Gasket Simulations process considering design parameters

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Abbreviations:
CAE – Computer Aided Engineering
FE – Finite Element
NLPARM – Non-linear Parameter
NINC – Number of Implicit Load Sub-increment

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Abstract

Gaskets are critical and widely used components of the vehicle since they are required to be used for many of the sealing joints between mating surfaces. It is a mechanical seal which prevents leakage through joints, while under compressive loading. Gaskets must be manufactured from materials capable of yielding so that they can satisfactorily fill the space and cover the irregularities between surfaces. High precision is required during installation of the gasket since the allowances are very low for most joints.

A joint can be leak proof if gasket fills the imperfections of the contact flanges. The thickness of gasket should be enough to flow or yield the gasket material. The gasket thickness plays a vital role in deciding the gasket stiffness & gasket closure curve is function of gasket thickness.

The focuses are given on the various aspects of design to be considered while designing gaskets for different purposes. Two models of gaskets are analyzed, namely the wheel hub gasket and the intake manifold gasket. The corresponding results are obtained. CAE analysis methodology is adopted to virtually find the effects of different gasket parameters on sealing.

Introduction

Sealing plays a vital role in the performance of any lubrication system. The same is true in case of bearing and grease used in wheel hub system. Any outside contamination if get mixed with grease would distort the overall structure of grease making it unfit for lubricating the bearings. If bearings get starved of lubrication due to grease contamination, it would generate heat between rotating members of bearing. This will result in excessive temperature and overall bearing failure. Gasket and hub cap together acts as a sealing system. Hence, while designing care to be taken to select the appropriate parameters for effective sealing.

In wheel hub, a cap and gasket combination is used for sealing. This helps to face the harsh operating conditions and prevents leakage even under severe conditions. The gasket is mounted on wheel hub face and cap is bolted on to it which generates compression, making the leak proof joint. Different design parameters like cap thickness, bolt preload are studied to find out the performance of the gasket joint. Pressure closure curve of the gasket is used for studying the behavior of gasket at different cap thicknesses.

For virtual analysis, the sealing performance of gasket is evaluated by doing nonlinear analysis of gasket joint.

During vehicle validation grease was noticed seeping out through hub cap gasket interface. This signifies that there is improper sealing between gasket and hub cap, hub interface allowing the grease to seep though as shown in Figure1. Secondly if there is a gap then the contamination would also be able to enter the hub and contaminate the grease. Grease if get contaminated would results in overall bearing failure.

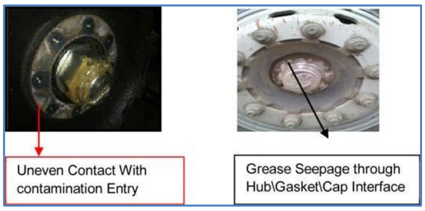


Figure1: Wheel Hub of Vehicle

One of the most important parameters regarding in-cylinder combustion is the internal temperature and the thermal efficiency. In order to maximize the effect of both these factors, the in-cylinder temperature must be regulated and the air must be completely sealed and unable to escape when combustion is taking place. This function is performed by the intake manifold gasket. Thus, it helps to ensure that the oxygen content in the combustion chamber is optimum with respect to the amount of fuel in the chamber.

Optistruct is used as a finite element analysis tool to simulate the gasket performance. The results obtained from this analysis are compared with the results obtained from other FEA software used for similar analysis. CAE results are then validated by fitment of parts on test vehicles and conducting measurements accordingly. Footprint of gaskets is taken on the vehicle and comparative study is performed with the virtual footprint obtained from the analysis.

Process Methodology

The components creating the interface and their properties or parameters contributing towards the seal are studied. Also, the combination of properties between components needs to be evaluated to find out the overall effect on seal. Each combination of properties is then evaluated virtually through CAE and then cross-verified on physical vehicle & Fuji Film Test.

This indicates that major portion of the external load is borne by bolt to create compression in gasket joint which makes the joint leak proof. Hence stiffness of cap and gasket plays a vital role in designing joint.

The total force on contact surface of gasket is depend bolt grade and number of bolts

Total Bolt Load

$F = n \times P$

Where P is bolt preload, n is number of bolt

$P = T / 0.2\, d$

Where T = Torque, d = Nominal bolt diameter

The very accurate measurement of bolt load is obtained by bolt elongation using an extensometer or strain gauges.

Gasket closure curve –

The gasket material response is captured in closure curve. The gasket surfaces displacement changes with respect to middle layer which is called the closure. A closure curve is defined to model the gasket in finite element analysis. To study the behavior of gasket in wheel hub & intake manifold only loading curve is used. An example of closure curve is shown in below Figure2.

