

O-Ring Elastomeric Analysis

O-Ring Analysis Using Advanced Elastomeric Material Laws with LS-DYNA

The analysis of O-rings has historically been difficult since the modeling process involves large displacement and large nonlinear strains couple to multi-body contact between the O-ring, its gland cavity and the mating part. In our prior engineering services work, we would have to run the model in explicit mode and just live with the long run times even through the model was axisymmetric. In the last couple of years, the implicit capabilities of LS-DYNA have significantly grown and we can now run such models much faster and with no inertia effects.

In this case study note, we'll cover four different O-ring simulations that we have done as LS-DYNA consulting services projects. Each project presents a different type of challenge using different material models and element types from 2-D plane strain to axisymmetric. Figure 1 provides a snapshot of the four models discussed in this note.

Representative O-Ring Elastomeric Analyses

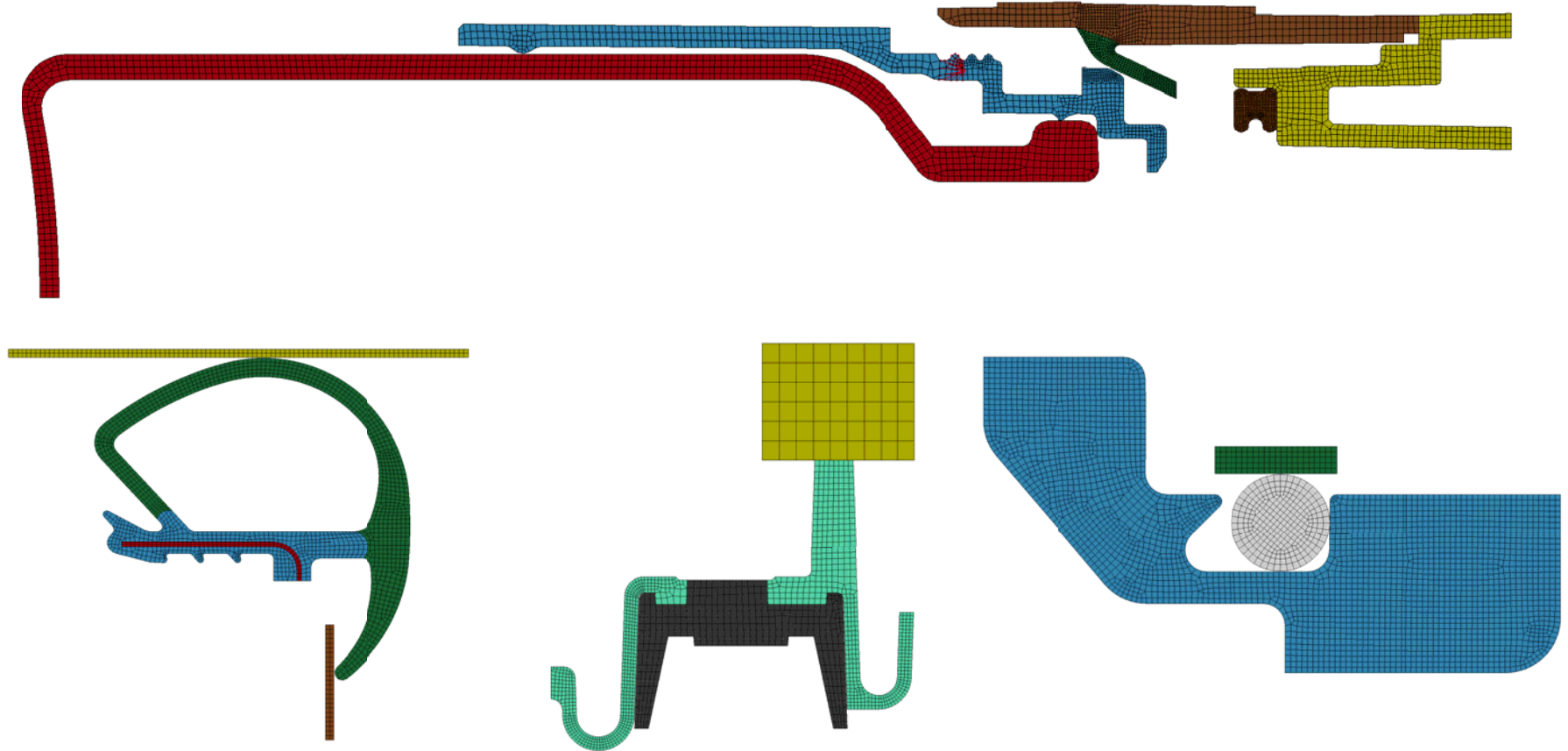


Figure 1: Different O-Ring simulations from 2-D to Axisymmetric

Idealization of Elastomeric Materials into Constitutive Stress v Strain Relationships

MOONEY-RIVLIN (*MAT_27) TO SIMPLIFIED RUBBER/FOAM (*MAT_181)

