IJARIIT
INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue2)
Available online at www.ijariit.com

Design, analysis and comparing for a different cylinder head of C.I. Engine

Kunal S. Nagrik
RSSOER Pune, Maharashtra
kunal.s.nagrik@gmail.com

Nawaz M. Merchant
RSSOER Pune, Maharashtra
nawazkai@gmail.com

Mukesh S. Rajpurohit
RSSOER Pune, Maharashtra
mukeshraj195@gmail.com

Swanand S. Pachpore
RSSOER Pune, Maharashtra
swanandspachpore@gmail.com

Abstract: The main aim of this work is to predict the design performance based on stress/strain and behavior of cylinder head under various operating conditions. The effects of various engineering operating conditions such as combustion gas maximum internal pressure, thermal stress behavior and fatigue stress of the cylinder head have been analyzed. In any working engine, the piston and the cylinder head are the most vulnerable members due to increased mechanical and thermal loadings. The mechanical loading is mainly due to gas pressure in the gas chamber and its magnitude can be judged in terms of peak pressure. Thermal loading is due to temperature and heat transfer conditions in the piston surface cylinder liner and cylinder head. The geometry modeling was carried out using popular computer-aided engineering tools, CATIA V5R19 and the analysis was carried out using a finite element analysis (FEA) software package ANSYS. The result can be used to determine the quality of design as well as identify areas which require further improvement, and also the maximum stresses is found not exceeding material strength of cylinder head. In this work, we have also designed and compare two types of cylinder heads and formulated the importance of fins.

Keywords: Cylinder Head, Mechanical Load, Thermal Load, FEA, Fins.

I. INTRODUCTION

An internal combustion engine is a device that converts chemical energy (fuel) to heat energy (combustion of fuel) to pressure energy (pressure forcing the piston down) to mechanical energy (movement of the piston) [1-6]. Throughout these conversions process, it is desirable to maximize the efficiency of these conversions. All this is done within the engine itself, hence the name internal combustion engine. There are generally two types of internal combustion engine; spark ignition engines also known as Otto, gasoline or petrol engines, and compression ignition engines also known as a diesel engine [7]. The peak temperatures of the burning gasses inside the cylinder of diesel engines are of the order of 1600K and hence to prevent overheating cooling must be provided to the cylinder and cylinder head. The cylinder head is one of the most complicated parts of an internal combustion engine as it is directly exposed high pressures and temperatures. In addition, it also needs to house intake and exhaust valve ports, the fuel injector and complex cooling passages.

In this project, we have put more emphasis on the design and analysis of cylinder head under various acting loads, stresses, and its failure. There are various regions of cylinder head which experience severe thermal loading like narrow regions between valves as these regions not only receive heat from in-cylinder burning gasses during the combustion period but also from the burned gasses flowing through the exhaust valve, this may lead to deformation of these areas which may lead to failure.

So as to reduce the temperature and thermal stresses acting on the cylinder head and improve the structural design we need to improvise the design by introducing air fins. Air fins provide an increase in surface area for heat transfer by convection.

Air cooled cylinder head: In this type of cylinder, head fins are provided on the outer surface of the cylinder head. The air-cooling system is characterized by a simplified layout that allows containing the engine cost and the engine weight [8]. In reason of its simplicity, in terms of heat transfer efficiency, the air-cooling approach is poorer than the liquid-cooling system.

The detailed FE heat transfer analysis can provide valuable information on the temperature distribution in the overall assembly of the cylinder head, especially in those regions where experimental data is almost impossible to gather.

1.1 Loads Acting On Cylinder Head

I.) Inertia force on cylinder due to unbalance forces from the piston and connecting rod setup.

II.) Vibration force in the cylinder due to the speed variation in the crankshaft.

III.) Thermal load on cylinder and cylinder head due to improper temperature distribution.

IV.) Mechanical load on cylinder head due to the improper stress distribution.

V.) Fatigue load due to cyclic load on the cylinder head.
VI.) Load on cylinder due to the explosion of fuel gasses.

