Press in Place Gasket Optimization using I-Sight

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Abstract: Press in place gasket is an elastomer based molded gasket which is pressed into a groove to seal fluids and contaminates and to isolate the noise and vibration in engine. For any particular groove design of a press in place gasket, the sealing performance is determined by its gasket design parameters. On varying the gasket design parameters, sealing performance can either improve or deteriorate. It is also possible to find optimum gasket design parameters which give the best sealing performance. The primary objective of this study is to find the gasket design parameters with optimum sealing performance when groove dimensions are fixed. The secondary objective of this study is to completely automate the gasket analysis and develop an optimization environment to determine optimum gasket design. I-sight is used for this study as it allows interfacing between different software and allows to automate the process of creating, running and post processing an analysis model. In this study, height to width ratio and gasket cross sectional area of the gasket were used as the gasket design parameters and also as inputs in I-Sight. Contact pressures and strains at different geometric conditions and at different operating temperatures are obtained as outputs in I-Sight and also function as sealing performance parameters. Height to width ratio and gasket cross sectional area are varied using optimization algorithms till the sealing criteria for contact pressure and strain are met. The results obtained from this study can be used to come up with the best possible gasket design.

Keywords: Sealing, press in place gasket, optimization, I-sight, gasket parameterization, sealing performance

1. Introduction

Sealing is one of the most important aspects to be considered when designing an automotive engine. Without proper sealing, fluids can leak inside the engine, which can damage engine components and even cause accidents. Leakage of fluids can also deteriorate the performance of the engine. Therefore, robust sealing is necessary for a reliable automotive engine.

Automotive engines mainly use gaskets and adhesive sealants for sealing. There are many different types of gaskets: O-rings, rubber coated metal gaskets, carrier gaskets, and press in place gaskets "(Bickford, 1997)". This paper is mainly concerned with press in place gaskets.

Press in place gasket is an elastomer based molded gasket which is pressed into a groove on the flange of a component to seal fluids by filling the space with in the groove. The sealing performance of any press in place gasket can be determined by the results of finite element analysis of that gasket. For good sealing in the automotive engine, the finite element analysis results of the gaskets have to meet certain sealing criteria. When the gasket fails to meet these sealing criteria, it is necessary to find a gasket design which meets the sealing criteria to ensure a leak free engine.

For a press in place gasket, the sealing performance depends on the gasket dimensions which determine the gasket design. On varying the gasket dimensions, the sealing performance of a gasket can either improve or deteriorate. Thus, it is possible to find the gasket dimensions at which the sealing criteria are met by varying the gasket dimensions. There are various optimization software available that allow the setup of optimization environment to make the search for optimum gasket dimensions simple and easy. Therefore, the objective of this study is to develop an optimization environment to find optimum gasket dimensions for which all sealing criteria are met.

Optimization of a gasket is a time taking and repetitive process. Due to the recent advances in computational hardware and software and also development of new optimization software, it is possible to create complex optimization environments and automate the simulation of repetitive analysis processes quickly and efficiently, in turn, reducing the time taken to perform optimization tasks significantly. Many studies have been carried out to optimize automotive components using either topology optimization "(Durali, 2003)", "(Zhang, 2009)", "(Pan, 2007)" or parametric optimization "(Chuang, 2009)", "(Trindade, 2009)", "(Baner, 2010)".

In this study, parametric optimization in I-sight is used to develop an optimization process for gasket, as the objective of the gasket optimization is to find the optimum dimensions without changing the shape of the gasket. Gasket parameters were chosen as design parameters and the groove dimensions were fixed in the optimization process. The impact of these parameters on the sealing performance of the gasket was investigated and the optimum design parameters at which the sealing criteria are met are determined.

2. Base Analysis Model

Base analysis model of the gasket is defined before setting up the optimization environment in I-sight. It consists of cover, groove and gasket as shown in the Figure 1.

