MAT JOURNALS

Journal of Automation and Automobile Engineering
Volume 3 Issue 1

CFD and Thermo Mechanical Coupled Analysis of Diesel Engine Cylinder Head

Boopathi.M[1] ,S.Deepankumar[2],R.Gobinath[3],S.Balachandran[4],
[1,2,3,4]Assistantprofessor, Dept Of Automobile Engg, Bannari Amman Institute of Technology,Sathyamangalam, Tamilnadu
[1]deepankumar@bitsathy.ac.in,[2]gobinathr@bitsathy.ac.in,
[3]balachandran@bitsathy.ac.in,[4]boopathi@bitsathy.ac.in

Abstract

Loading conditions and complex geometry have led the cylinder head to become the most challenging part of diesel engines. A diesel engine Cylinder head analysed by means of both fluid-dynamic and thermo-structural simulations. First, the CFD analysis was done by using whole cylinder head i.e. covering both the cooling jacket and metal cast.

A 3-D geometric model of a cylinder head with water jacket was constructed using Creo Parametric 2.0 software. A mesh was then imposed on the model using the ANSYS Fluent software. Input conditions and Thermal boundaries are defined and the standard $k-\varepsilon$ model is utilized to carry out simulations with the CFD software Fluent. The pressure distribution and velocity field distribution of the cylinder head water jacket are presented and analysed. In addition, the temperature boundary conditions of the cylinder head which are obtained from CFD analysis has been transferred as a boundary condition to structural analysis through thermal analysis, Particular attention has been paid to the CFD & Structural boundary conditions, because which will affects the results significantly.

INTRODUCTION

Internal Combustion (IC) Engines play anvital role in the modern industry**.**Great efforts are put to enhance the electricity overall performance and fuel economy of IC Engines. As the speed and loading functionality of IC engines boom, the thermal and mechanical load increase substantially. Under normal operating situation, the height temperatures of burning gases inside the cylinder of IC Engines are of the order of 2500 k, consequently the temperatures of parts, such as valves, cylinder head, and piston in touch with gases, upward push rapidly because of a big amount of warmth absorbed. The big warmth fluxes and temperatures cause thermal growth and stresses, which in addition damage the clearance fits between components and increase the distortions and fatigue cracking of elements.

To prevent overheating, cooling should be furnished for the heated surfaces. but, it ought to be stated that overcooling can even motive a few severe problems, along with combustion roughness, lower general efficiency and excessive emission pollutants. similarly upgrades at the performance of an IC Engine rely on the effective resolution of heat switch troubles. therefore, an top-rated layout of the cooling system is required to keep trouble-loose operation of engines, which need to take into account all of the considerations described above.

As one of the most complex components of an IC Engine, the cylinder head is directly exposed to high combustion pressures and temperatures. similarly, it wishes to house intake and exhaust valve ports, the gas injector and complex cooling passages. Many compromises have to be made in design to satisfy these kind of requirements. The complex structure of a cylinder head leads to the difficulty in obtaining important facts for layout for carrying out waft and warmth transfer experiments. With progressed laptop overall performance and speedy improvement of Computational Fluid Dynamics (CFD), numerical simulation presents a device for engineers to apply in comparing their design. With the help of numerical simulation techniques, some fundamental capabilities, which include stress and pace distributions of the drift area, may be effortlessly predicted. Coupled with laptop-Aided design (CAD), the shape of a cooling system for an engine may be modified and optimized, with a purpose to control the temperature at key zones, decrease the power loss, and improve the reliability of components running at excessive temperatures.

Further cylinder head is subjected to thermal loading, the temperature is low when the engine stopped, then rapidly increases to high operating temperature after the engine started. The rapid increase of temperature would cause plastic and viscoplastic deformation. After a long time of thermal loading, the accumulated plastic deformation would lead to the initiation of thermal fatigue cracks, the growth of the cracks and the final failure. So conducting thermo mechanical analysis is an important for finding out the critical regions of cylinder head.

COOLANT PASSAGES

A cooling machine works by sending a liquid coolant via passages within the engine block and heads. Coolant flows from the low gradient of the engine to high gradient. Because the coolant flows via the coolant passages, it picks up heat from the engine. The heated fluid then makes its way via a rubber hose to the radiator in the the front of the automobile. as it flows through the skinny tubes within the radiator, the hot liquid is cooled by the air. as soon as the fluid is cooled, it returns to the engine to take in more warmth. The water pump has the activity of keeping the fluid moving through this system.