VII.) Load on cylinder due to compression of fuel gasses [8].

1.2 Assembly of Cylinder head

In the present study, the cylinder head of direct injection diesel engine is analyzed the engine is used in power generation units. The cylinder assembly contains one intake and one exhaust valve. The valve guides and valve seats are pressed into the head. The exhaust valve seat is cooled by cooling water flowing through annular cavities around the seats. The cylinder head assembly lies on the cylinder and it is fixed with four pre-pressed bolt connections.

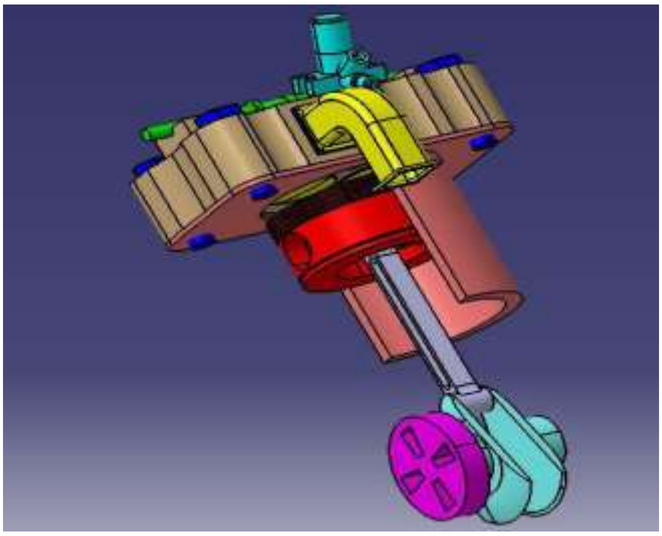

Fig -1: Cylinder Head Assembly

II. CYLINDER HEAD MODELLING

In this work we have modeled two different cylinder heads and the software used is CATIA. The reason for the modeling (designing) of two different cylinder head is to compare the statistics and to predict results obtained. The cross-sectional view of two different cylinders is as shown in Figure 2 and Figure 3.

Figure 2, is the basic cylinder head in which one exhaust and one inlet valve are present along with fuel injector and also we can see that there is no cooling system i.e. oil/water jacket or air fins present, hence during the combustion process large amount of heat is produced.

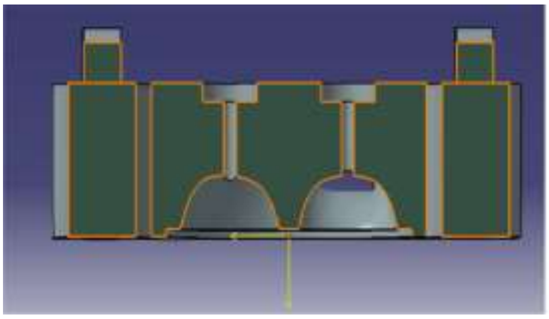

Fig -2: Basic cylinder head

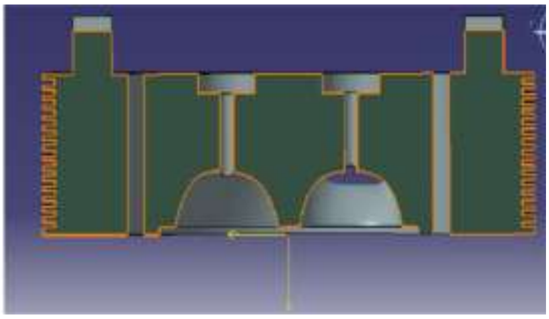

Fig -3: Cylinder head with fins

Figure 3 represents the modification of basic cylinder head by providing fins for heat transfer (cooling) the cylinder head as it provides a large contact area for heat convection and hence the total heat generated in this cylinder head considerably less than the basic cylinder head.

III. MATERIAL

As means for reducing weight, there are several methods available substituting light-weight materials for conventional materials, that is to decrease specific gravities, rationalization of structure (decrease number of parts through integration), and downsizing (decrease the volume of each part) [9]. Hence the material used for cylinder head is Aluminum alloy.

