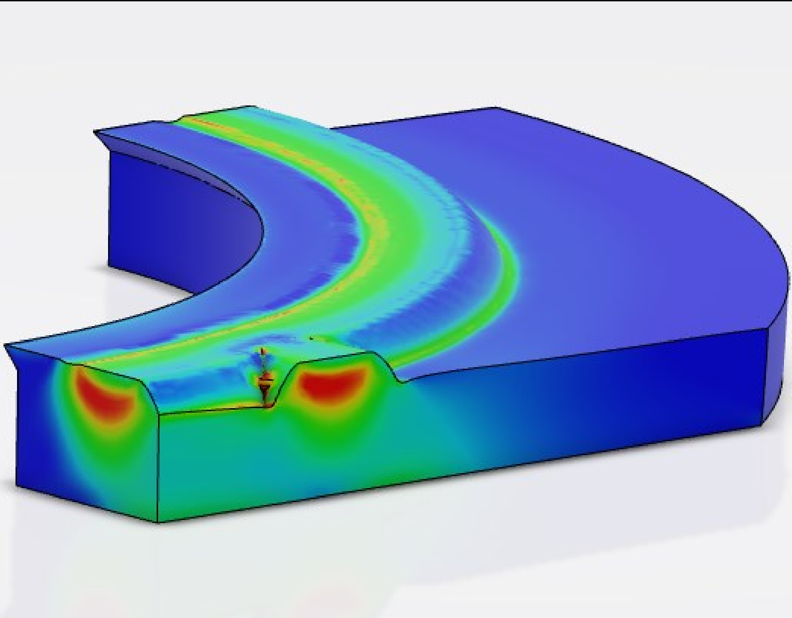

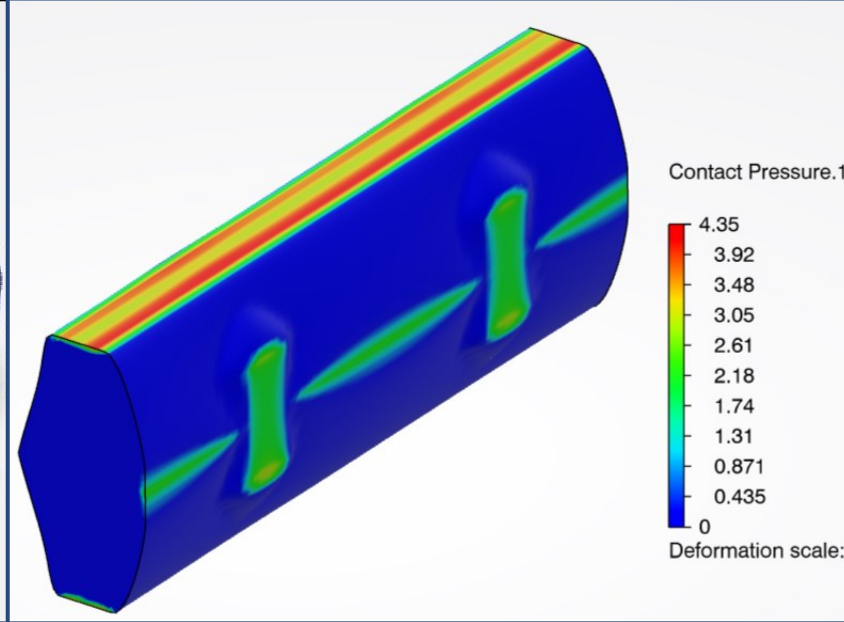


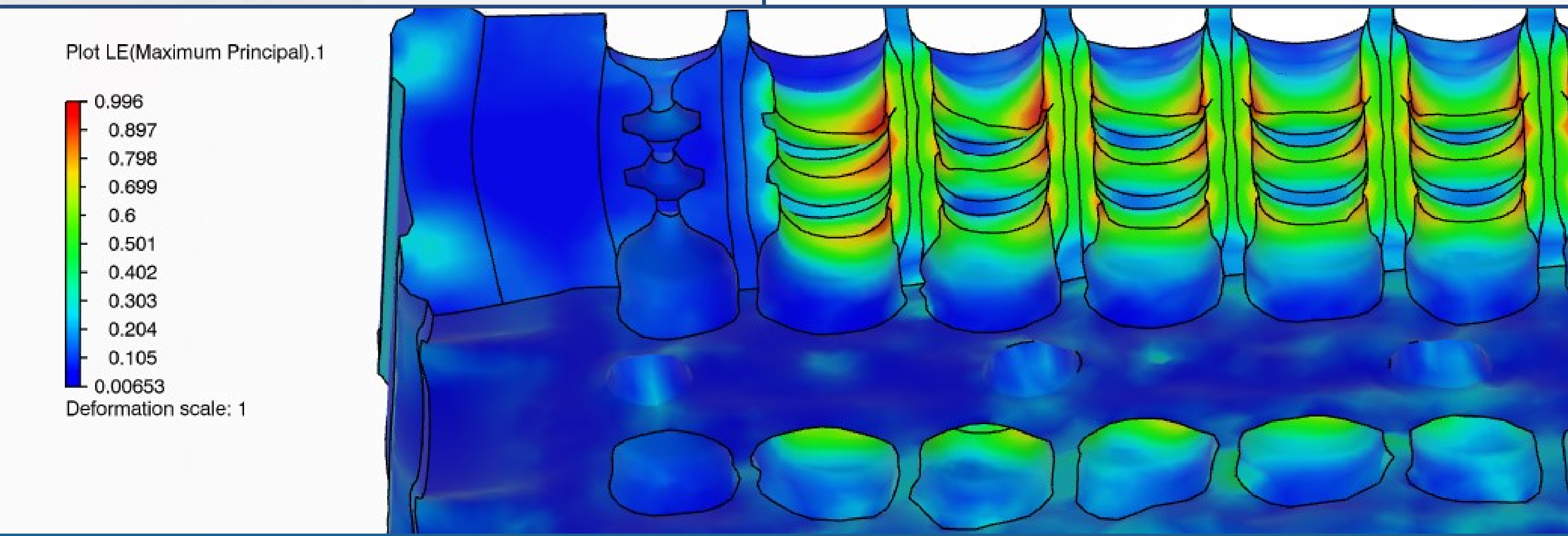


MORGAN
POLYMER SEALS

WHITE PAPER

# Elastomer Seal FEA Results Review

## HOW TO INTERPRET THE RESULTS OF ELASTOMER ANALYSIS IN SEALING APPLICATIONS

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POLYMER SEALS

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## INTRODUCTION

Rubber gaskets and seals are critical components for mechanical systems in many automotive and industrial applications. These components seal against external elements such as dust, debris, and liquids, and also against internal elements such as air, coolant, oil, and fuel.