Fig. 1*Cylinder head Air passage and Coolant passage*

NEED FOR FEA AND CFD

In the past, optimization of engine additives, such as cylinder heads, turned into based on building a sequence of physical prototypes, and acting a series of various experiments and assessments. Regrettably, the traditional method of design and development turned into time-eating, and it became tough to construct bodily prototypes at some stage in the early tiers of the layout. The development and checking out of many prototypes is regularly required to fulfil a stringent design requirement. This can turn into an high priced method and delay the whole design and development cycle. Although the constructing and testing of engine issue prototypes can yield a correct layout, designated information isn't always available, and the common sense behind a specific design can't be tested.

As a result, engineers attain little general information from each test. consequently, the Finite element evaluation (FEA) and the Computational Fluid Dynamics methodologies were added and have become a scientific technique within the early tiers of engine layout to save time and value in production tactics. The Finite element analysis method (FEA) assists engineers in predicting the first-class method for warmth removal prior to building the primary prototype, by calculating the temperature and strain distribution of every aspect.

Therefore, Finite Element Analysis (FEA) is considered one of the most effective computer-aided design tools for engineers. inside the procedure of an engineering analysis, a theoretical and numerical version is the starting point for researchers to increase or layout an engineering device. This approach has been frequent for designing and growing complex geometry over a shorter time period and at tons lower value. The cylinder head is one of the most complicated and difficult elements of an engine, inside the optimization of which FEA performs an essential position.

PROPERTIES OF COOLANT AND CYLINDER HEAD METAL CAST

The proposition of coolant is a 1:1 water/ethylene glycol mixture whose properties at the actual conditions are taken into account.The important properties of coolant and cylinder head metal cast was found from the literature has been furnished in the below table 1

***Table 1** Properties of Coolant and Cylinder head metal cast*

S.no	Properties	Coolant	Grey cast iron
1	Density (kg/m^3)	1035	7200
	ecific Heat (J/Kg K)	37	0
	nductivity (W/m K)	4798	[illegible]

MODELING STRATEGY

Cylinder head, Ports and Cooling jacket are designed using Creo Parametric 2.0.Cylinder head, ports and cooling jacket are assembled in Creo Parametric 2.0 and export to Fluent, where the ports and cooling jacket are mentioned as fluid and cylinder head as solid.

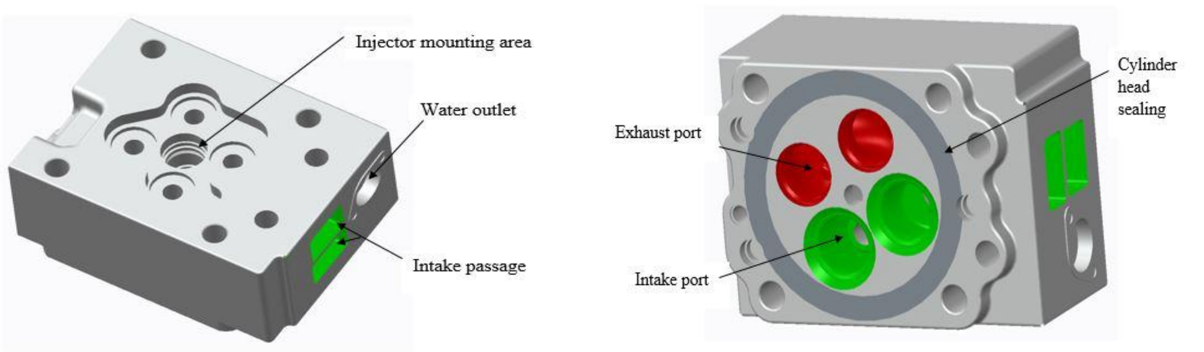

***Fig 1**Top view of Cylinder head model &Bottom view of Cylinder head model*

As mentioned before, first CFD analysis was done by applying proper boundary conditions in ANSYS Fluent 15.0. For an accurate result, mesh generation plays an important role. The small and sensitive areas are meshed with high resolution. The shape at the valve opening tapers outward near the fire deck, which has given the valve bridge a smaller cross-section than any other location in the cylinder head. The valve bridge area is a region of concern and is finely meshed to determine stress gradients accurately as known from the literature survey. The whole cylinder head was meshed with element size of 2mm. Total number of elements and nodes generated was 8991563 &1680168 respectively with orthogonal quality of 0.81. Energy equation and k-ε (viscous model) models are taken to account heat transfer and turbulence effects respectively.