Table 1 represents properties of aluminum alloy

Properties	**Value**	**Unit**
Density	2770	Kg m^-3
Coefficient of Thermal Expansion	2.3E-05	C^-1
Young’s Modulus	7.1E+10	Pa
Poisson’s Ratio	0.33	
Bulk Modulus	6.9608E+10	Pa
Tensile Yield strength	2.8E+08	Pa
Compressive Yield strength	2.8E+08	Pa
Tensile Ultimate strength	3.1E+08	Pa

IV. FINITE ELEMENT ANALYSIS

For analysis purpose, ANSYS software is used. The CATIA model is imported to the ansys workbench. Finite element models of each cylinder heads used in the numerical analysis were generated in order to estimate the stress distribution and structural displacement. FEA will provide results that may be used to evaluate the strength of design based on the Von Mises criterion, Temperature Distribution (Thermal analysis) criterion and fatigue strength to identify areas that require improvement.

4.1 Static structural analysis

The application of material properties is done in the Ansys. We have established contact between the bolt and cylinder head, valve seat and cylinder head. After establishing the contact properties the 3D model meshes. Meshing is followed by application of load (pressure) and support. A vertical load of 9*10^6 N/m2 is applied on the inner face of the cylinder head. Then fatigue analysis is carried out on both cylinder heads to calculate life cycle and Factor of safety.

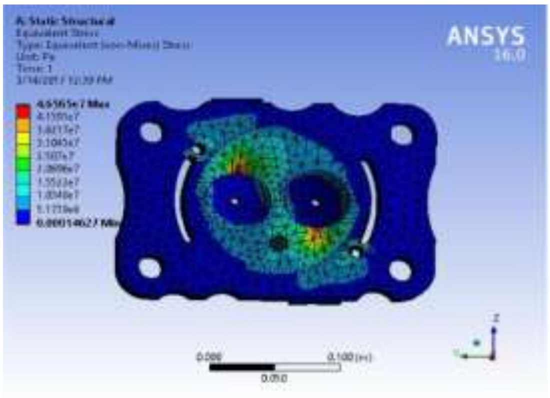

Fig -4: Basic cylinder

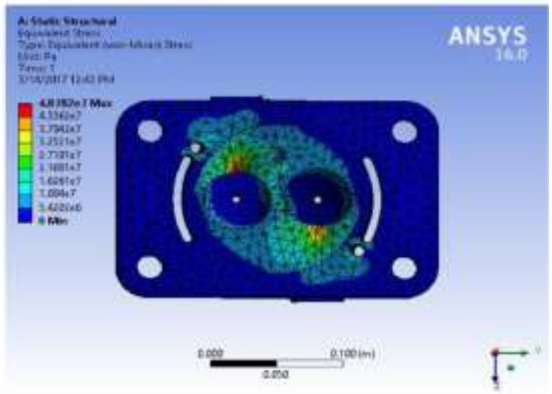

Fig -5: Cylinder head with fins

Figure 4 represents the static structural analysis of basic cylinder head. This analysis model is tested for equivalent (Von-mises) stress. It shows the maximum equivalent stress of 4.6565*10^7 Pa.

Figure 5 represents the static structural analysis of cylinder head with fins. This analysis model is tested for equivalent (Von-mises) stress. It shows the maximum equivalent stress of 4.8782*10^7 Pa.

4.2 Thermal analysis

The second step is to do thermal analysis on the cylinder head to get the temperature distribution of the part under working conditions. The lowest temperature on the cylinder head is observed at intake manifold and highest temperature is observed at exhaust manifold (explained in Table-2), this is because the exhaust gasses product of the combustion is very hot. After every cycle, the exhaust gasses are pushed out of the cylinder through the exhaust manifold. Each of such cycle takes place every fraction of a second thus the exhaust manifold is constantly exposed to hot exhaust gasses, and thus the temperature in the exhaust manifold is considerably high as compared to the temperature in the inlet manifold.