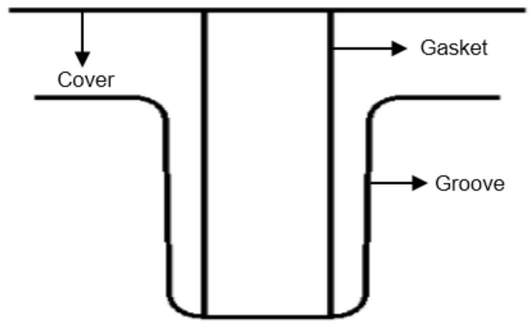

Figure 1. Base analysis model

Cover represents the flange of the component that presses the gasket into the groove, which represents another component that has a cut made on its flange in order to fit the shape of the press in place gasket. To account for the effect of manufacturing on the components, gasket, cover and groove are modelled for different geometric conditions and analyzed. Hyper elastic material properties provided by the supplier were used for setting up the gasket analysis model. Contacts were defined at all interfaces of the components.

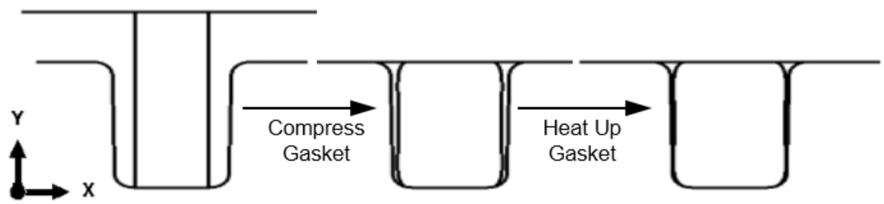

Figure 2. Load steps

Groove was constrained in all degrees of freedom. Cover was constrained in all degrees of freedom except y-direction. Cover was displaced in the negative y-direction in order to compress the gasket into the groove and then the gasket is heated up. The analysis load steps are shown in Figure 2.

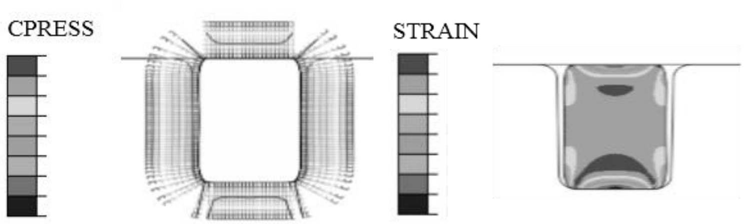

Figure 3. Contact pressure and strain plots for base analysis model

Contact pressure and strain function as sealing performance parameters. The contact pressure and strain results were taken at different operating temperatures for different geometric conditions. Figure 3 shows contour plots for contact pressure and strain in the base analysis model.

3. I-sight Model Setup

After the base analysis model is setup, an optimization environment is built around it. Figure 4 shows the flowchart showing the steps involved in setting up the optimization environment in I-sight.

