Design and Analysis of Gasket Sealing of Cylinder Head under Engine Operation Conditions

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Abstract- The pre-stressing force of bolts maintains the efficiency of the gasket sealing between the cylinder head and the cylinder block. Therefore, the applied approach of the pre-stressing force is significant for the calculation of the numerical simulation. Montgomery provided six different kinds of approaches to describe the pre-stressing force of the bolts. By using the analytical element of the ANSYS software combined with the curve of the pressure versus the displacement obtained from the experiment

Keywords – Bolts, Water Jacket ,Valves, cylinder head

I. INTRODUCTION

The main idea of this analysis is to introduce the pre-tension element into the simulation of the bolted assembly with the other components. Compared with the traditional method, the pre-tension element has many advantages over the method of controlling the raising and lowering of the temperature. Owing to the complicated engine structure and the lack of experimental data on engine performance, especially of the cylinder head, there is little literature vailable that fully discusses the structural analysis of the cylinder head. In this report, the commercial FEM software, ANSYS, is introduced into the numerical simulation of the structural analysis(3,14)

1.Gasket Function :A cylinder head gasket is required to affect a seal between the cylinder head and block of a gasoline or diesel engine. It is an integral component of the engine and is required to perform many functions at the same time during engine operation. The head gasket must maintain the seal around the combustion chamber at peak operating temperature and pressure

2.Gasket Design :Every application requires a unique cylinder head gasket design to meet the specific performance needs of the engine. The materials and designs used are a result of testing and engineering various metals, composites and chemicals into a gasket that is intended to maintain the necessary sealing capabilities for the life of the engine.

The most widely used materials are as follows:

- Steel and stainless steel of various grades and forms.
- Fibre based composite materials.

Graphite in various densities

3. Gasket Analysis :Both the design and the development of the automobile engine are complicated processes. To acquire the best performance of an engine in any operating condition, including harsh natural environments, many

analytical tools and experimental methods are used to find the optimum parameters for engine design. However, numerous measured results point out that the gas escaping from the engine not only affects the output efficiency of the horsepower substantially, but also pollutes the environment(1,4)

4. Thermal stresses:Due to the analyses of the operating conditions for the engine, both the hot assembly and the hot firing are included in this research. Hence, the heat transfer analysis concerning the cylinder head must be carried out prior to the structural analysis. According to the principle of conservation of energy, the heat condition equation in the material can be expressed as

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = 0,$$

Where T is the temperature. The temperature distribution in the material can be obtained with appropriate boundary conditions. From the generalized Hooke's law, the strain components of the element including the thermal strains are listed as follows:

$$\begin{aligned}
\varepsilon_x &= [\sigma_x - \upsilon(\sigma_y + \sigma_z)]/E + \alpha\Delta T, \\
\varepsilon_y &= [\sigma_y - \upsilon(\sigma_z + \sigma_x)]/E + \alpha\Delta T, \\
\varepsilon_z &= [\sigma_z - \upsilon(\sigma_x + \sigma_y)]/E + \alpha\Delta T, \\
\gamma_{xy} &= \tau_{xy}/G, \\
\gamma_{yz} &= \tau_{yz}/G, \\
\gamma_{zx} &= \tau_{zx}/G,
\end{aligned}$$

where _ is the normal stress, _ is the normal strain, E is the Young's modulus of elasticity, v is the Poisson's ratio, is the coefficient of thermal expansion, _T is the incremental temperature, G is the shear modulus, is the shear stress, and _ is the shear strain. After further calculation, the distribution of the contact pressure on the gasket and the strain/stress deformation of the entire structure can be obtained..(3,8)

II. Finite element models and analysis procedure

To establish the analytical methodology of the cylinder head in respect to the structure, the line style of a gasoline engine, having 4 cylinders and 4 strokes, is adopted in this research. The Pro/E model provided by China Engine Corporation for investigating the efficiency of gasket sealing is displayed in below figure. For the convenience of the observation of the distribution of contact pressure on the gasket, only 1 cylinder head is considered in this study. It must be noted that the procedure as described above has other advantages, including: (a) reduction of the complications of boundary conditions considered in the analytic processes, (b) economizing on the element counts of the finite element analysis. In other words, the computed time can be shortened substantially