Conditions applied on cylinder head for thermal analysis are shown in table

Table -2: The experimental values of α and T [7]

Location	α -W/(m2.K)	T
Upper and side surface of the cylinder head:	23	293K
The surface of air intake channel	350	335K
The surface of exhaust gas channel	650	973K
The surface of combustion chamber	1000	1200K
Immediately below the nose bridge	3600	383K

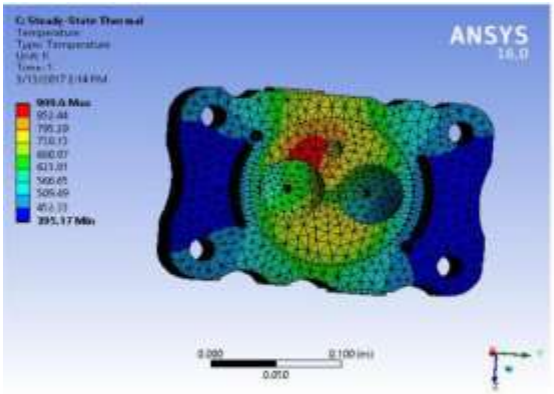

Fig -7: Basic cylinder head

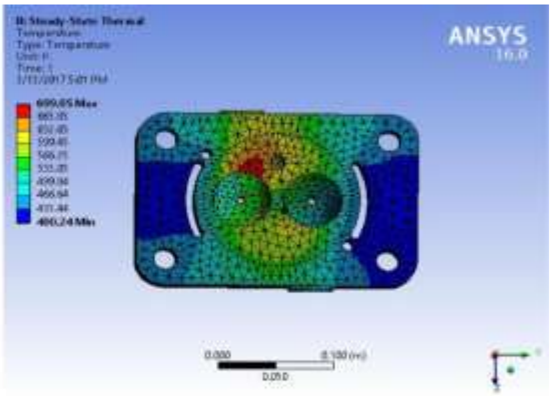

Fig -8: Cylinder head with fins

Figure 7 represent steady state thermal analysis done on the basic cylinder head to observe maximum temperature on the cylinder head. In this analysis, maximum temperature observed is 909.6K. This is maximum in both the cylinder heads that we chose.

Figure 8 represent steady state thermal analysis done on cylinder head with fins to observe maximum temperature on this cylinder head. In this analysis, maximum temperature observed is 699.05K.

4.3 Fatigue strength verification

The theory used to verify the fatigue strength of the component is based on the high cycle fatigue shall resist up to 1*10^6 cycles.In both cases this condition gets satisfied. Both cylinders should have a factor of safety greater than 1.5.

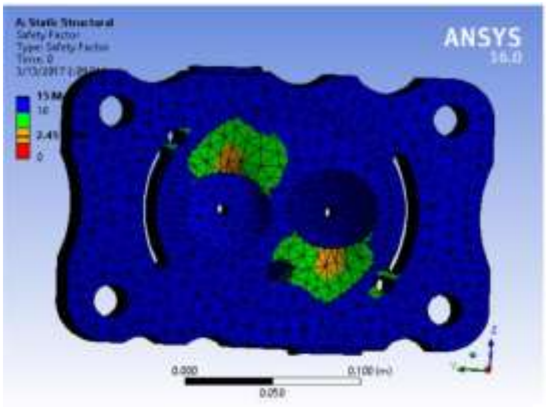

Fig -9: Basic cylinder head

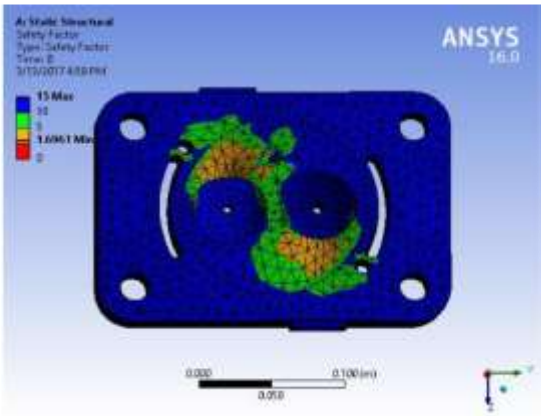

Fig -10: Cylinder head with fi

Figure 9 shows that basic cylinder head has a factor of safety 2.45 which is greater than 1.5. Figure 10 shows that cylinder head with fins has factor of safety 1.6961