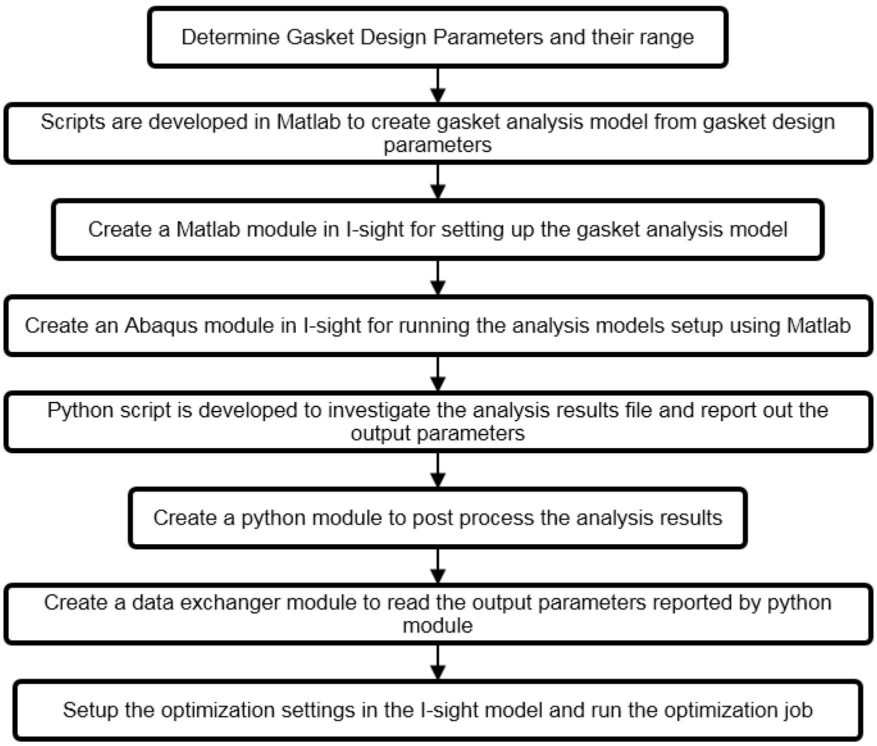

Figure 4. Flowchart for I-sight model setup

The most important aspect to be considered when setting up the I-sight model is to determine the gasket design parameters used for varying the gasket geometry. Carefully determining the gasket design parameters can resolve several issues associated with the gasket optimization problem. First of all, it is possible that the gasket can overfill when it is pressed into the groove. Overfilling of the gasket can cause convergence issues in the finite element analysis, making it difficult for the optimization environment to find the optimum solution. Secondly, the gasket optimization problem has multiple solutions. When the optimization environment is run it can capture only one solution and it can give a completely different solution depending on the optimization settings.

Therefore, it is necessary to determine the gasket design parameters in such a way that different optimum solutions can be captured and the issue with overfilling is also addressed. In this study, gasket height to width ratio and gasket cross sectional area were used as gasket design parameters instead of gasket height and gasket width.

Gasket cross sectional area was chosen as the design parameter as this can eliminate the gasket overfill cases from the optimization search. Height to width ratio is required to completely define the gasket design when gasket cross sectional area is used as a design parameter. To capture multiple optimum solutions, gasket cross sectional area is fixed at six different values and height to width ratio is varied at these values. A schematic showing the actual gasket dimensions and gasket design parameters are shown in Figure 5.

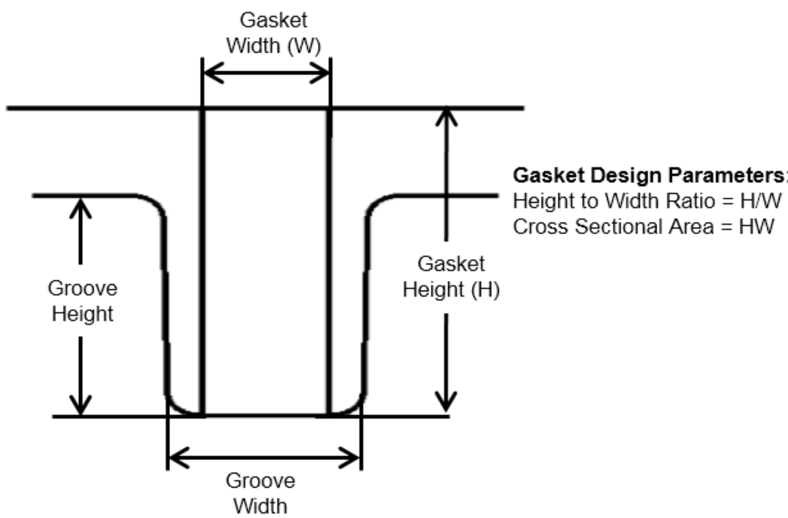

Figure 5. Gasket dimensions and design parameters

The other important aspect to be considered while setting up the optimization process in I-sight is to establish the range for gasket design parameters. The lower and upper bounds for the design parameters are chosen in such a way that the gasket width is always less than groove width and is not too small and gasket height is always larger than groove height.

After the gasket design parameters and their ranges were determined, the base FE model is parameterized using Matlab so that Matlab can accept the gasket design parameters as input and provide the finite element analysis model as output. This process can build different gasket designs based on the input design parameters and generate finite element analysis models that can be run using Abaqus module in I-sight.

Once the analysis modules were setup in I-sight, a module was setup to post process analysis results using Python and the output parameters to be constrained or optimized were also setup in the optimization module. Schematic for the complete workflow in I-sight is shown in Figure 6.

