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Cylinder Head Gasket Leakage Trouble Shooting Analysis

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Abstract

The present paper describes a CAE analysis approach to evaluate the transient cylinder head gasket sealing performance of a turbo charged GDI engine in the bench test development. In this approach, both transient gasket sealing force and gasket wear work are calculated to allow design engineers to find out the root cause of cylinder head gasket leakage failures.

In this paper, the details of the method development are described. Firstly how to use and get the cylinder head gasket property are described, which is the basic theory and data for the gasket sealing analysis. A transient heat transfer calculation for accurately simulating the engine thermal shock test is established, which is mapped to the transient gasket sealing calculation as pivotal boundary. The transient gasket sealing calculation which considering the cylinder pressure change, transient thermal load change, bench installation, fretting wear of gasket coating in cycling thermal shock conditions, is different from the traditional steady sealing analysis, it can reflect the comprehensive influence of various factors and simulate the test more truly.

The simulation results show that the local gasket regions with low gasket pressure and high wear work were identified accurately, and the simulation results were consistent with the experimental leakage area.

The scheme of adding the limiting gasket stopper rib locally in the leakage area is proposed. Through local structural shape optimization of gasket, the simulation results show that the gasket sealing pressure is effectively improved and wear work in the leakage area are greatly reduced, finally the optimized gasket has passed the thermal shock test successfully.

Introduction

In recent years, fuel consumption regulations and emission requirements have become increasingly stringent. Engine design is facing higher requirements, including better fuel economy, lower emissions, lighter weight, higher power output, higher torque output, etc. Therefore, high thermal efficiency, miniaturization and lightweight become the main development trend of modern engine. However, turbo charging and other technologies may cause higher combustion temperature and explosion pressure in cylinder, which makes engine parts bear higher thermal load and mechanical load [1, 2]. At the same time, the main ways to realize miniaturization and lightweight of engine include integrated exhaust manifold, aluminum body and cylinder head; The elastic modulus and rigidity of aluminum cylinder head and body are low, which makes the mechanical deformation larger; Because of the high coefficient of thermal expansion of aluminum, aluminum cylinder block and cylinder head are more sensitive to temperature change and temperature gradient, The integrated exhaust manifold will further increase the thermal load of the cylinder head, resulting in greater thermal deformation. This series of changes bring great challenges to the design of engine parts, especially the design of cylinder head gasket.

The cylinder pad is located between the body and the cylinder head, which mainly plays the role of sealing, intercepting and adjusting the installation thickness. Its structure is complex and the working environment is bad. At present, the most widely used type of cylinder head gasket is MLS (Multi layers steel) cylinder head gasket, which has high structural strength, small stress relaxation, strong resilience, temperature resistance and corrosion resistance. The leakage failure of cylinder head gasket may cause air leakage, coolant water leakage and oil leakage, the main failure forms and reasons are shown in Table 1, which alone or jointly lead to leakage.

The tests to investigate the sealing performance of cylinder gasket mainly include full speed full load endurance test, thermal shock test and cold start test. In the early stage of gasket design, the sealing performance is usually predicted by finite element analysis. The conventional steady-state analysis of cylinder gasket sealing is mainly based on the steady-state temperature field to predict the sealing performance of cylinder gasket under full speed, full load and cold start conditions. At present, it is relatively mature and has been widely used in major automobile companies and gasket suppliers. Y. Wei optimized the cylinder gasket structure based on the steady-state analysis results [3]. S. K. Kandreegula