RESULTS AND DISCUSSION

From the analytical solution & the analysis result, we get the values of stresses produced in cylinder head due to the application of temperature and pressure are within permissible limit. As we have used two different types of the cylinder head, hence we can make the following conclusions:

From Table 3 we can conclude that factor of safety for both the cylinder head is above 1.5 which states that both the design are safe, and hence we cannot differentiate the cylinder head according to the basis of factor of safety

Table -3: Result Comparison

Cases	**Basic Head**	**Head with fins**
Equivalent (Von-mises) stress (Pa)	4.6565*10^7	4.8036*10^7
Maximum Temperature	909.6 K	894.9 K
Factor of safety	2.805	1.7945
Life (Cycle)	10^7	10^6

From table 3 we can conclude that the equivalent stress for a cylinder head with fin has more equivalent stress than that of the basic cylinder head.

Also, we can conclude that maximum temperature is obtained in the basic cylinder and the temperature obtained in the cylinder head with fins is less and hence it is the most desirable design.

CONCLUSION

In this paper, a structural analysis, thermal analysis and fatigue analysis of two different types of cylinder head were carried out using FEA and following observations were made.

1. Cylinder head without any fins can withstand for higher equivalent stress and it also has a higher factor of safety but it performs poorly in thermal analysis.
2. Cylinder head with fins does well in equivalent stress analysis as well as thermal analysis and its maximum temperature is less than that in the basic cylinder head and life cycle is also less than that of the basic cylinder head.
3. According to the above discussions, we can conclude that the cylinder head with fins is more favorable for variation in temperatures, and pressure as it will not break.

REFERENCES

[1] A. Aziz, A. Rashid, Firmansyah and R. Shahzad. Combustion analysis of a CNG direct injection spark ignition engine. International Journal of Automotive and Mechanical Engineering, (2010), Vol. 2, pp. 157-170.

[2] A. Aziz Hairuddin, A.P. Wandel, and T. Yusaf. Effect of different heat transfer models on a diesel homogeneous charge compression ignition engine. International Journal of Automotive and Mechanical Engineering, (2013), Vol. 8, pp. 1292-1304.

[3] K. Bhaskar, G. Nagarajan, and S. Sampath. Experimental investigation on cold start emissions 7733 using an electrically heated catalyst in a spark ignition engine. International Journal of Automotive and Mechanical Engineering, (2010), Vol. 2, pp. 105-118.

[4] K. Kalyani Radha, S. Naga Sarada, K. Rajagopal and E.L. Nagesh. Performance and emission characteristics of CI engine operated on vegetable oils as alternative fuels. International Journal of Automotive and Mechanical Engineering, (2011), Vol. 4, pp. 414-427.

[5] M. Kamil, M.M. Rahman and R.A. Bakar. An integrated model for predicting engine friction losses in internal combustion engines. International Journal of Automotive and Mechanical Engineering, (2014), Vol. 9, pp. 1695-1708.

[6] N. Kapilan, T.P. Ashok Babu, and R.P. Reddy. Improvement of performance of dual fuel engine operated at part load. International Journal of Automotive and Mechanical Engineering, (2010), Vol. 2, pp. 200-210.

[7] Athirah Abdul Aziz, Design of customized modular cylinder head for SI engine. ARPN Journal of Engineering and Applied Sciences, (2015), Vol.10, pp. 7731-7732.

[8] Mahammadrafik J. Meman, Design, modeling and analysis of structural strength of cylinder and cylinder head of 4-stroke (10 H.P.) C.I. Engine. International Journal of Advanced Engineering, Management and Science (IJAEMS), (2016), Vol.2, pp. 156-157.

[9] Sreeraj Bbair K., Static stress analysis of I.C. Engine cylinder head. International Review of Applied Engineering Research. (2014), pp. 123-128.