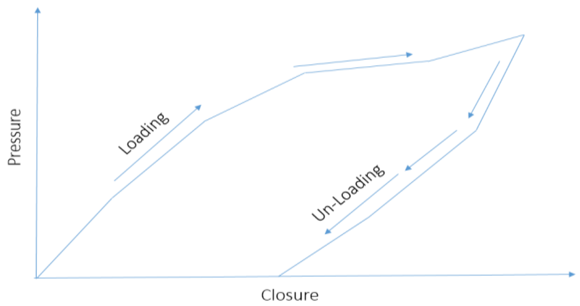
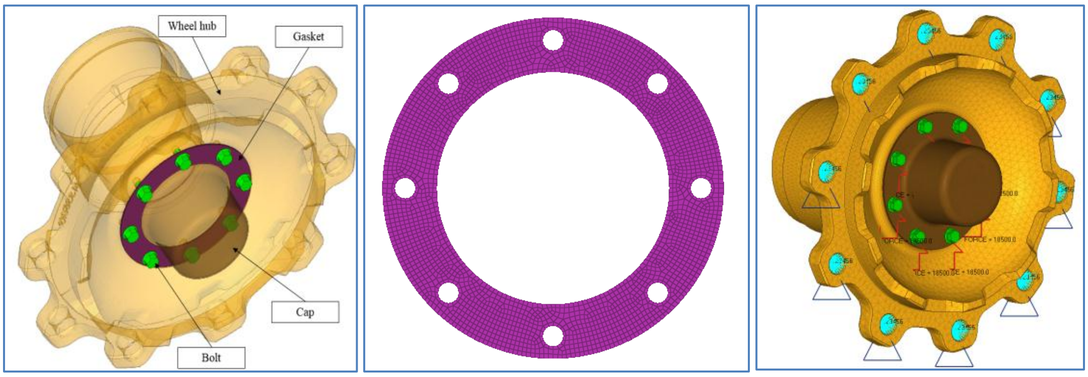


Figure2: Gasket Closure Curve

Finite Element Modeling –

1) Wheel hub gasket

The 3-D finite element model is used for analysis. Figure3 (a) shows the geometry details of wheel hub assembly. The hub assembly considered for FE Analysis consists of the wheel hub, gasket, cap and bolts. All the components are modelled with 3D elements. Figure3 (c) represents the Finite Element Model of the wheel hub assembly meshed using HyperMeshTM



a) Wheel Hub Assembly *b) Gasket Meshing* *c) FEA Model of Wheel Hub Assembly*

Figure3: Wheel Hub Assembly and FEA model

2) Intake manifold gasket analysis

In intake manifold gasket, leakages may allow unmeasured air into the cylinder. Also leaks decrease the oxygen in the air for combustion. The leakage of air may reduce the efficiency of the engine. Asymmetrical *connections, vibrations and high temperatures may reduce the quality and must be monitored for intake manifold gaskets.*

For intake manifold gasket analysis also a 3-D model is used. Figure4 shows the geometry details and meshing of the intake manifold and gasket assembly. Finite Element Model of the intake manifold assembly is prepare using HyperMeshTM.

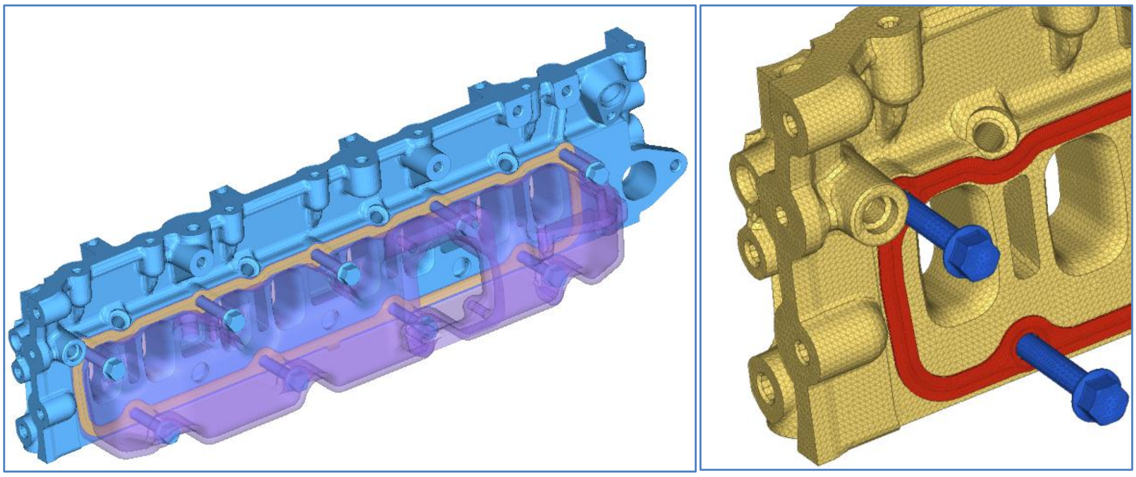


Figure4: Intake Manifold Gasket Assembly and FE Model

Non-Linear Analysis Setting –

To account for the non-linear nature of the problem here Non-Linear Quasi-static loadcase type is used. Supporting Non-linear cards like NLPARM, NLADPT were defined to the increment sizes & convergence controls. Optistruct have dedicated material MGASK for gaskets, PGASK for property & CGASK as element types and same were used. For the present analysis the total load acting on the system was divided into three subcases. Gasket closure- loading/unloading curves were defined in with MGASK & PGASK.

