal parameters are interpreted as analogous fluid flow parameters. For example, the temperature degree of freedom becomes equivalent to a pressure degree of freedom.

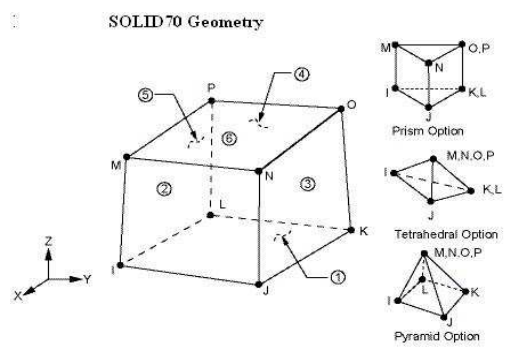

FIG. 1 SOLID70 ELEMENT GEOMETRY.

3.3 SOLID70 Input Data

The geometry, node locations, and the coordinate system for this element are shown in Figure 5.5 “SOLID70 Geometry". The element is defined by eight nodes and the orthotropic material properties. A prism-shaped element, a tetrahedral-shaped element, and a pyramid-shaped element may also be formed as shown in Figure “SOLID70 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 1 "SOLID70 Geometry". Heat generation rates may be input as element body loads at the

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nodes. If the node I heat generation rate HG (I) is input, and all others are unspecified, they default to HG(I).

SOLID70 Input Summary

Nodes: I, J, K, L, M, N, O, P

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

face 1 (J-I-L-K), face 2 (I-J-N-M), face 3 (J-K-O-N),

face 4 (K-L-P-O), face 5 (L-I-M-P), face 6 (M-N-O-P)

Body Loads: Heat Generations --

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

Material Properties:

The cylinder head is made up of Aluminium material. The analysis is carried out at worst atmospheric temperature of 55 ^{0}C. Thermal

conductivity of Aluminium = 167 w/mk Film coefficient (air) = 1.5 w/m^{2}k

Bulk temperature = 318 K (45^{0}C

3.4 Steady State Thermal Analysis Of Existing Rectangular Cylinder Head.

3D model of the amplifier developed using Solid works:

3.4.1 Boundary Conditions For Thermal Analysis

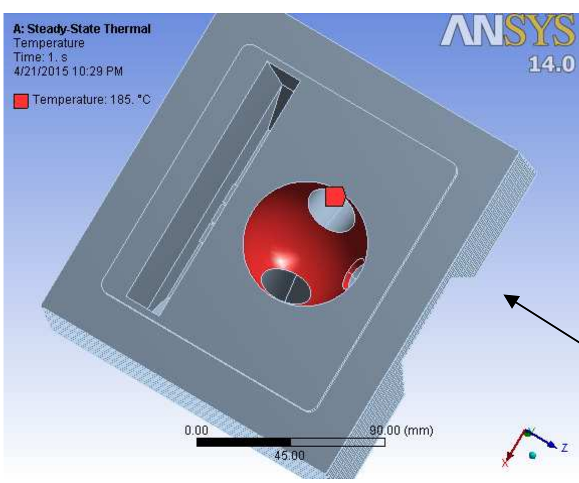

Fig.2 Temperature Applied On The Surface Of C.C

Temperature generated of 185^0 C at the c.c

Degrees of Freedom: TEMP

Material Properties: KXX, KYY, KZZ, DENS, C, ENTH, VISC, MU (VISC and MU used only if KEYOPT (7) = 1

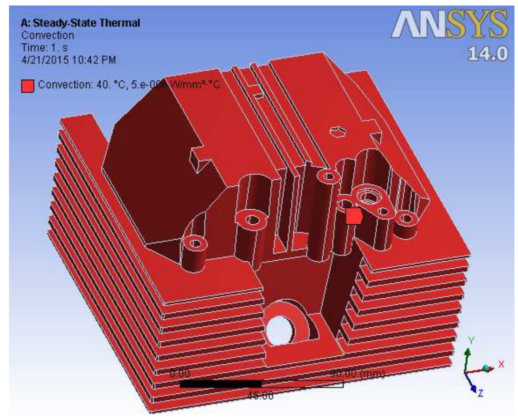

Fig.3 Convectional Temperature Applied On The Surface Of Cylinder Head.