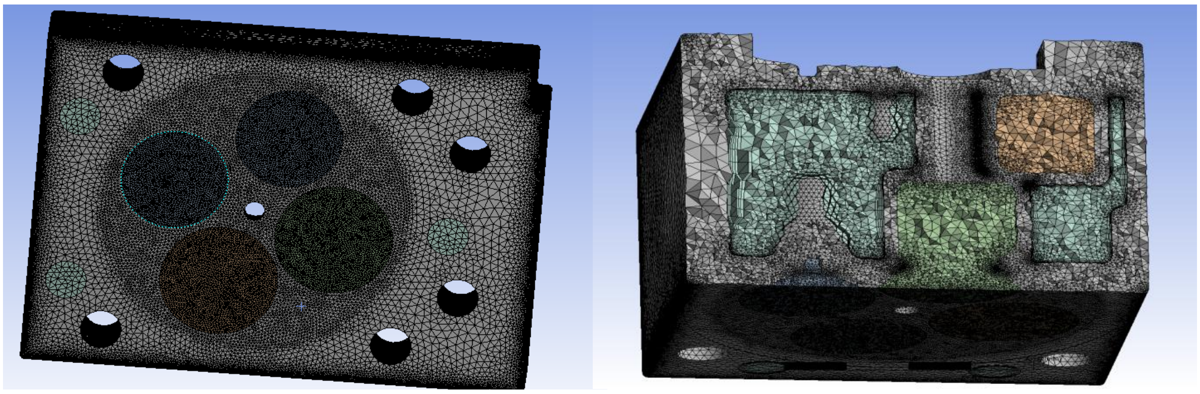

***Fig 2** Meshed Cylinder head with Ports and Cooling jacket*

Secondly, the temperature distribution which was found from the CFD is given as input condition to the steady-state Thermal analysis and the maximum temperature was found out. This solution was given as boundary condition to Structural analysis with combustion pressure and bolt force.

RESULT AND DISCUSSION

CFD analysis Result

Velocity distribution of the cylinder head water jacket is shown in the below figure.