FIGURE 37 Transient sealing force is increased after optimization

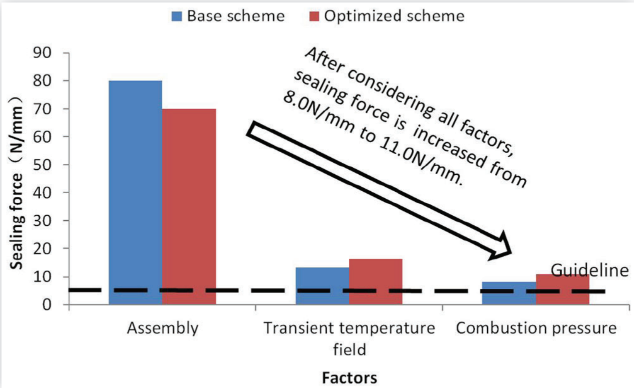


FIGURE 38 Reason for the increase of transient sealing force

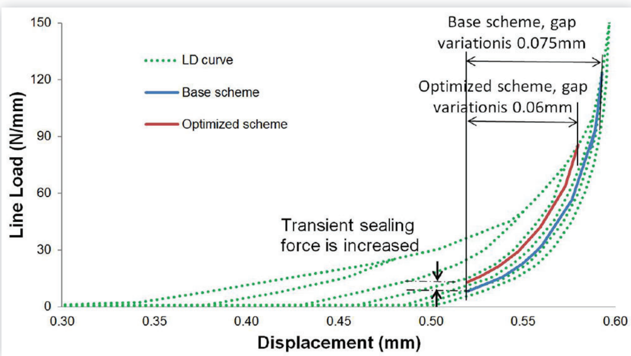
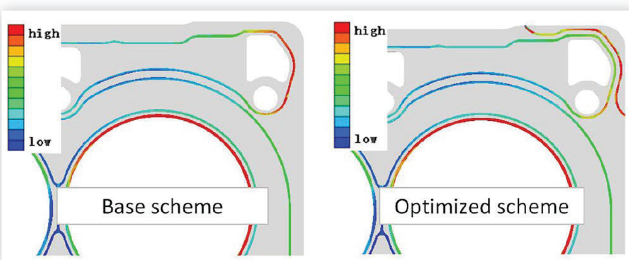


FIGURE 39 Comparison of calculation results of wear work between the base scheme and optimized scheme

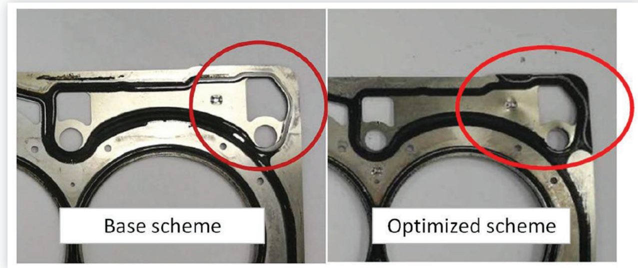


mainly occurs at the support rib, which has little effect on the sealing, as shown in Figure 39.

Validation

The thermal shock test was carried out again using the optimization scheme, no leakage occurred on the interface between cylinder head and block during the test. After the completion of the test, the coating inspection shows that the coating wear on the sealing rib is obviously improved, the supporting rib is slightly worn, which has little effect on the sealing, as shown in Figure 40. Therefore, the simulation results are consistent with the dyno validation results, which show that the simulation is feasible.

FIGURE 40 Comparison of coating loss between the base scheme and optimized scheme



Conclusion

This paper describes a CAE diagnosis methodology for leakage failure evaluation of cylinder head gasket, the calculated results show that the location with high wear work is consistent with the leakage location in the test.

Through local structure optimization of gasket, the transient sealing pressure is improved and the wear work is reduced effectively, which can meet the design guideline. The improvement scheme successfully passed the thermal shock test and all other durability tests.

The main idea of this paper to solve the leakage issue is to reduce the wear work of gasket rib while ensuring the transient Gasket sealing force .In this failure case, the wear work of gasket convex rib is the main factor, but the transient sealing pressure is also need to be improved at the same time. It is necessary to ensure that the above two indicators meet the design requirements, so as to effectively reduce the risk of leakage in the actual working process of engine.

In the present simulation methodology, several main factors affecting gasket sealing are comprehensively considered. It truly reflects the actual working condition of cylinder head gasket and could be also used to evaluate the cylinder head gasket leakage risk at the early design stage of engine development, so as to make the design robust.

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Definitions/Abbreviations

MLS - Multi layers steel

CAE - Computer aided Engineering

FEA - Finite element analysis

CFD - Computational Fluid Dynamics

L-D curve - Load-displacement curve

E - Modulus of elasticity