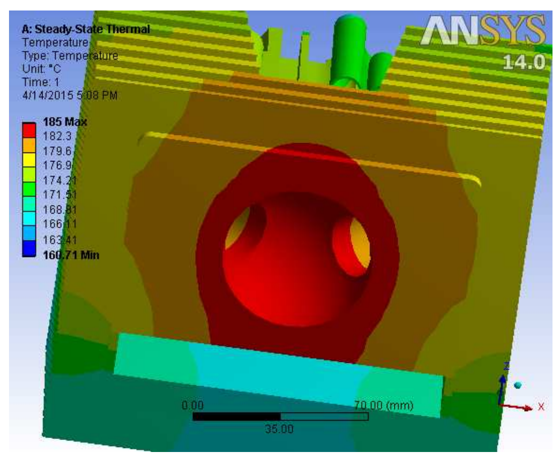

Fig.4 Temperature Distribution At The Bottom Surface

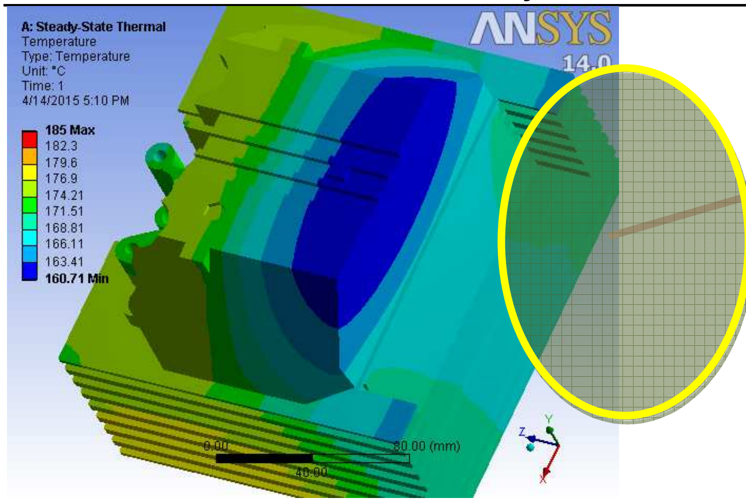

Fig. 5 Isometric View Of Temperature distribution Of The Cylinder Head (Top Cover)

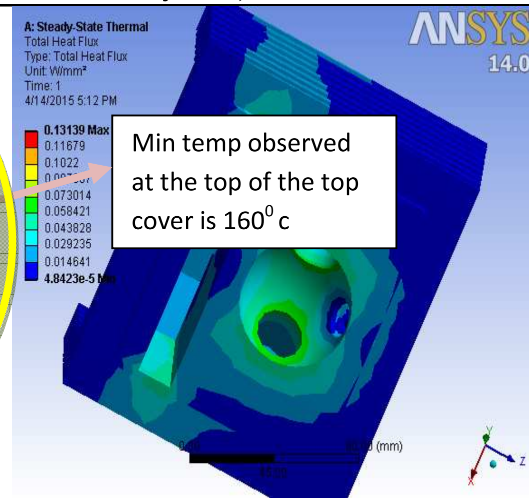

Fig 7 Bottom View Of Total Heat Flux Of The Cylinder Head

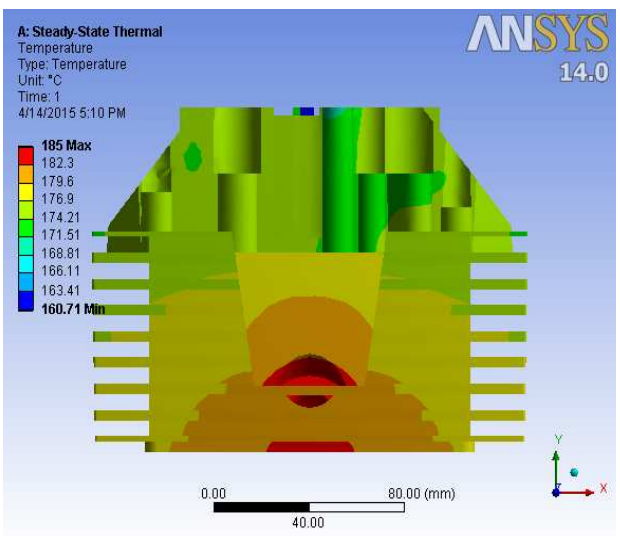

Fig. 6 Front View Of Temperature Distribution Cylinder Head

3.5 Total Heat Flux

Heat flux is defined as the amount of heat transferred per unit area per unit time from or to a surface. In a basic sense it is a derived quantity since it involves, in principle, two quantities viz. the amount of heat transferred per unit time and the area from/ to which this heat transfer takes place.

From The above results it is observed that: Maximum temperature observed at top cover is 160^0 C.Max temp observed around combustion chamber area is 185^0 C.Maximum heat flux observed at bottom is 0.1313 W/mm^2.

3.5.1 Steady State Thermal Analysis Of Modified Circular Cylinder Head

3D model of the amplifier developed using Solid works:

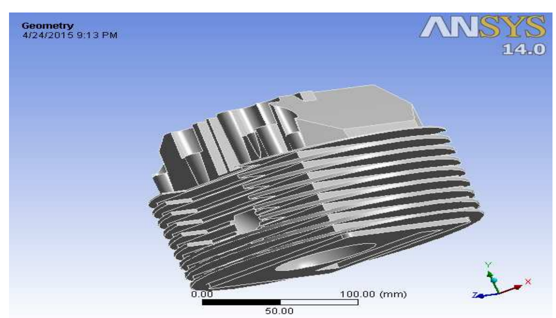

Fig 8 Imported To Ansys For Thermal Analysis

MESHING:

Ansys meshing is a component of Ansys workbench. It's a next generation meshing platform which combines strengths of pre-processing offerings from Ansys: ICEM CFD, TGRID, CFX-MESH, Gambit, etc.