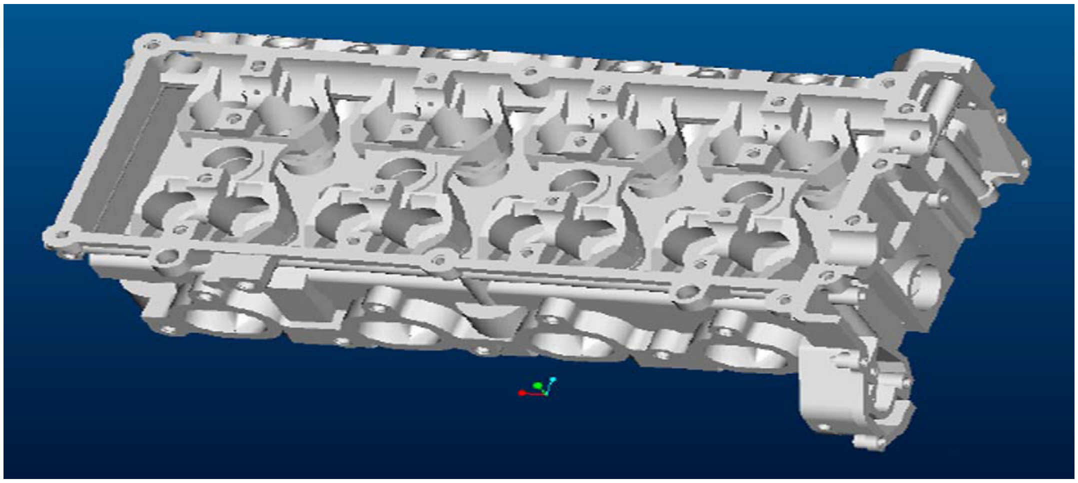


Fig. 1. Top view of 2.0 L cylinder head

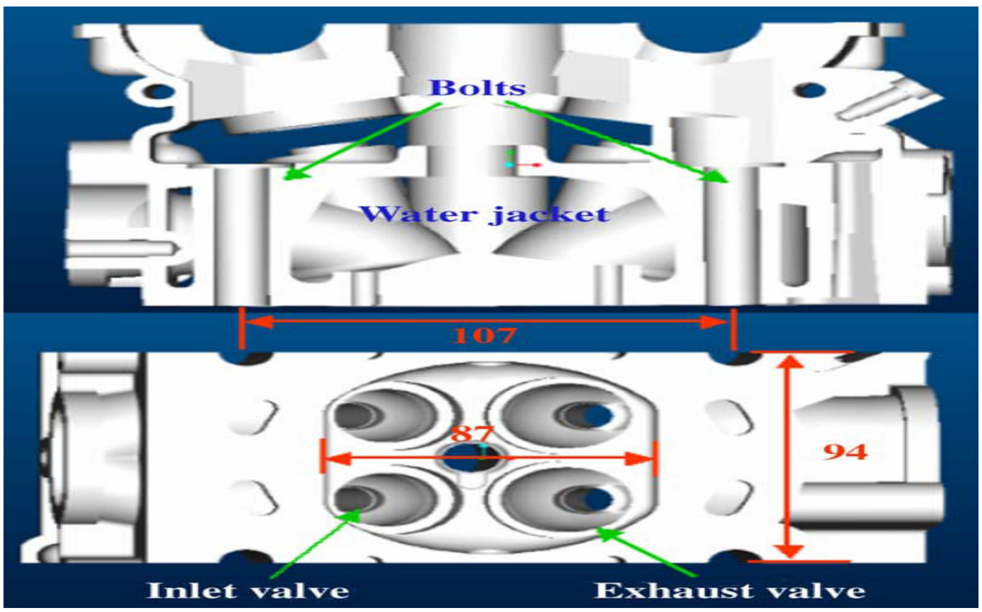


Fig. 2. The relative dimensions of the 2.0 L 2nd cylinder head (mm

Table 1
Material properties of each component of the structural analyses

	Young's modulus (Gpa)	Poisson's ratio	CTE (ppm/°C)	*k* (W/m-°C)
Exhaust valve (214N)	215	0.290	16.8	15.3
Inlet valve (EN52)	90	0.290	13.0	23.4
Cylinder head (Al alloy)	71	0.330	24.0	177.2
Cylinder block (Al alloy)	71	0.330	24.0	177.2
Liner (Cast iron)	107	0.295	11.7	0.0591
Bolt (SCM 435)	205	0.29	11.2	N/A
Gasket	Multielastic	0.29	32	1.968E-4

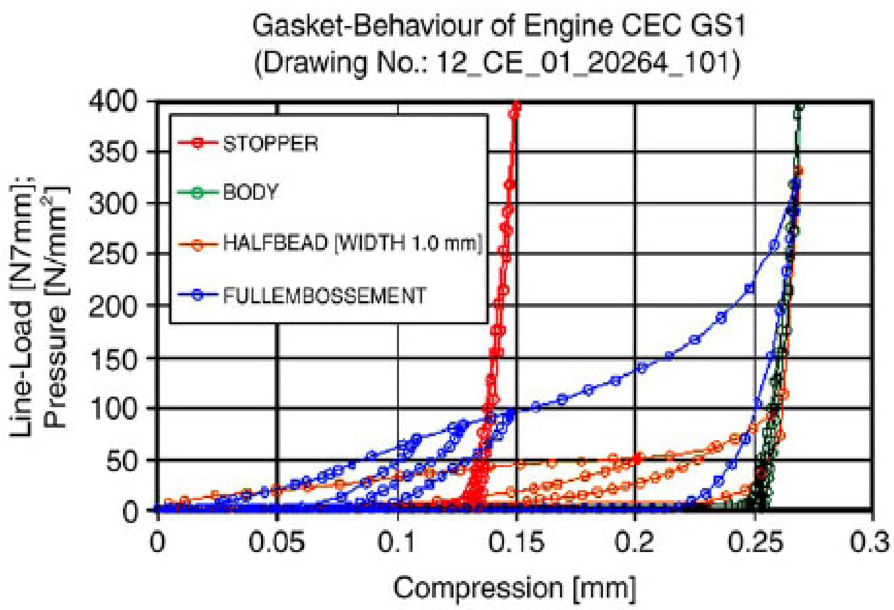


Fig. 3. The relation between pressure and compression in the gasket.

And the part of the exhaust valve. Moreover, the distances between the central line of the combustion chamber and the location of the bolts are not identical. Table 1 lists the material properties of each component of the structural analyses in this research. The main body of the cylinder head and the block are made of aluminum alloy (JIS H 5302, 1990). The material of the exhaust valve is steel (214N, 1960). The inlet valve is made of a new steel developed since 1960 (EN52, 1970). The pre-stressed bolts are made of carbon–steel material (SCM 435). At the same time, the internal part of the gasket is in contact with different components having dissimilar material characteristic Fig3(1,14)

