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Static Stress Analysis of IC Engine Cylinder Head

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Abstract

The main aim of this work is to predict the design performance based on the stress/strain and behavior of cylinder head under various operating conditions. The effects of engine operating conditions such as combustion gas maximum internal pressure, components on the stress and thermal stress behavior of the cylinder head have been analyzed. The analysis was carried out using a finite element analysis (FEA) software package, which is use to simulate and predict the Von-Mises stress and strain pattern and thermal distribution of the cylinder head structure during the combustion process in the engine and the geometry modeling was carried out using a popular computer-aided engineering tool, Solidworks. The result can be used to determine the quality of the design as well as identify areas which require further improvement. In this investigation, structural analyses of the cylinder head highlight several areas of interest. The maximum stress is found not exceeding the material strength of cylinder head, and thus the basic design criteria, namely no yielding and no structural failure under firing load case, can be satisfied. In addition, the effect of thermal stress/strain provides a good indication on structural integrity and reliability of the cylinder head, which can be improved in the early stages of design. This steady-state finite element method (FEM) stress analysis can play a very effective role in the rapid prototyping of the cylinder head.

Keywords: Cylinder Head, Von mises Stress, Static Stress.

1. Introduction

The main objective of design is to reduce weight to power ratio & will result in producing high specific power. The preliminary design cylinder & cylinder head of a horizontally opposed SI engine, which develops 120 BHP and posses the maximum rotational speed of 6000rpm. Four stroke opposed engine is inherently well balanced due to opposite location of moving masses and also it provides efficient air cooling. For the requirement of weight reduction the materials selected for design of cylinder head is Aluminum alloys LM13 and A356 alloys.[1] Two materials are compared for strength. The main objective of this work is:

1. The use of light weight aluminum alloys for cylinder head.
2. The analysis of von Mises stress distribution in the cylinder head.
3. The comparison of these alloys for minimum stress for the given design.

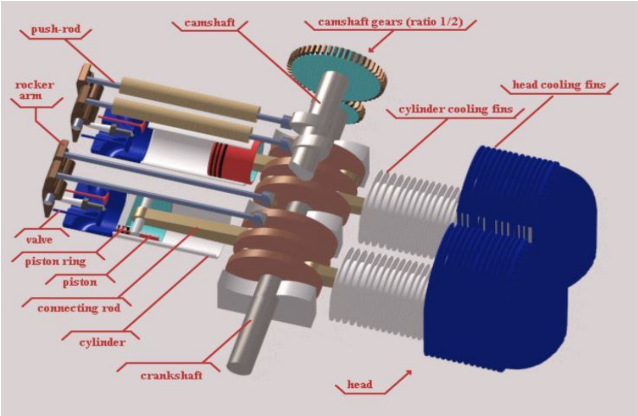

Fig. 1: Engine Assembly.

A flat-4 or horizontally-opposed-4 is a flat engine with four cylinders arranged horizontally in two banks of two cylinders on each side of a central crankcase. The pistons are usually mounted on the crankshaft such that opposing pistons move back and forth in opposite directions at the same time. The configuration results in inherently good balance of the reciprocating parts, a low centre of gravity, and a very short engine length. The layout also lends itself to efficient air cooling. However, it is an expensive design to manufacture, and somewhat too wide for compact automobile engine compartments, which makes it more suitable for cruising motorcycles and aircraft than ordinary passenger cars.[2] This is no longer a common configuration, but some brands of automobile use such engines and it is a common configuration for smaller aircraft engines such as made by Continental. Although they are somewhat superior to in-line 4stroke engines in terms of vibrations, they have largely fallen out of favour because they have two cylinder banks thus requiring twice as many camshafts as for in-line engines.