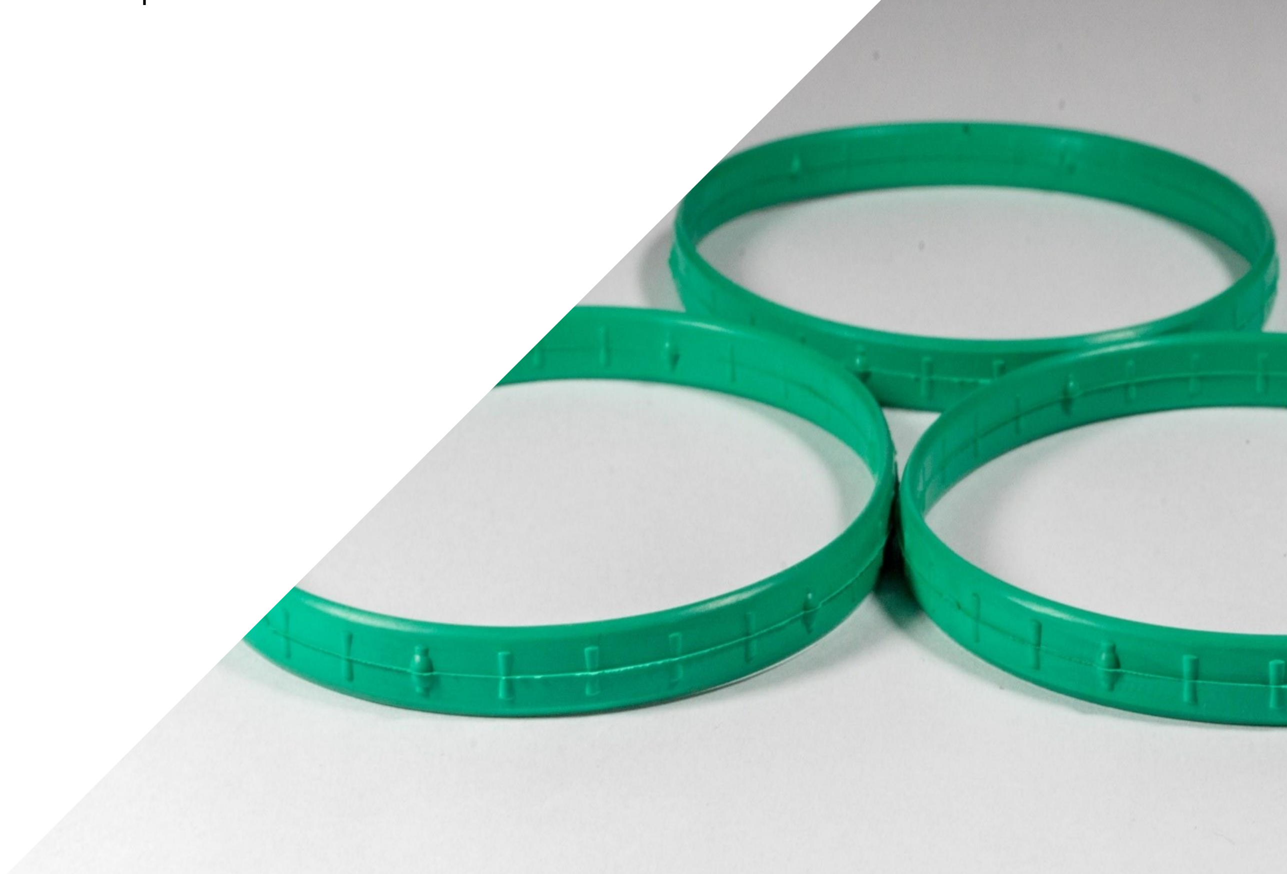
Being critical components, design validation is a required step in developing a successful gasket or seal. The design validation stage of development is important in helping determine the robustness of the design and assists in preventing design issues later on in the production process.

Historically, product designers relied on basic calculations to approximate the capability of a design. However, these calculations were limited and could only validate relatively simple design shapes, so product development relied on iterative real-life testing and prioritized previously proven and standardized designs. Due to the increased complexity, complex shapes and more challenging material properties were rarely used.

To validate critical seal designs in the modern era, many industries have adopted Finite Element Analysis (FEA) to reduce the need for extensive testing and reduce the timeline of the product development cycle.

This paper is part three of a series on the FEA process for rubber elastomer seals. Part one covered the material properties and approximations used with elastomers that are important when running FEA. Part two covered the scenarios that are typically required for a proper and complete design process of sealing elastomers.

This paper will explain the different areas of interest within the results, what is important to review, and how different seal types have different requirements and results.



## RESULTS OF LMC ANALYSIS

LMC results of elastomer seals primarily focus on the contact pressure profiles at the mating surfaces. For press-in-place (PIP), face, and carrier seals, the overall contact pressure is largely determined by the force applied upon the mating surface by compressing the elastomer. As can be seen in the examples of FEA cross sections shown below, different types of seal designs will have different contact pressure profiles. Face seals and encapsulated carrier seals have centered and even contact pressure profiles. On the other hand, the edge bonded carrier seal is biased towards the carrier, and the circular PIP gasket has higher contact pressures where the stabilizers are located.