Contact Details –

The following contact settings are used for the contact interface-

Contact between bolt head and cap – Friction

Contact between bolt thread and hub – Freeze

Contact between gasket and cap – Freeze

Contact between gasket and hub – Freeze

Load and Boundary Conditions –

All the bolt holes are fixed of the wheel hub to apply displacement boundary conditions while bolt preload is used a load boundary conditions.

A similar kind of loads and boundary conditions are applied to intake manifold analysis as well. Symmetric constrain is applied to the cylinder head. Bolt preload is applied to all the bolts using pretension manager tool. The contact definitions are used similar to wheel hub analysis for respective interface.

Here there is bead in the gasket geometry. Convergence was achieved using different convergence controls & parameters in Optistruct.

Results & Discussions

Wheel hub gasket Analysis –

After the results from Optistruct were obtained they were properly analyzed. Taking input from pressure Vs compression curves, simulation study is done based on the combinations made as per Table: 1 contact pressure analysis studies is done for each iteration for wheel hub analysis.

Iterations	Gasket Thickness (mm)	Cap Thickness (mm)	Contact Pressure at inner edge (mm)	Min Compression (micron)
Current Design	0.8	1	1.2	28.4
IT1	0.8	2	2.0	83.3
IT2	0.8	3	2.8	105.1
IT3	1.5	1	1.3	60.6
IT4	1.6	2.5	3.1	152.9

Table1: Results Summary of Wheel Hub Gasket Analysis

From above analysis it is clear that increase in cap stiffness would result in even contact pressure. Maximum compression would take care of the cap uneven flatness issues. Compression plots have not been shown here. It has been observed that there is deformation in positive direction (opening) for current design which has high chances of leakage. Figure5 and Figure6 have shown the comparison of contact pressure of current design and final iteration with the test results (Fuji film test). A good correlation has been achieved.

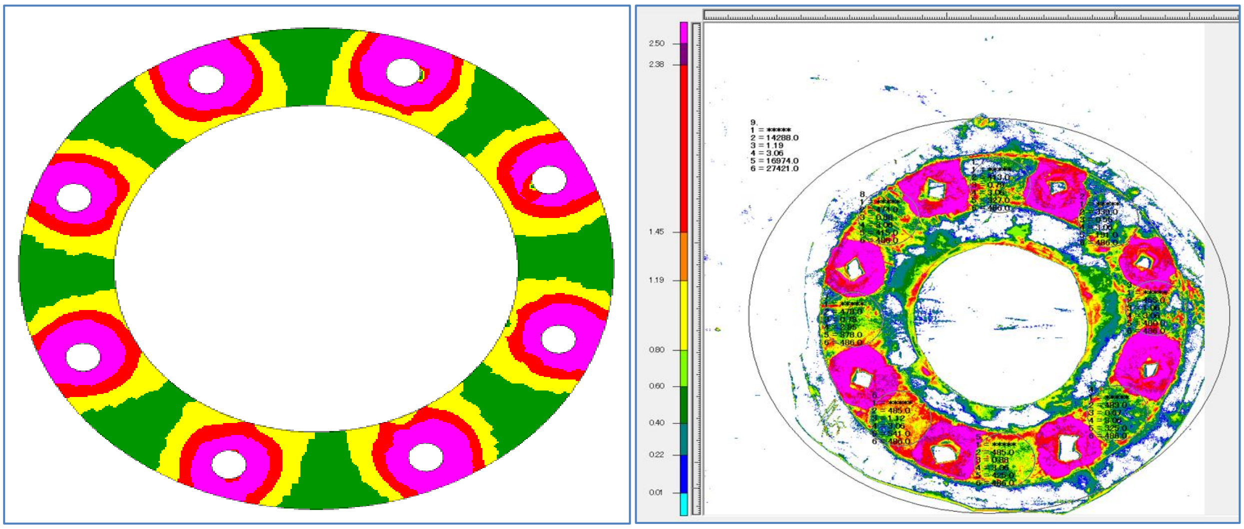


Figure5: Comparison of Contact Pressure between CAE (left) and Test (right) for Current Design