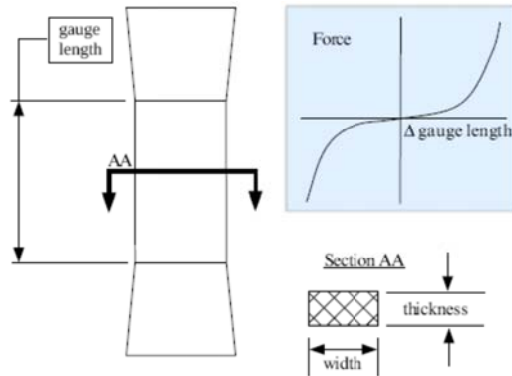


Figure M27-1. Uniaxial specimen for experimental data

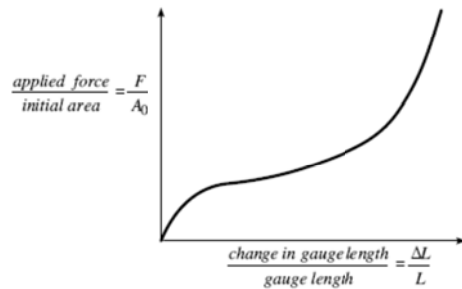


Figure 2: Classic Mooney-Rivlin idealization to the more accurate exact stress-strain formulation of *MAT_181

Classic rubber models use a polynomial approach to fitting the elastomeric material's stress strain response. This often ends up as a two polynomial model (Mooney-Rivlin) and for the most part gets the job done; however the tensile and compressive behaviors are equal. A more sophisticated approach is that done by Du Bois and Benson where the material's engineering stress and strain response from compression to tension is used to directly derive the elastomer's constitutive true stress-strain behavior in an exact mathematical model (not a curve fit).

O-Ring Modeling with Elastomeric Materials

MEDICAL DEVICE HIGH-PRESSURE O-RING SEAL

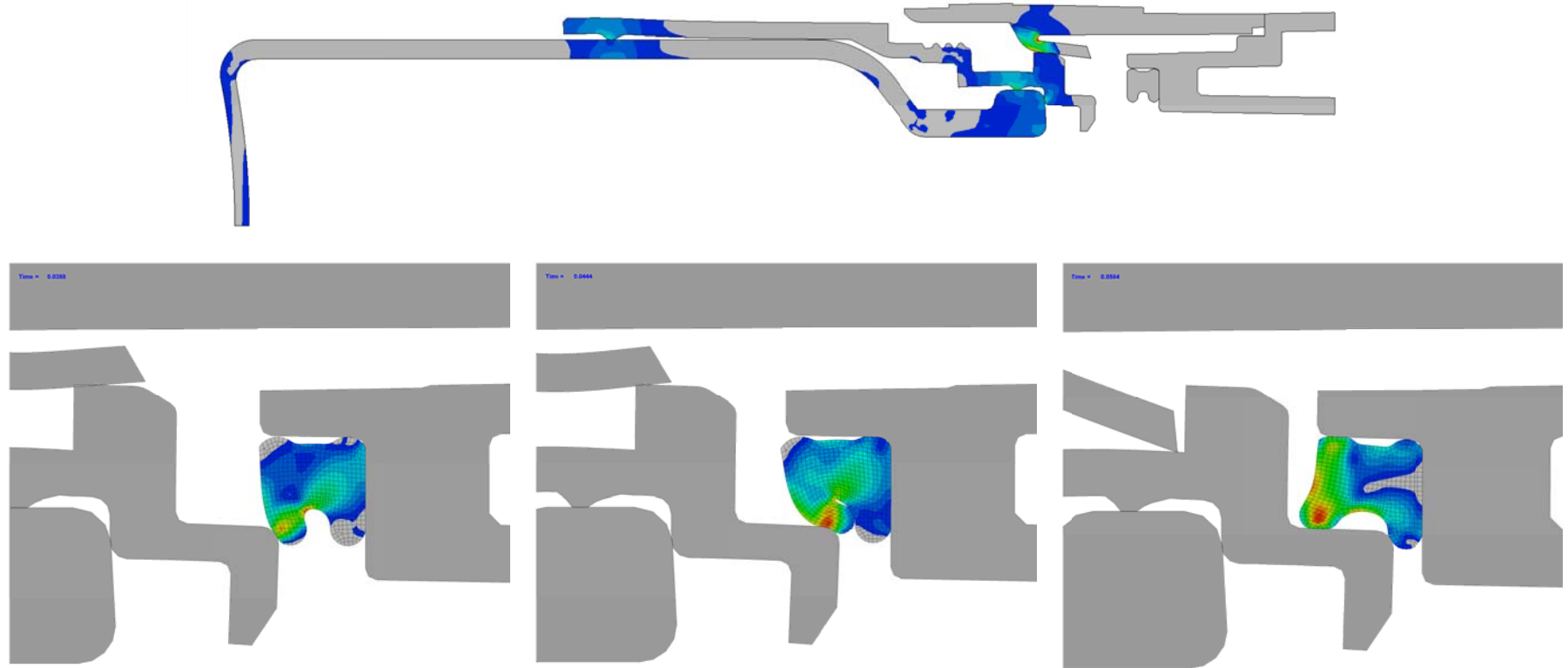


Figure 3: Snap-through followed by high-pressure O-ring sealing

This model was of a high-pressure medical device that required a 3x sealing margin prior to manufacturing. The FEA simulation was validated against test and shown to correlation well. The trick was to ensure that the bounce-back from the snap-fit closure would still provide sufficient force on the O-ring to prevent leakage. The axisymmetric model used materials laws representing polystyrene and silicone rubber.