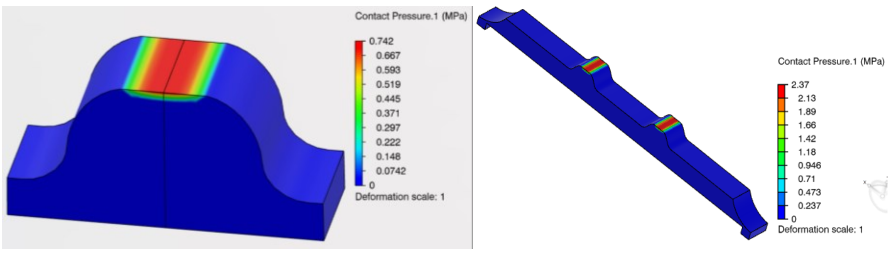



***Figure 1: Face seal and Overmolded Carrier seal***

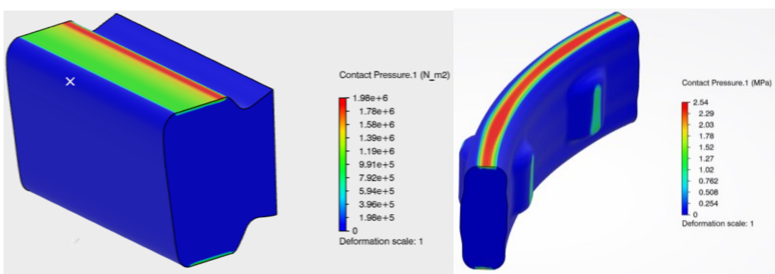
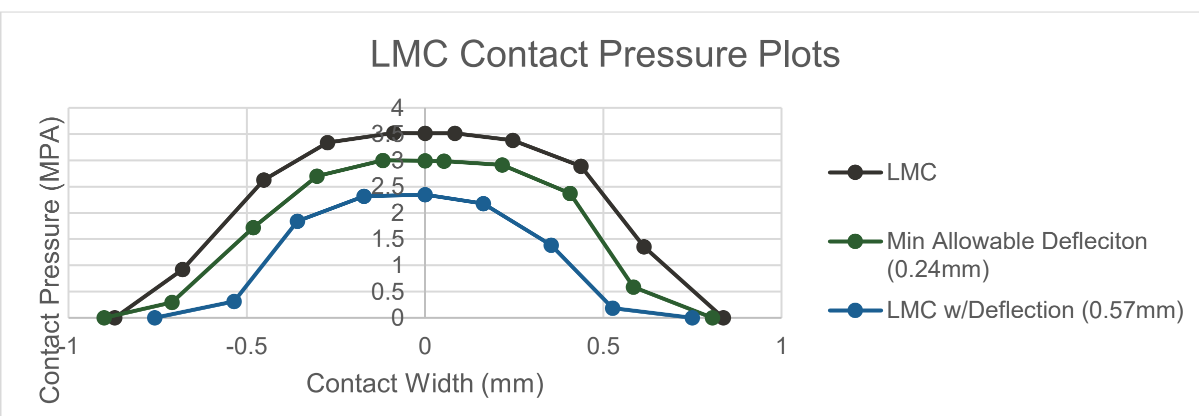
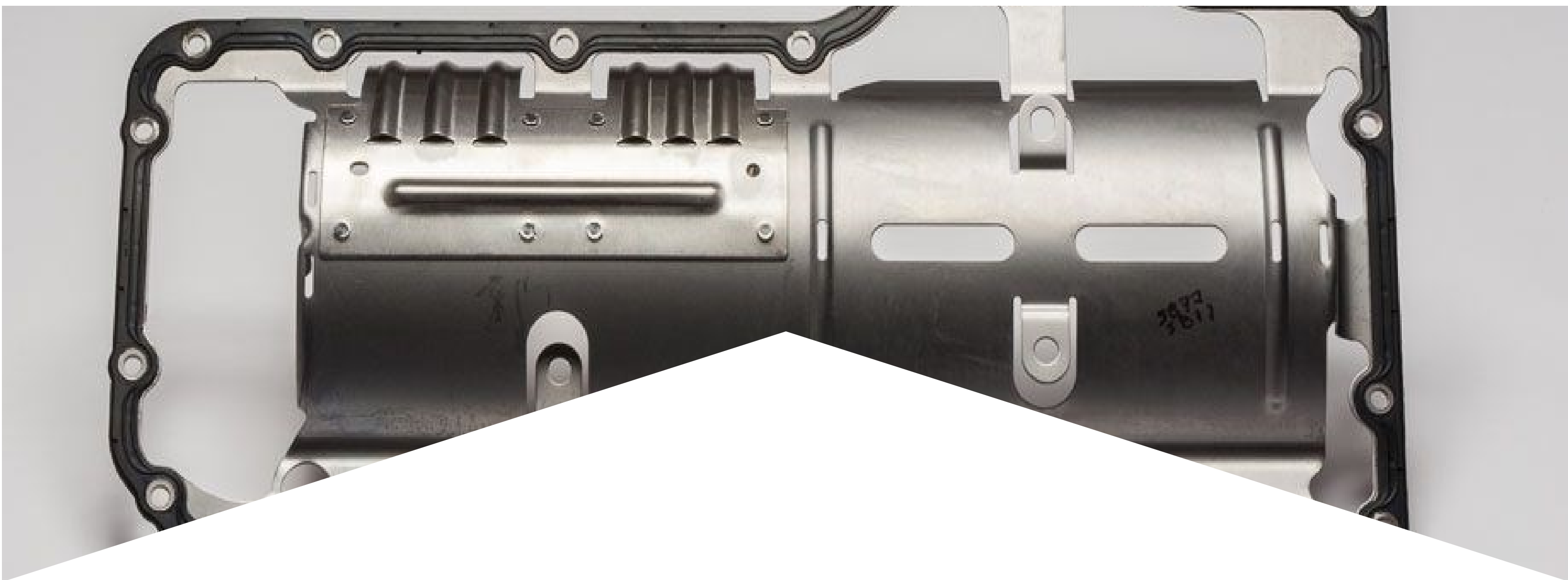