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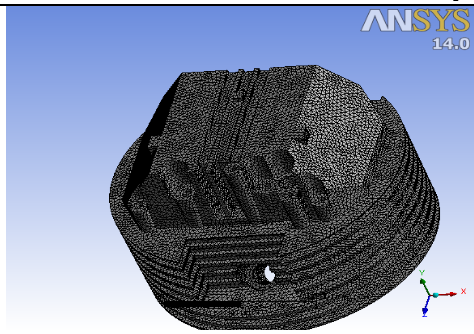

Fig.9 Meshing The 3d-Model

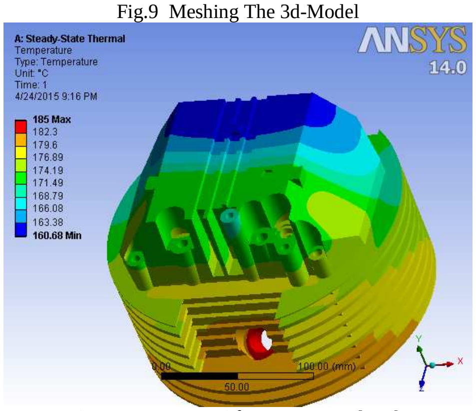

Fig.10 Isometric View Of Temperature distribution Of The Circular Cylinder Head.

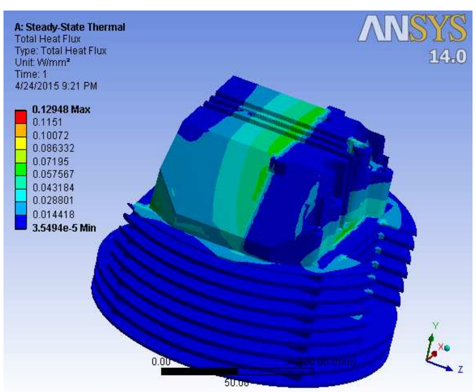

Fig.13 3d View Of Total Heat Flux Of The Circular Cylinder Head

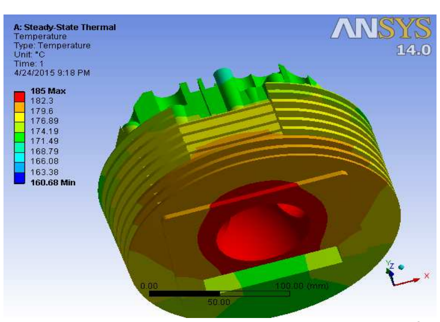

Fig. 11 Temperature Distribution At The Bottom Surface.

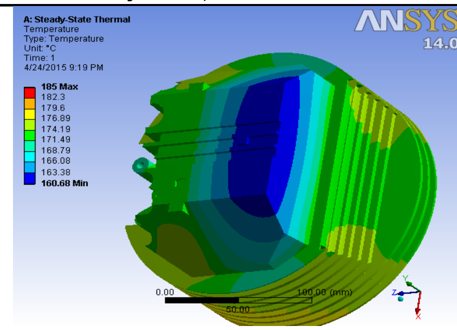

Fig. 12 Isometric View Of Temperature distribution Of The Circular Cylinder (Top Cover)

IV. RESULTS AND DISCUSSIONS

In this project we have calculated the efficiency, heat loss, heat flow rate and effectiveness of rectangular and circular cylinder head by using standard formulas. The values are tabulated in below.

Table 1 Theoretical Values

	Material	Thickness (mm)	Heat lost (w)	Effectiveness	Efficiency
Rectangular	Al6061	3	128.64	82.46	32
Circular	Al6061	3	151.04	79.46	35

After completion of theoretical values we created 3D model in solidworks software and imported the model into ANSYS software to do steady state thermal analysis for calculating nodal temperature and heat dissipation along fins of the rectangular and circular cylinder head. The values are tabulated in below.

Table 2 Theoretical Values

Material	Thickness mm	Nodal Temperature (K)		Thermal Gradient (K/mm)	Thermal Flux (w/mm^2)	Efficiency %
		Inlet	outlet			
Al6061	3	458	160.7	6.99	0.13	33
Al6061	3	458	160.6	14.608	0.12	35

Mass of the cylinder head Rectangular = 4.096 kg Circular = 4.506 kg

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CONCLUSION

By comparing theoretical values with analytical values of existing rectangular cylinder head we got equal values. After changing cylinder head to circular shape and conducting the same experiments with same boundary conditions we got the difference in the efficiency as around 3% which is a considerable difference. The mass is increased in circular cylinder by 10%.In this project we conducted steady state thermal analysis for free convection for rectangular and circular fins. From above results we conducted that the circular fin are more suitable than rectangular fins because in this project we have designed a cylinder fin body used in a Motorcycle and modeled in parametric 3D modeling software Solidworks. We are using Aluminum alloy 6061 and thickness. The shape of the fin is rectangular and circular. The default thickness of fin is 3mm. By changing the shape of the fin, the weight of the fin body increasing thereby increasing the efficiency. We have done thermal analysis on the fin body by geometry and thickness.

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About the author

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