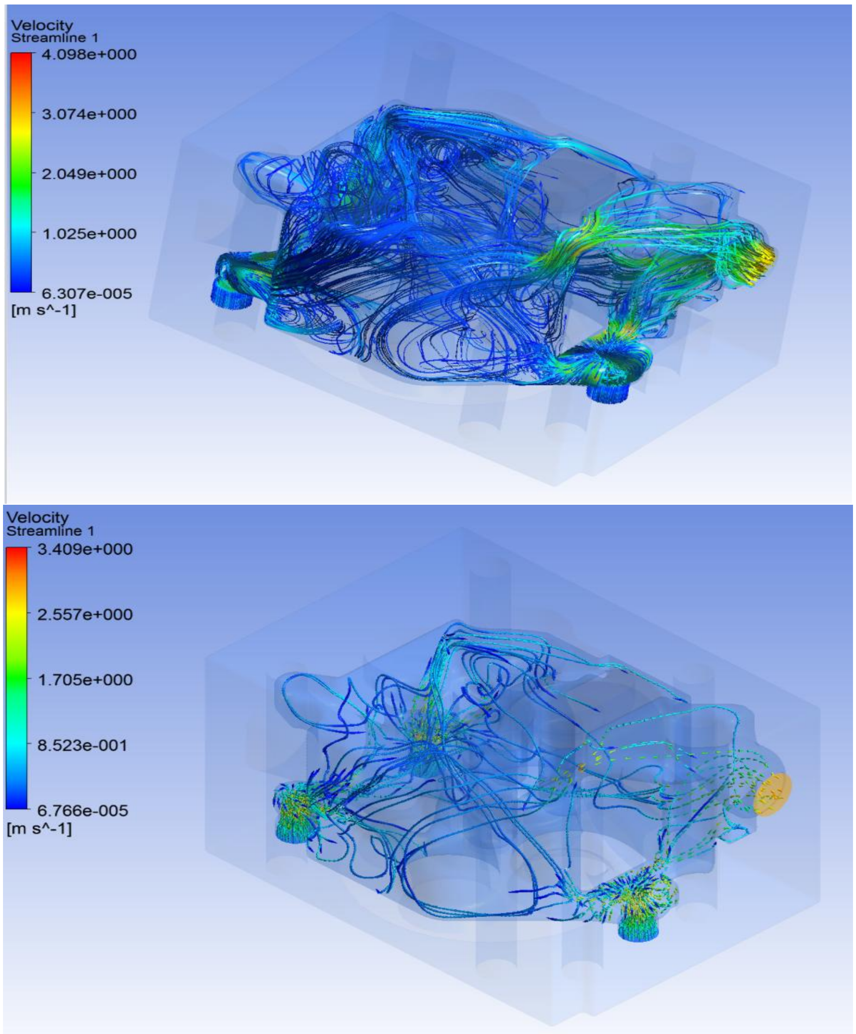

***Fig.3** Velocity Distribution of Cylinder Head*

The Average Velocity vector over the whole flow field is 0.606 m/s. The design for this cylinder head forced the flow to go around the exhaust port by using the two water inlet passage, where most of the heat was output. Remaining one inlet passage is used to cool the intake port, where the heat was less. It is observed from the velocity distribution that the outlet flow velocity is high.

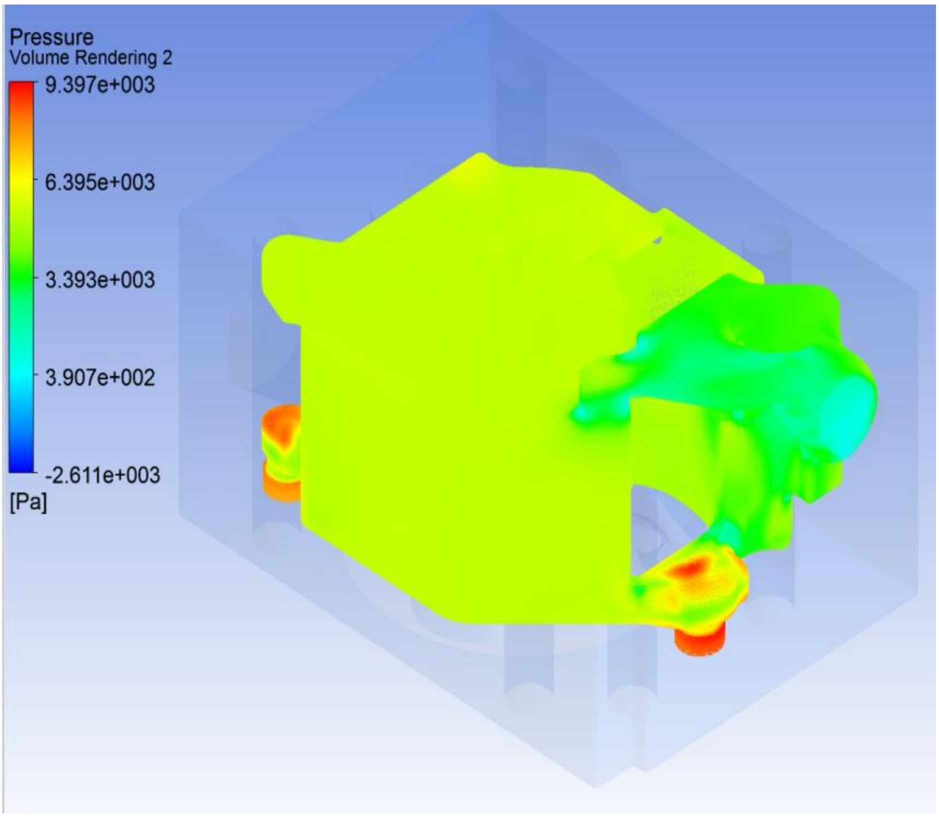

***Fig.4** Pressure Distribution of Cylinder Head*

It is observed from the pressure distribution that the outlet indicate lowest pressure. The pressure distribution plot indicates the pressure distribution over the water jacket surfaces. The average pressure of the flow field is 0.4916 bar and maximum temperature on the cylinder head is 579K.

Structural analysis Result Comparison

In order to reduce the complexity of the boundary conditions for stress analysis, the interaction between the cylinder head and cylinder block are not modelled because their importance is less. Another boundary condition is the pressure load that is applied to the combustion chamber. The maximum pressure of 19 MPa is used in this analysis. The boundary condition of the bolt is very significant since a pre-load is necessary to define tightening of the bolt.

Deformation of cylinder head due to thermal load as well as structural load can be observed in below figure 7.1.3 and figure 5.