***Figure 2: Edge Bonded Carrier Seal and Circular PIP Seal***

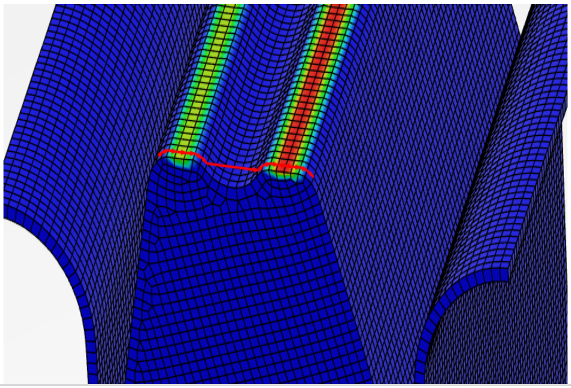
By taking the contact pressure results at each node on the surface, a contact pressure plot can be created, like below. In this PIP seal example, the design was required to have 1mm of contact width that is above 1.5MPa, which allows a maximum of 0.24mm of deflection. The LMC with 0.57mm of mating part deflection did not meet the requirements.

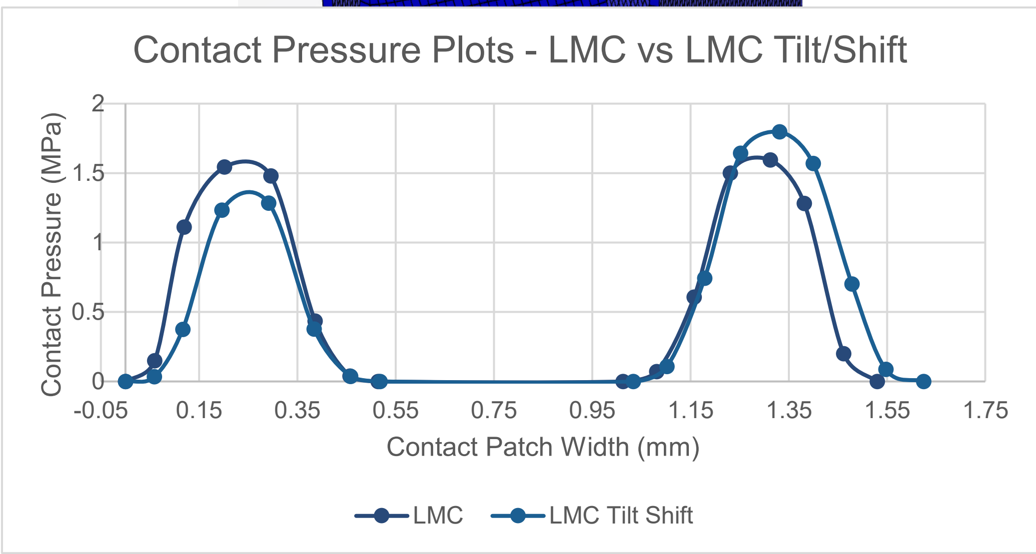




## LMC WITH ASSEMBLY OFFSET

For PIP seals with long and straight sections, it may be necessary to run a shifted assembly analysis to mimic an incorrectly installed gasket/pan assembly. This is completed by partially compressing the seal, shifting one of the mating surfaces sideways slightly, then completing the compression. This analysis looks at both the contact pressure profile and the overall seal shape, making sure that the seal does not fold over within the groove during the shift. An example below shows both the non-shifted and shifted contact pressure profile results on a PIP gasket.





## LMC IN PRESSURIZED SYSTEMS

Applications with internal pressure will also need to be analyzed under pressure. For some OEMs, this can be checked with a nominally sized gasket in an LMC groove and stack up, but others may require a fully LMC assembly. For this, we're looking for not only the contact pressure profile but also the overall shape of the gasket within the groove. Since it is difficult to accurately apply internal pressure to a volume within an FEA simulation without including fluid analysis, we instead apply the pressure to the internal faces of the seal. Therefore, we are looking for stability and lack of movement from the seal after pressure is applied. If movement is happening, then that means that the force of friction isn't enough to hold the seal in place, and therefore probably is not high enough to hold the internal fluid inside.

An example is shown below, at two different compression amounts before applying pressure. The first photos are at a higher compression, which holds the seal in place without any shifting. The second set of photos is at a lower compression, in which the force of friction is no longer high enough to hold the seal in place, and therefore not likely to hold pressure.