1.1 Cylinder Head Assembly

In this study, the cylinder head of a large turbo-charged direct-injection diesel engine is analyzed. The engine is used in power generators. The cylinder head assembly contains one intake and one exhaust valves. The valve guides and also the valve seats are pressed into the head. The exhaust-valve seats are cooled by cooling water flowing through the annular cavities around the seats.[4] The fuel injector is situated in the center of the cylinder, and it is held in place with pre-pressed bolt connections. The bottom face of the cylinder head, which is directly exposed to the in-cylinder gases, is cooled by special bores, which represents a complication in the design of this mechanically highly loaded region of the cylinder head. The cylinder head assembly lies on the cylinder, and it is fixed with six pre-pressed bolt connections.

2. Material Selection

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 the number of parts through integration), & downsizing (decrease the volume of each part).In the past, the engine performance has been compromised in order to improve emission. The methods presented here, however are fundamentally different from the past one. The engine weight has reduced by 37 Kg from a base one of 162 Kg (excluding engine oil).This corresponds to 23% weight reduction. As shown in fig. 2 the component weight ratio of the materials are 53% steel for the weight-reduced engine (86% in the base engine), 33% (13%) Aluminum alloys, 7% (1%) plastics & elastomers, 6% (0%) other light weight materials such as titanium alloys & magnesium alloy, & 1% (0%) ceramics.

Table 1: Chemical Compostion.

Parameter	LM13	A356
Chemical composition (%)		
Si	11/13	6.5/7.5
Fe	0.8	0.5
Cu	0.5/1.3	0.25
Mg	0.8/1.5	0.2/0.45
Ni	0.7/2.5	0.3
Mn	0.5	0.35
Pb	0.1	
Mechanical properties		
σ u (N/mm2)	173 to 252	230
Brinell Hardness Number (BHN)	100	75

The materials substitutions applied for the engine structure component represented by a cylinder is no more than simple weight reduction. But, when applied this to several moving & functional components, it not only weight reduction method but also contributes to improve engines & emission performance.

3. Design of Cylindre Head

The cylinder head is modelled according to the standard dimensions. The modeling software used is Solidworks. The valve spacing, fins and inlet and outlet ports are modelled in the cylinder head

Table 2: Engine Parameters[3]

Design parameters	Calculated value
D	78mm
L	78mm
Bmep	11.76 bar
Imep	13.85 bar
Pmax	138.5 bar
Volume	1500cc
Indicated power	141.176 HP
Friction Power	21.176 HP
Mechanical Efficiency(assumed	85%
Break power	120 HP

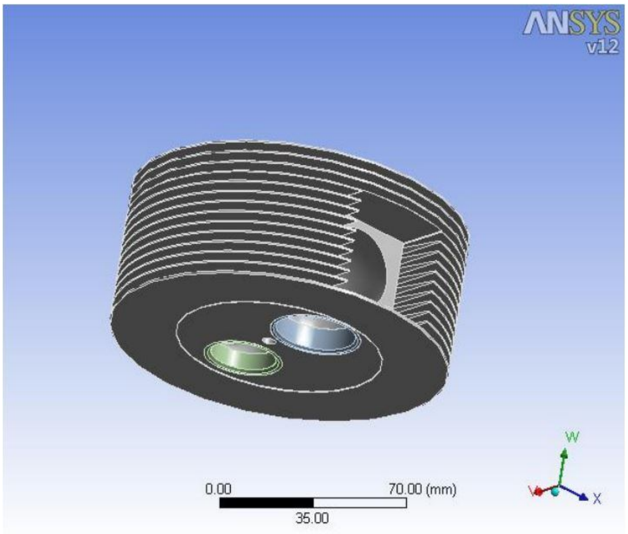

Fig. 2: Cylinder head Model.

4. Static Structural Analys

For analysis purpose the Ansys software is used. The Solidwork model is imported to the Ansys workbench. The application of materail properties is done in the Ansys. Establish contact between the valve seat and cylinder head, and valve seat and valve cap. Also establish contact between cylinder head and spark plug cap. After establishing the contact properties the 3D model is meshed into 116344 elements with 232404 nodes.Meshing is followed by application of load (pressure) and support. A vertical load of $1.38x10^7$ N/m^2 is applied on the inner face of the cylinder head and the model is constrained as the lower portion of the model.