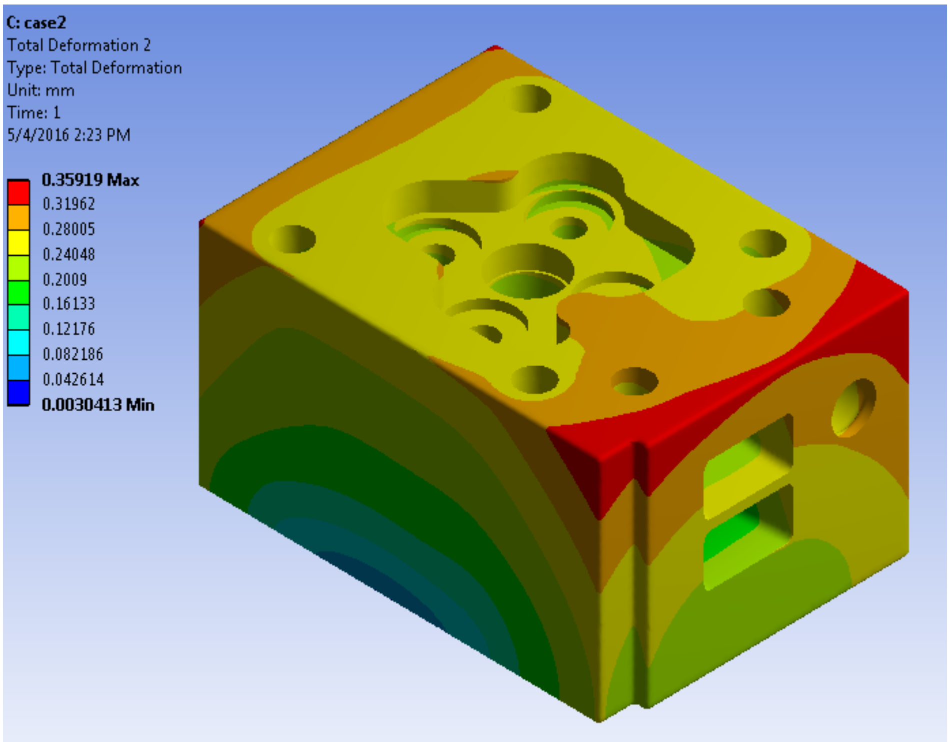

Fig.5 *Deformation of Cylinder Head (Isometric View)*

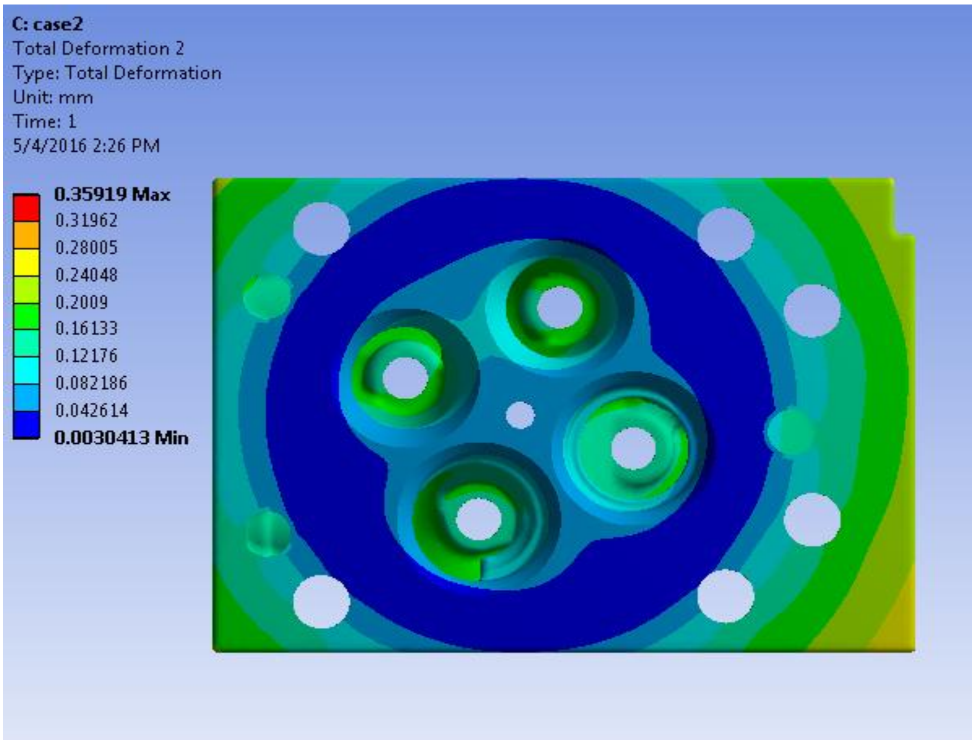

Fig.6 *Deformation of Cylinder Head (Bottom view)*

The maximum deformation of the cylinder head obtained from the thermo-mechanical analysis is 0.36 mm. This maximum deformation value is within the limit.