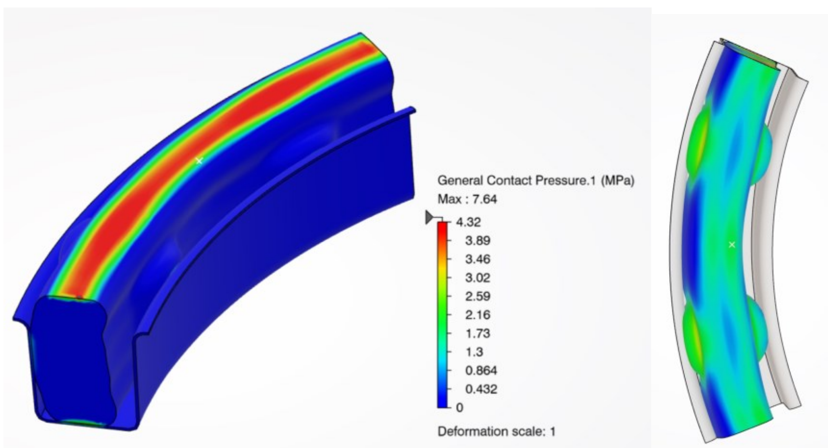



*Figure 3: High Compression with Internal Pressure*

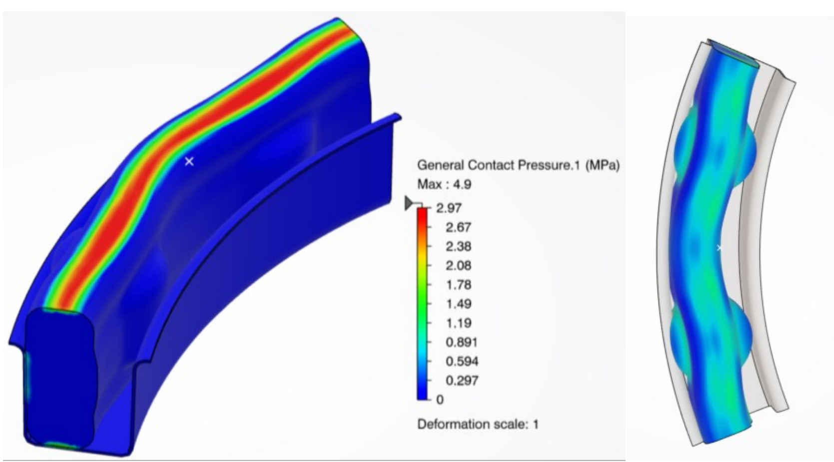



*Figure 4: Low Compression with Internal Pressure*

## LMC ON CIRCULAR SEALS

For circular (i.e. wire) seals, we look at the ID and the OD beads separately for peak contact pressures. Unlike the other seal types, the contact pressures on circular seal beads are largely determined by the difference in diameter between the mating surface and the bead. Because of this, the ID and OD results can be somewhat independent of each other.

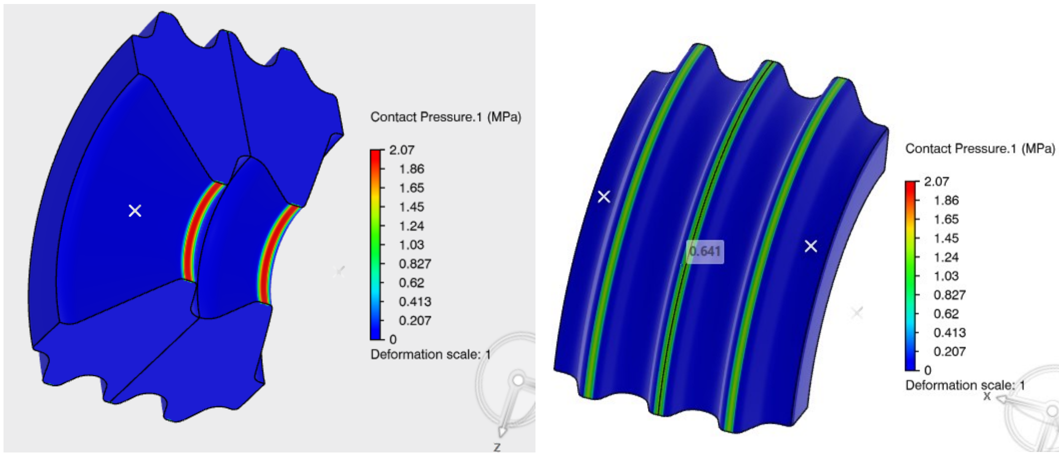
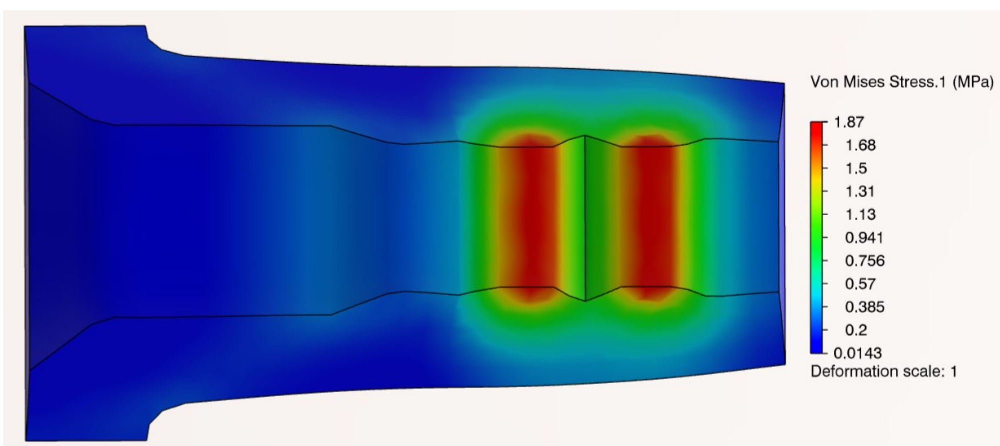



*Figure 5: ID and OD Contact Pressure on a Single Wire Seal*

The wire seal "boot" below is a good example of this phenomenon, where the beads are stretched over the wire on the inner diameter of the seal. No mating surface is required on the outer diameter to still meet the contact pressure requirements on the ID.



# MMC RESULTS

While LMC analyses require careful meshing to guarantee accurate contact pressure results, MMC analyses allow for more lenient meshing techniques, such as more course meshes or tet elements. However, due to the high deformation/elongation that elastomers can handle, MMC analyses can have stability, energy, and volumetric compression issues that can increase solve time, or cause failures of the analysis altogether. The right blend of meshing techniques, solver type, and modeling is needed for accurate and efficient FEA analyses.

As with the LMC results, different types of seals will have peak stresses and strains at different locations. For carrier bonded parts, the adhesion of the elastomer to the carrier decreases the strains and stresses near those surfaces and transmits the strains towards the center of the seal. A face seal, on the other hand, is allowed to shift, and the peak stresses tend to be closer to the outer edges.