Table 3: Mechanical Properties[3]

Materials	Aluminium LM13 alloy	Aluminium A356 alloy
Density	2700 Kg/m3	2713 Kg/m3
Poison ratio	0.34	.33
Young's modulus	7x1010 N/m2	7x1010 N/m2
Yield strength	3.46x1010N/m2	2.50x1010N/m2

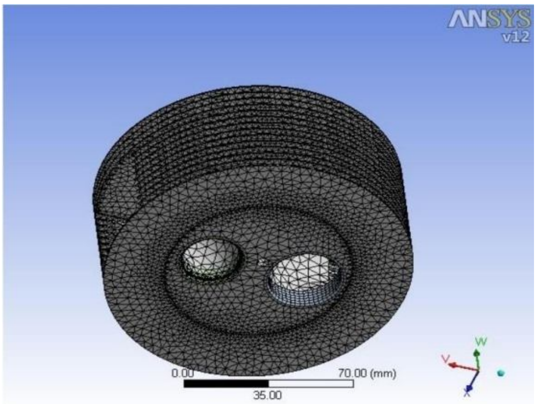

Fig. 3: Meshed Model.

5. Results and Discussion

After applying the boundary conditions and load to the cylinder head the system is solved using the solver and visualized results are obtained in the GUI.

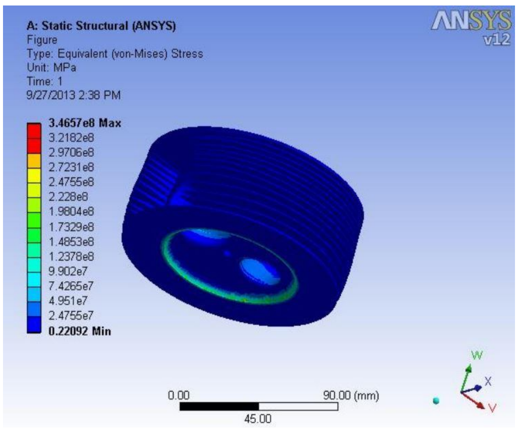

Fig. 4: Results for Aluminium LM13

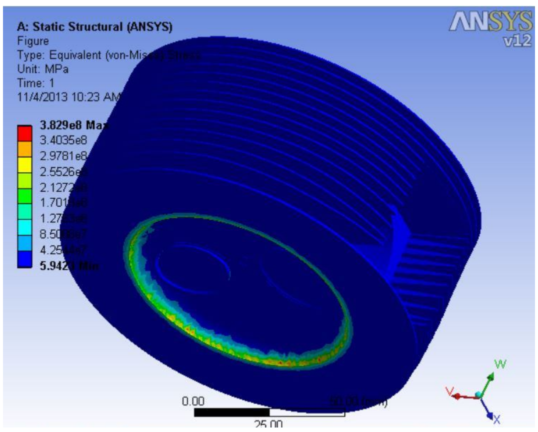

Fig. 5: Results for Aluminium A356

From the analytical solution & the analysis result we get the values of stresses produced in cylinder and cylinder head due to application of temperature and pressure are within permissible limit. The results are obtained by analyzing the model in ANSYS software. Two materials are used for the cylinder head. It is seen that the static stress values are lower than the yield point values of both the materials.

Table 4: Results.

Materials	Aluminium LM13 alloy	Alluminium A356 alloy
Maximum stress	4.17x108Pa	4.19x108Pa

6. Conclusion

The stress analysis on cylinder head was done with two different materials namely Aluminium LM13 and Aluminium A356 alloys. From the result obtained it was seen that the maximum stress values are lower than the permissible values of the materials. Hence we concluded that the basic design of cylinder and cylinder head is safe with reference of pressure. By using these materials we can effectively reduce the weight of cylinder and cylinder head with improved strength. Also we can see that by using Aluminium LM 13 alloy the maximum stress value is slightly lesser than that of Aluminium A356 alloy. Thus concluded that by the use of Aluminium LM13 alloy we can produce lightweight cylinder heads for IC engines.

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