STRESS

Stress induced in the cylinder head due to thermal load as well as structural load can be observed in below figure 7.

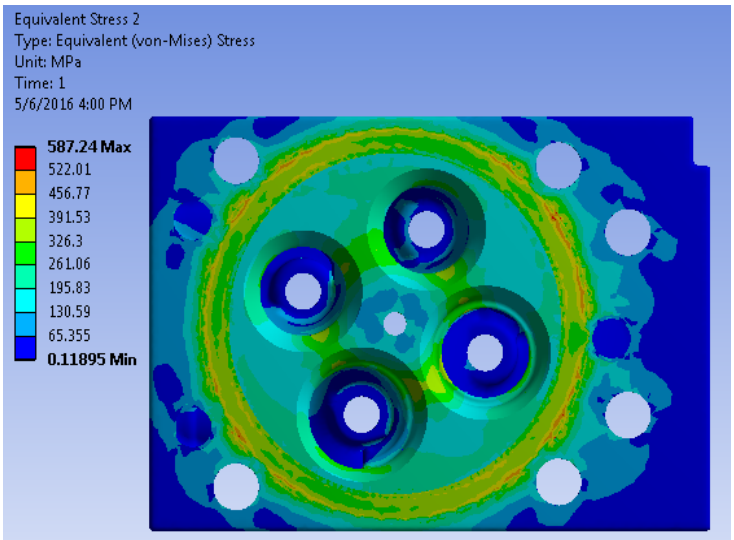

Fig.7 *Stress Distribution (Bottom View)*

The Maximum Stress induced in the cylinder head is 809 Mpa.

CONCLUSION

The work of this cylinder head water jacket satisfied the demand of cooling effects. The coolant in cylinder head performed a good flow rate distribution, and relatively even pressure distribution.

By the careful comparison with all available, but limited papers on the heat transfer analysis of a cylinder head, it can be seen that the simulation results of the pressure and flow rate distributions are relatively consistent with each other.
As it w
as a coupled field analysis, this gives more accurate results in both CFD as well as in Thermo-Mechanical analysis. Stress and deformation which are obtained from the thermo-mechanical analysis are within the limit.

REFERENCES

1. Chyuan S (2000),'Finite element simulation of a twin-cam 16-valve cylinder structure', International Journal of Finite Element in Analysis and Design, 35(3), pp. 199-212.
2. Stefano Fontanesi and MatteoGiacopini (2013), 'Multiphase CFD-CHT optimization of the cooling jacket and FEM analysis of the engine head of a V6 diesel engine' , Science direct, Applied Thermal Engineering 52, 293-303.
3. Fadaei M, Vafadar H, and Noorpoor A (2011), 'New thermo-mechanical analysis of cylinder heads using a multi-field approach', ScientiaIranicaB 18 (1), 66-74.
4. Esfahanian V, Javaheri A and Ghaffarpour M (2006), 'Thermal analysis of an SI engine piston using different combustion boundary condition treatments', Appl.Therm. Eng. 26, 277-287.
5. Sreeraj Nair L, Kiran Robert and Shamnadh M (2014), 'Static Stress Analysis of IC Engines Cylinder Head', International Review of Applied Engineering Research, ISSN 2248-9967 Volume 4.
6. Spaniel M, Macek J, Divis M and Tichanek R (2003) ,'Diesel engine head steadystate analysis', International Journal of Middle European Construction and Design of Cars, 2(3), pp. 34-41.
7. Gonella R and Peselli V (2009), 'Thermal-Structural Analysis on Cylinder Head using Workbench Platform as Unique Calculation

Environment for Different vertical codes', European Automotive Simulation Conference.
8. Tichanek R, Spaniel M and Divis M (2003), 'Steady state heat analysis of engine head', International Journal of SzéchenyiIstván University of Applied Sciences, 20(3), pp. 74-75.
9. Yunus A. Cengel and AfshinJ.Ghajar (1998), 'Heat and Mass Transfer'.
10. Zhao W M and Zhang W (2012), 'Study on thermal fatigue life prediction of cylinder Head', Adv. Mater. Res. 3, 433-440.