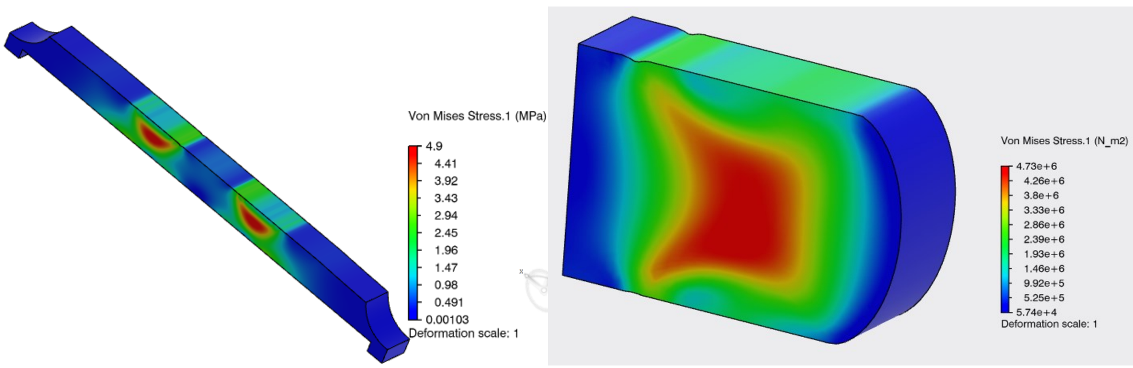



***Figure 6: Overmolded Carrier Seal and Edge Bonded Carrier Seal***

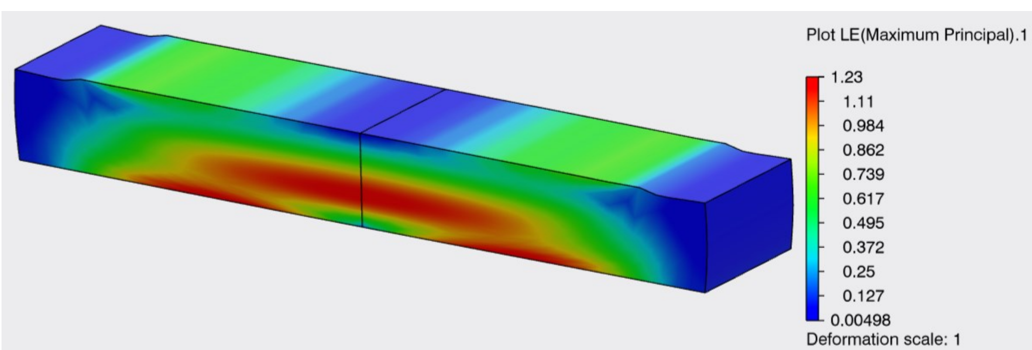
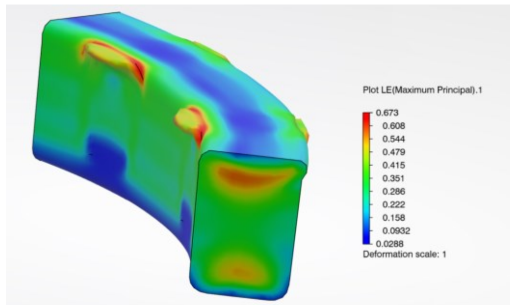
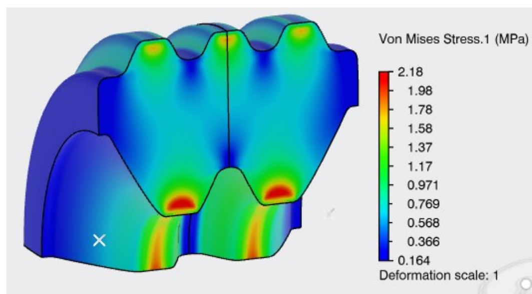



***Figure 7: Face Seal***

With PIP gaskets, high volumetric compression is very typical at MMC, which causes extreme distortions in certain areas. The example below shows the stabilizers being pushed up to the groove opening. The stresses and strains should be closely monitored in these locations in the analysis, as they are the most likely locations to cause issues.

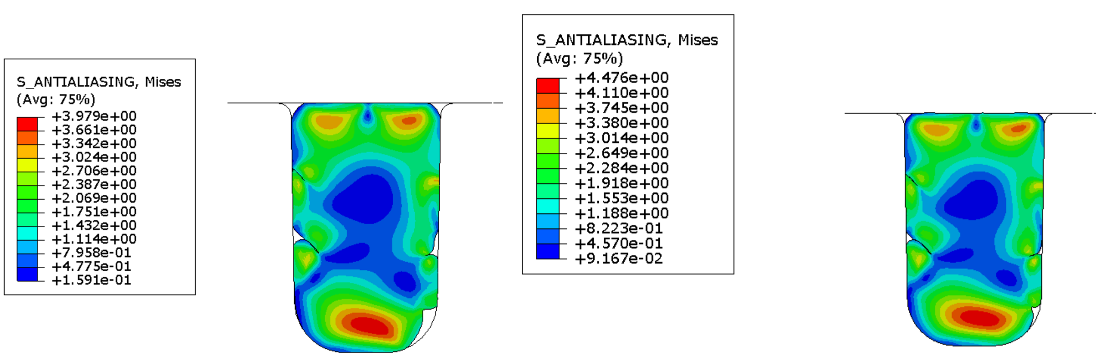



Lastly, wire and circular seals will have high stresses near the beads. Much like the contact pressure results in the LMC analyses, circular seals also have the most “stretch” or “compression” just inside of the beads.




## APPLICATION TEMPERATURE

For applications under high temperatures, an additional thermal step should be added to the analysis to determine the max stresses, strains, and increased loading forces. For face and carrier seals, only the elastomer needs to have the coefficient of thermal expansion (CTE) applied. For PIP seals installed into composite (plastic) parts, the groove will also expand due to heat.  In that case, the difference in CTE between the plastic and rubber materials is calculated and applied just to the gasket, which simplifies the complexity of the analysis. An example below shows the increase in volumetric compression going from 23C to 150C on a PIP gasket.