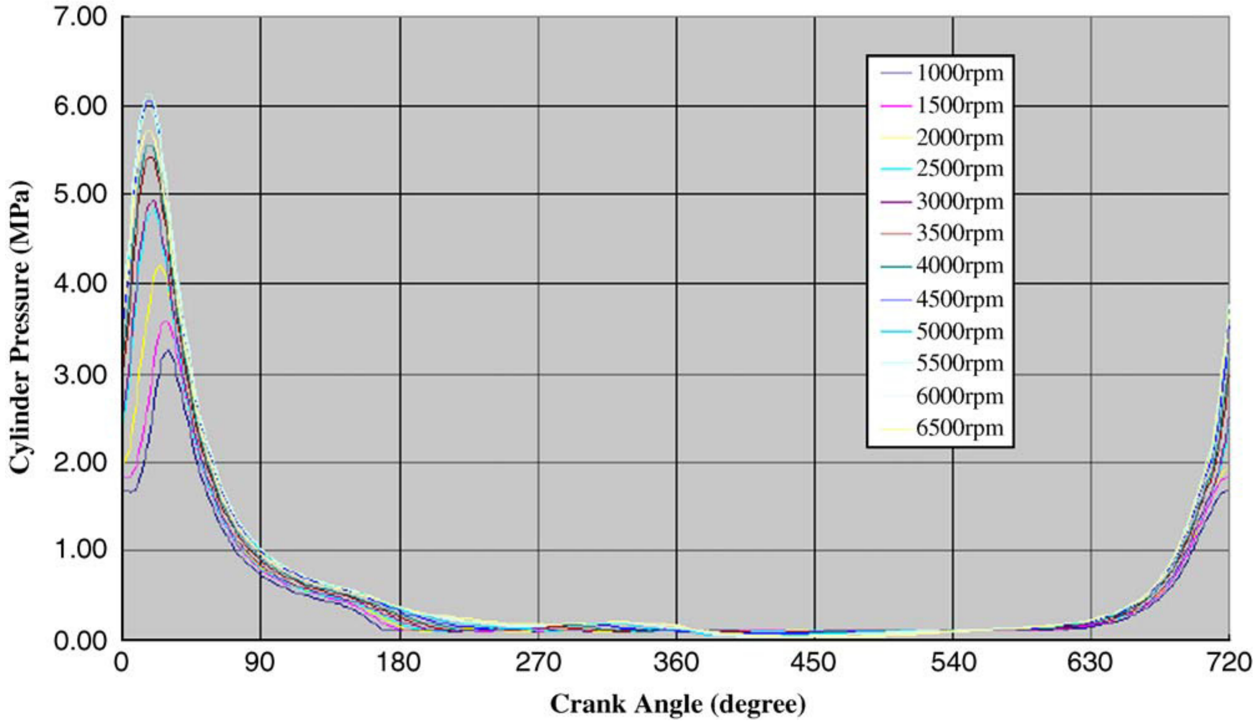
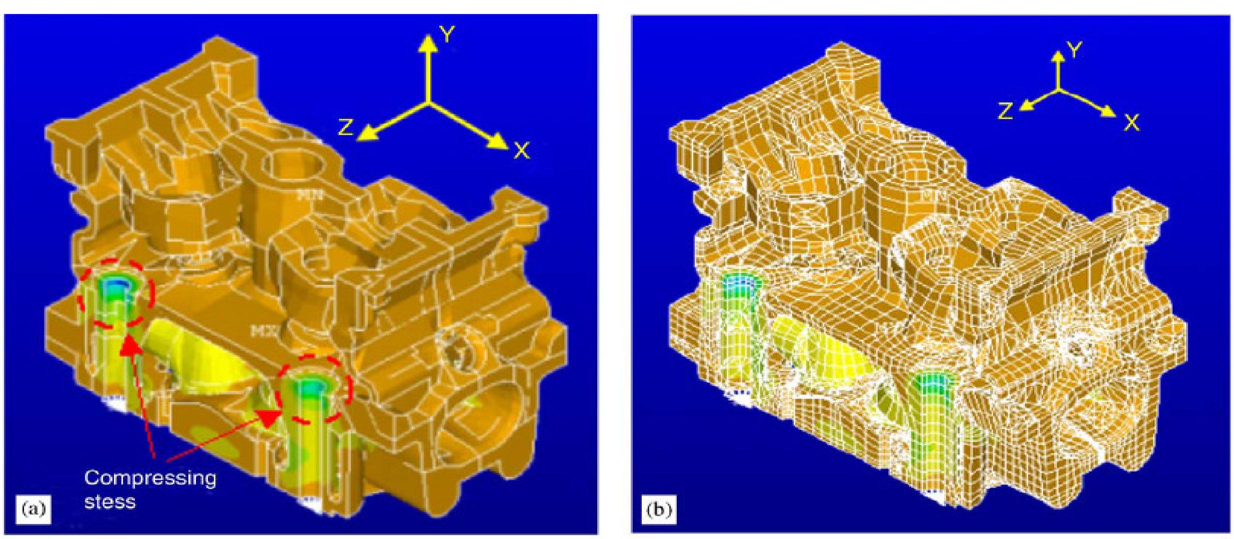