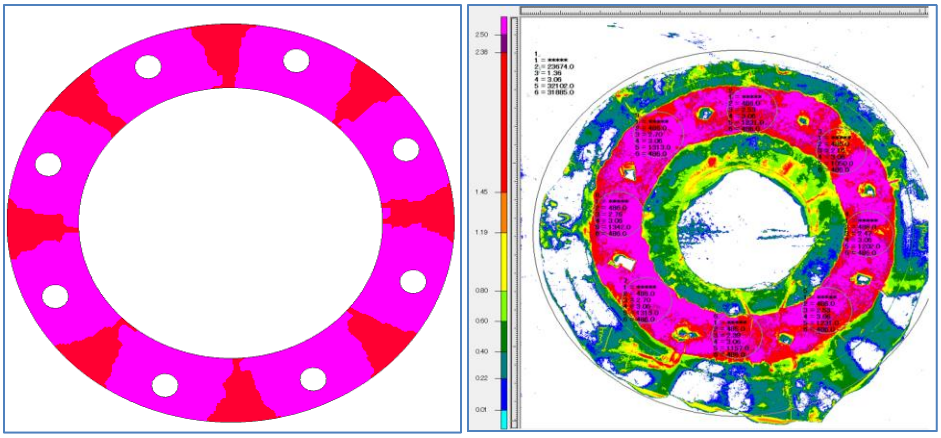


Figure6: Comparison of Contact Pressure between CAE (left) and Test (right) for IT4

Intake manifold gasket analysis –

A gasket thickness direction pressure is studied for this analysis. Similar analysis is done using another FEA software for comparison purpose. The correlation was achieved with test as well as other software which gives the confidence to use Optistruct for further nonlinear gasket analysis project. The trend & value of contact pressure was matched.

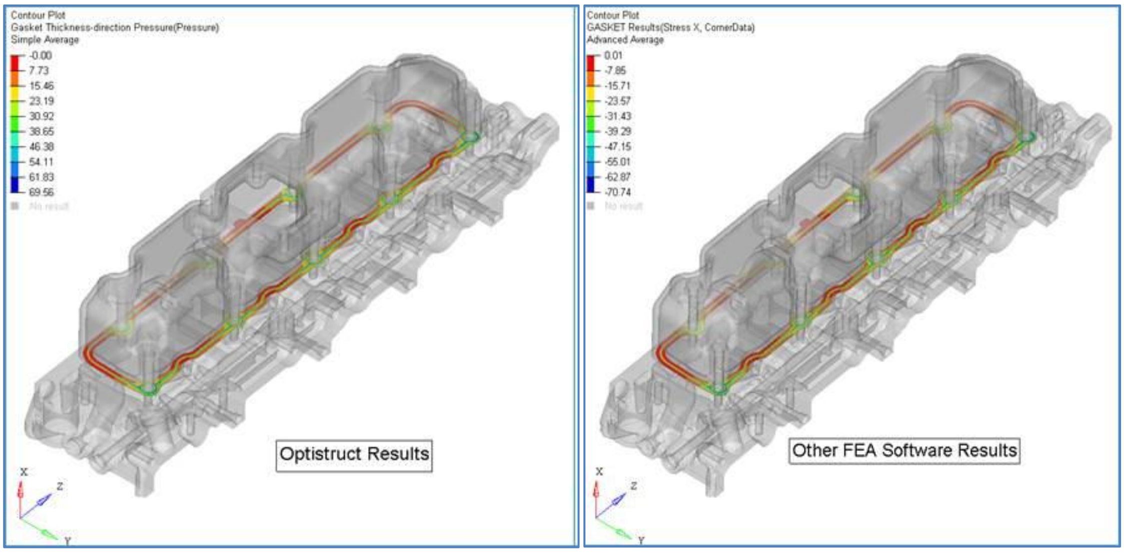


Figure7: Intake Manifold Gasket Analysis-contact pressure from Optistruct

Conclusion

It gives an insight that thicker gaskets can deal with more mating part irregularities as they compress more. If flanges are uneven (out of flatness) then thicker gaskets are better options. Thicker gasket ability to fill flange irregularities is based on the amount of gasket compression at a given load. After performing the above analysis & studying the results it is found that the results from Optistruct are in good correlation with the results

from test & existing non-linear solver. The contact (gasket) pressure results have been correlated with physical testing results (Fuji Film).
Therefore, the current procedure can be used for solving other non-linear problems involving material non-linearity, contact and structural loads.

Benefits Summary

In this paper analytical calculations were performed on various factors contributing in Gasket joint stiffness. Combination of these factors is evaluated in CAE to understand the contact pressure developed in gasket joint using part stiffness and gasket Pressure Vs Compression curves. Physical trial then taken to correlate CAE results physically. Finally, implementation feasibility is workout to finalize the implementation.
A huge testing cost and license cost of other non-linear software is reduced.

Future Plans

This paper would give an insight into the various factors considered while selecting the cap /Gasket system for sealing of wheel ends.

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