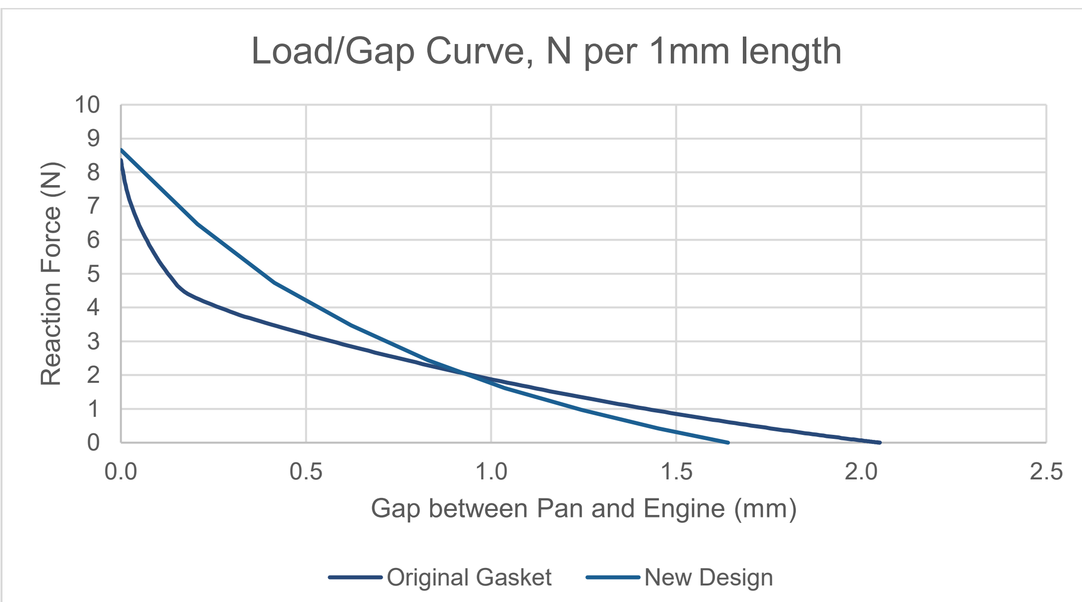


## LOAD/DEFLECTION CURVES

For many seals, especially large seals installed into large plastic components, the reaction forces of the MMC assembly may need to be recorded. Depending on the assembly, these force curves can be used for running the deflection analysis on the mating parts to anticipate the deflection caused by heat and age over time.

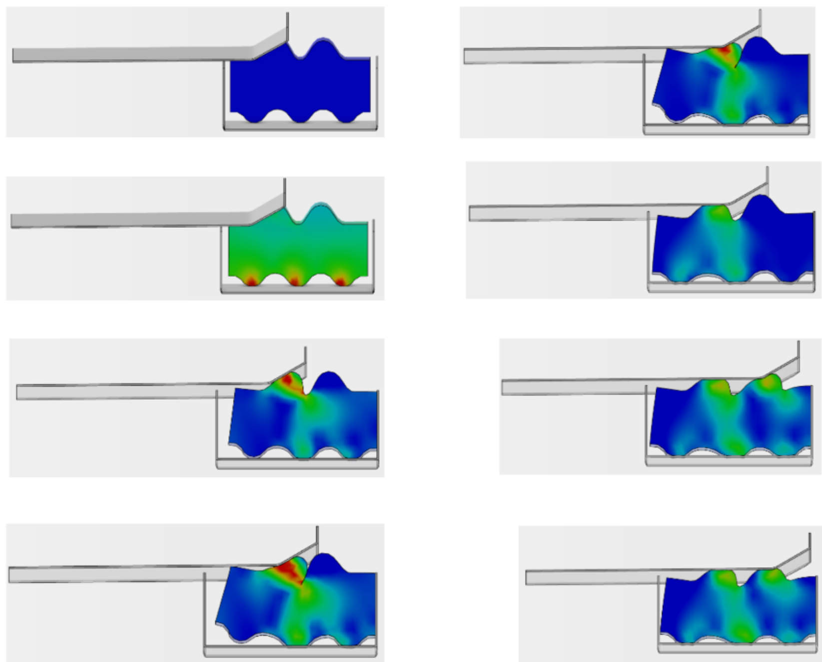
Differences in the design of the seal will change the shape of the curve and may change the overall deflection applied to the mating part. This is especially true for PIP seal designs, where changes in the amount of volumetric compression can affect the loading profile.

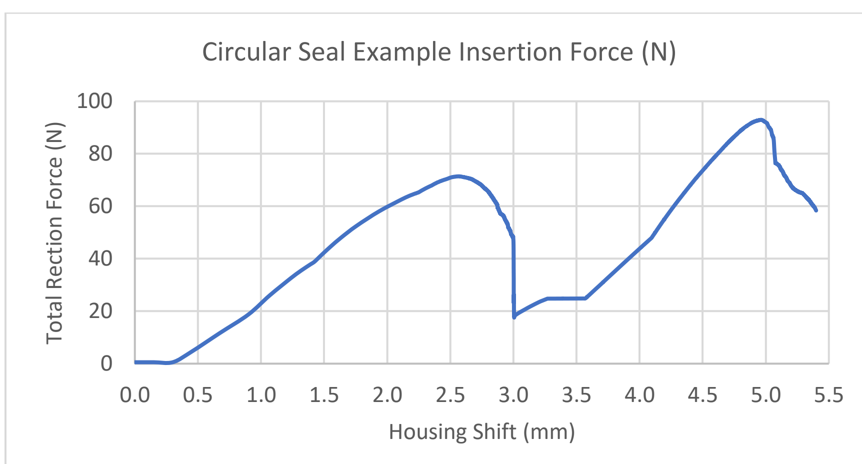
The graph below is an example involving a changeover from one style of PIP gasket to another. The original gasket was taller, and had more volumetric compression, while the new shorter design had a higher rate of force overall, but had lower volumetric compression. The old design had a sharp increase in the rate of force once below 0.15mm of gap due to the seal taking up 95% of the groove volume. By reducing the height, and therefore the overall volume, the newer design has a fairly linear curve and reduced volumetric compression.



## INSERTION FORCES

For assemblies in which seals are inserted manually, it may be necessary to check the amount of force required to insert the seal into the assembly. Dynamic analyses such as these require the use of advanced solvers (Implicit Dynamic, Explicit, etc) and tend to be very computationally expensive to complete. The use of symmetry will help in many cases, if possible, to reduce the number of nodes in the assembly to a reasonable amount. An example is shown below of a check at the MMC case on a circular seal, and the resulting insertion force profile when inserted into the assembly.





## RETENTION FEATURE FORCES

On PIP gaskets, it is common to use retention features, which are designed with interference to the groove at LMC, and are to hold the seal in place during handling. There are two methods for retention features commonly used: retention posts and continuous feature.