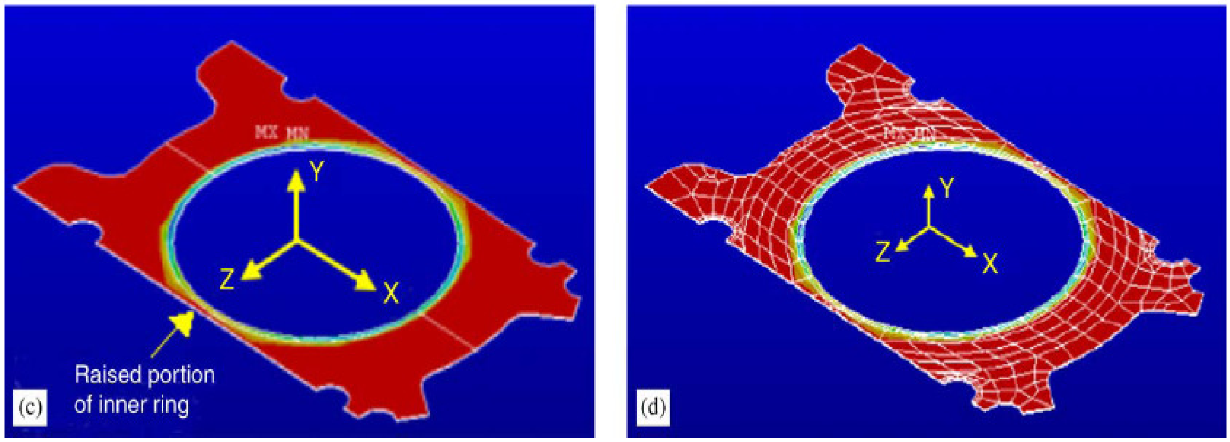
Fig.4The gas pressure of the engine at different cycle durations at specific operation speeds.

III. EXPERIMENT AND RESULT

The location of the weakest contact pressure on the gasket is used to investigate the efficiency of the gasket sealing. The analytical results under different operating processes of the engine will be discussed in detail