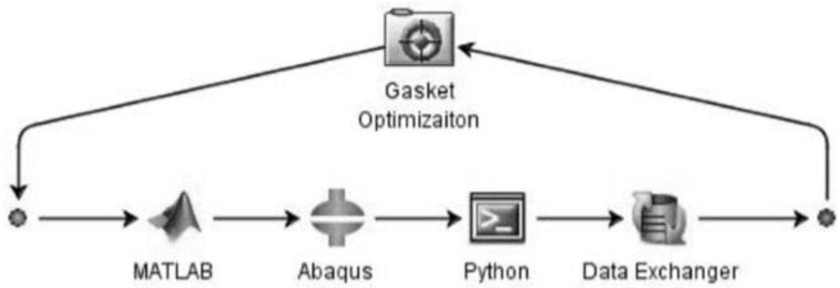

Figure 6. I-sight work flow

4. Results Discussion

The sealing performance and gasket design have a non-linear relationship and a reliable method is required to find the optimum solution. NLPQL (sequential quadratic programming), a nonlinear optimization method, is used for running the optimization environment in I-sight. NLPQL is mainly used for running long simulations "(I-Sight Manual)". As finite element analysis of gasket takes a significant amount of time when it is run repetitively, NLPQL method is used for optimizing the gasket.

The optimization settings in the optimization environment play an important role in finding the optimized solution. Relative step size and absolute minimum step size affect the chosen values of the gasket design parameters, which in turn affect the final optimized solution. These values have to be set in such a way that very close values of design parameters are not chosen in consecutive iterations. Therefore, relative step size is set at 0.04 and absolute minimum size is set at 0.01. Maximum possible iterations is set at 40 to give enough number of iterations for the optimization algorithm to find the optimized solution.

Gasket Cross Sectional Area	150 mm²	160 mm²	170 mm²	180 mm²	190 mm²	200 mm²
Initial Height to Width Ratio(H/W)	4.4	4.4	4.4	4.4	4.4	4.4
Optimized Height to Width Ratio (H/W)	4.6	4.3	4.0	3.8	3.6	3.4

Table 1. Optimized designs for the example groove

For the example problem, a groove width of 10 mm and groove height of 20 mm is considered. The optimization runs were performed by fixing the gasket cross sectional areas at six different values and varying the values of height to width ratio at the fixed cross sectional areas. Contact pressures at different geometric conditions and operating temperatures were constrained using sealing criteria and the maximum strain observed at different geometric conditions and operating temperatures was chosen as the objective to be minimized. The weight factor was also set to 1.0 for all the output parameters. Table 1 shows the different optimized height to width ratios obtained by running the optimization environment for the example groove with groove width of 10mm and groove height of 20 mm.

Table 2 shows the results for I-sight iterations when gasket cross sectional area is 16 and initial height to width ratio is 4.4.

Iteration #	Gasket Cross Sectional Area	Height to Width Ratio	Cases with Contact pressure not meeting sealing criteria	Strains
1	160	4.4	1	156
2	160	4.44	1	164
3	160	4.12	2	100
4	160	4.15	1	106
5	160	4.3	0	136
6	160	4.34	0	144
7	160	4.26	1	128
8	160	4.29	1	134
9	160	4.17	1	110
10	160	4.24	1	124

Table 2. Iteration results in I-sight for a gasket cross sectional area of 160

It can be observed from the Table 2 that Iteration #5 showed the minimum strain. Iteration #6 meets sealing criteria for contact pressure at all cases but has a higher value of strain than Iteration #5. All other runs do not meet sealing criteria for contact pressure at all cases.

5. Summary/ Conclusion

In this study, an optimization process to determine the optimum gasket design parameters for a fixed groove is described. Several different software like Matlab, Abaqus and python are interfaced together using I-sight to establish the optimization process. An example problem is solved using the optimization environment developed. Optimum gasket designs that meet the sealing criteria are obtained at different values of cross sectional area by varying the height to width ratio using a non-linear optimization algorithm. The results obtained from the example allow the designers to choose from multiple optimum designs for the groove. This process can be used to find optimum gasket designs for a groove of any size.

6. References

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