A continuous feature (CF) design has a continuous cross-section along the entire length of the seal. These will have a rib on both sides that are in slight interference with the groove. Typically, these require a non-symmetric design, and can only be inserted in one direction.

A “post” design has a continuous main section with vertical posts of retention features (interference at LMC) and stabilizers (clearance at LMC) at specified intervals. A single retention post should be able to hold the weight of the seal on either side of it. For example, a design with a retention post every 50mm of length must have enough retention force to hold 50mm of seal weight. Since they are just a post, these designs can be inserted in either direction and still hold against the angled sidewall of the groove.

The example below shows how these two designs have similar overall retention forces for the same length of gasket.

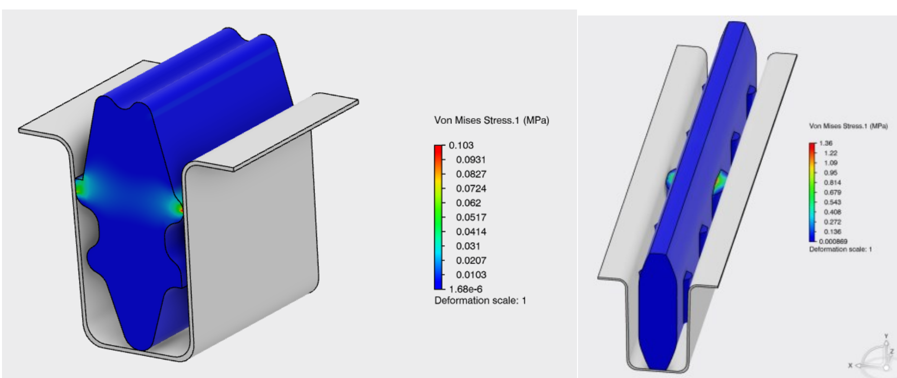
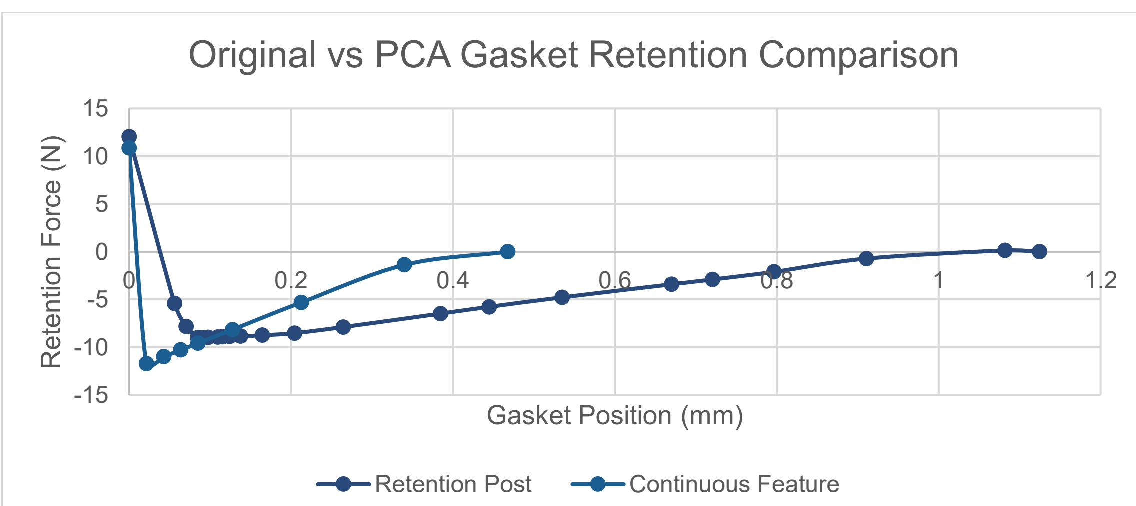
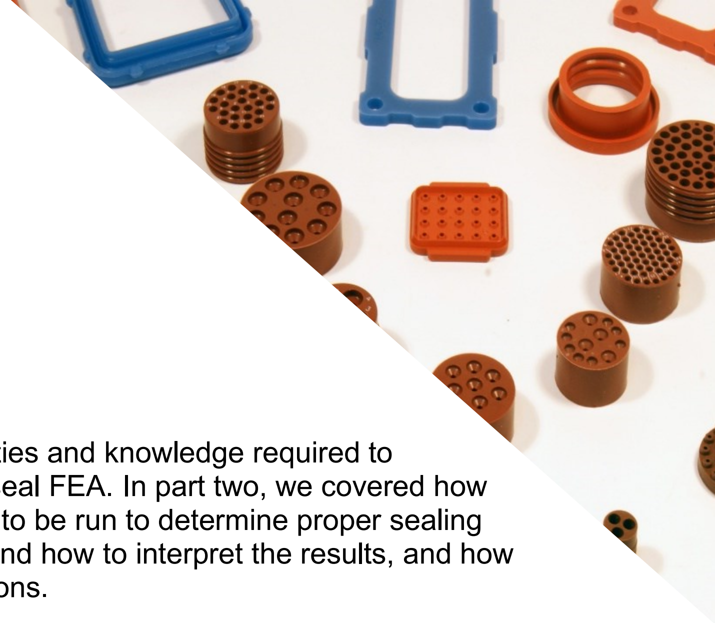



***Figure 8: Continuous Feature (CF) vs Post Designs***





## CONCLUSION

In part one, we reviewed the material properties and knowledge required to understand what’s necessary for elastomer seal FEA. In part two, we covered how FEA is run, and what kind of scenarios need to be run to determine proper sealing performance. In this paper, we now understand how to interpret the results, and how those results correlate to real-world applications.

Putting all of this together allows an engineering team to be confident in the results of the seal design, and reduces the need for additional real-life testing. Periodic comparisons of manufactured parts to a matching FEA test are encouraged to determine if there are any unknowns in the setup, design, or properties.

At Morgan Polymer Seals, our technical experts understand the complexities of developing, testing, designing, and manufacturing with elastomers. Since 1997, we have manufactured quality rubber products for OEMs like Ford, Stellantis, and GM, delivered across the globe from our manufacturing sites in Baja California, Mexico.

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