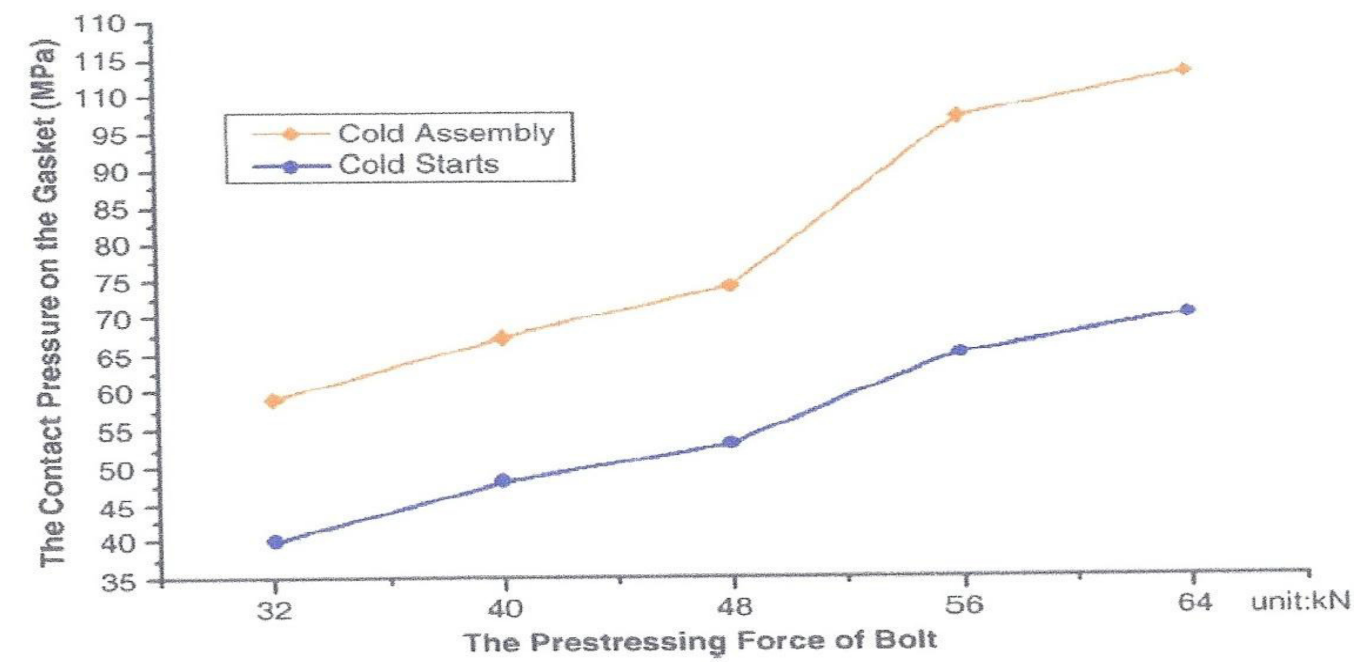
The weakest contact pressure on the gasket at different magnitudes of the pre-stressing force(cold assembly)





The discussion of the Y-axial stress for both the main body of the cylinder head and the gasket(cold assembly) (a)Isotropic view. (b) Isotrophic view(meshed). (c) Isotrophic view. (d) Isotrophic view (meshed)

The gasket sealing of the automobile in a motionless state is considered to be purely without any other external loading. Therefore, the maximum source of loading in this case is the pre-stressing of the bolts. In addition, the magnitude of pre-stressing the bolts with regards to dissimilar styles of engine structure and stroke volume is not identical. For this reason, the parametric analysis for the pre-stressing of bolts is implemented. The results reveal that the weakest contact pressure on the gasket appears at the raised location of the inner ring between two adjacent combustion chambers (Fig. 9). This situation results from the fact that the distance between the bolts and the foregoing location on the gasket is the greatest. Moreover, the maximum contact pressure on the surface of the gasket at the inlet part is slightly different from the exhaust part by virtue of the structural asymmetry[1,12]



The Comparisons of the Weakest Contact Pressure Between the Operating Conditions of the Cold Assembly and Cold Starts

IV.CONCLUSION

In this paper, the structural analyses of a cylinder head under various loading conditions are accomplished by means of the numerical simulation of finite element analysis. The main results combined with each analysis concerning the different operating processes of the engine can be separated into two parts as follow. First, the capacity of gasket sealing mainly depends upon the pre-stressing of the bolts, which are the source of the maximum external loading on the inner structure of the cylinder head. In addition, the location of the weakest contact pressure on the raised portion of the gasket can be transferred as a result of the effect of thermal stress/strain. In this investigation the analytical results indicate that the thermal stresses provide a positive support for the efficiency of gasket sealing. However, because of the opposite direction to the pre-stressing applied to the bolts, under the operating conditions with gas, the pressure will increase the possibility of gas escaping. Therefore, an effective method was proposed to enhance the sealing capacity of the gasket by increasing the magnitude of the assembly force without exceeding the material strength of each component in the engine structure. At the same time, the structure of the gasket in the region of the worst sealing can be improved in the early stages of design. This is especially true for the raised portion

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