O-Ring Modeling with Elastomeric Materials and CTE Expansion

HIGH-VACUUM ELECTRONICS INDUSTRY O-RING SEALING WITH CTE EXPANSION

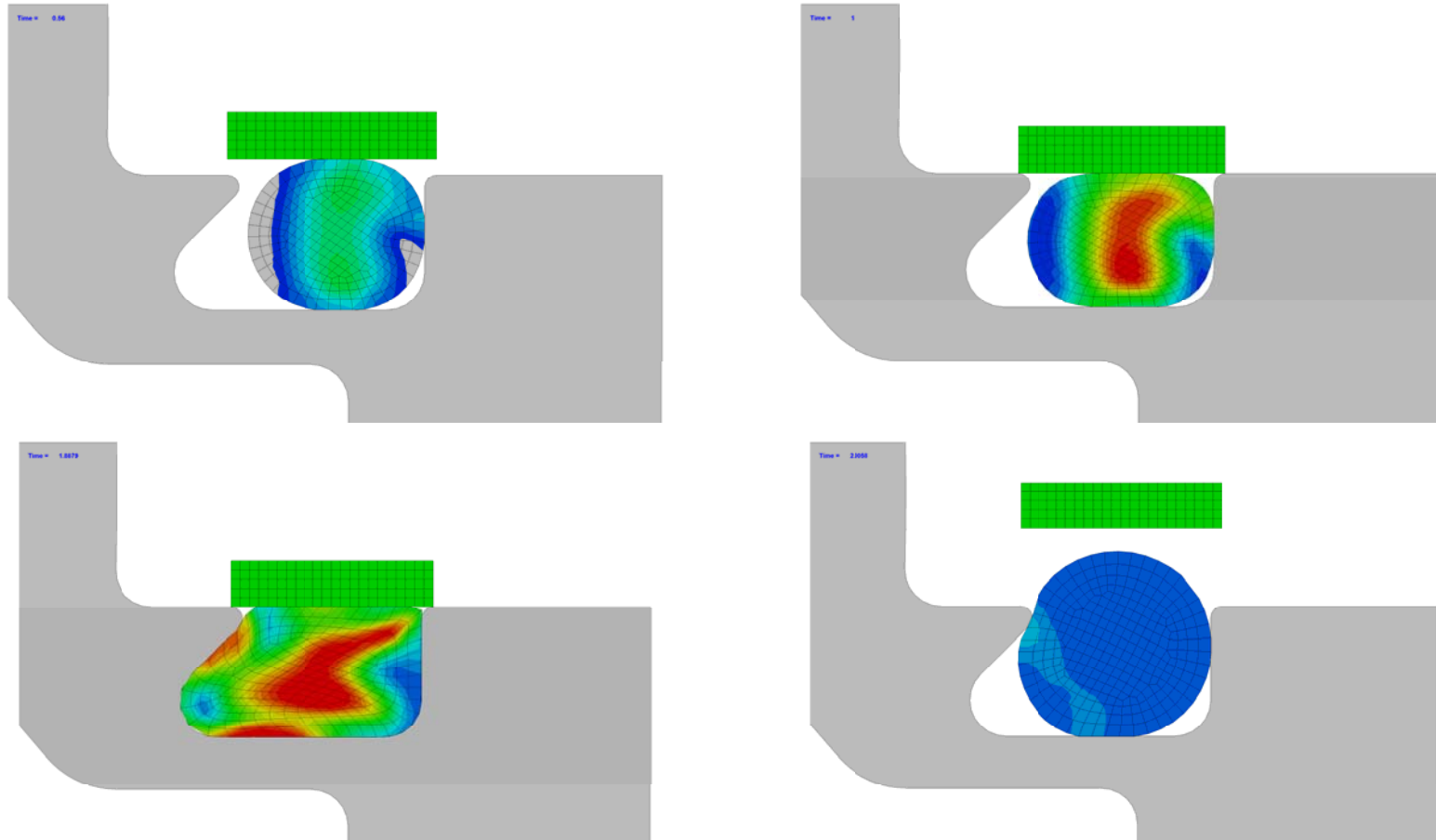


Figure 4: O-Ring compression following by CTE expansion to release of clamp (spring-back)

This was a standard O-ring analysis with a platen (simulated matching flange) pushing down on the O-ring. At room temperature, the O-ring seals adequately and works as design. As the device is heated to cure sub-components of the structure, the O-ring expands and completely fills up the gland space. Since rubber is incompressible, the constrained expansion creates sufficient forces that it bursts open the flange. The material model for this work was *MAT_181 coupled with thermal expansion. Results were correlated to prior experimental work.

O-Ring Modeling with Elastomeric Materials to Crush Load and Failure

CRUSHING OF ELASTOMERIC O-RINGS SEALS AND HIGH-HARDNESS RUBBER LATCHING MECHANISM

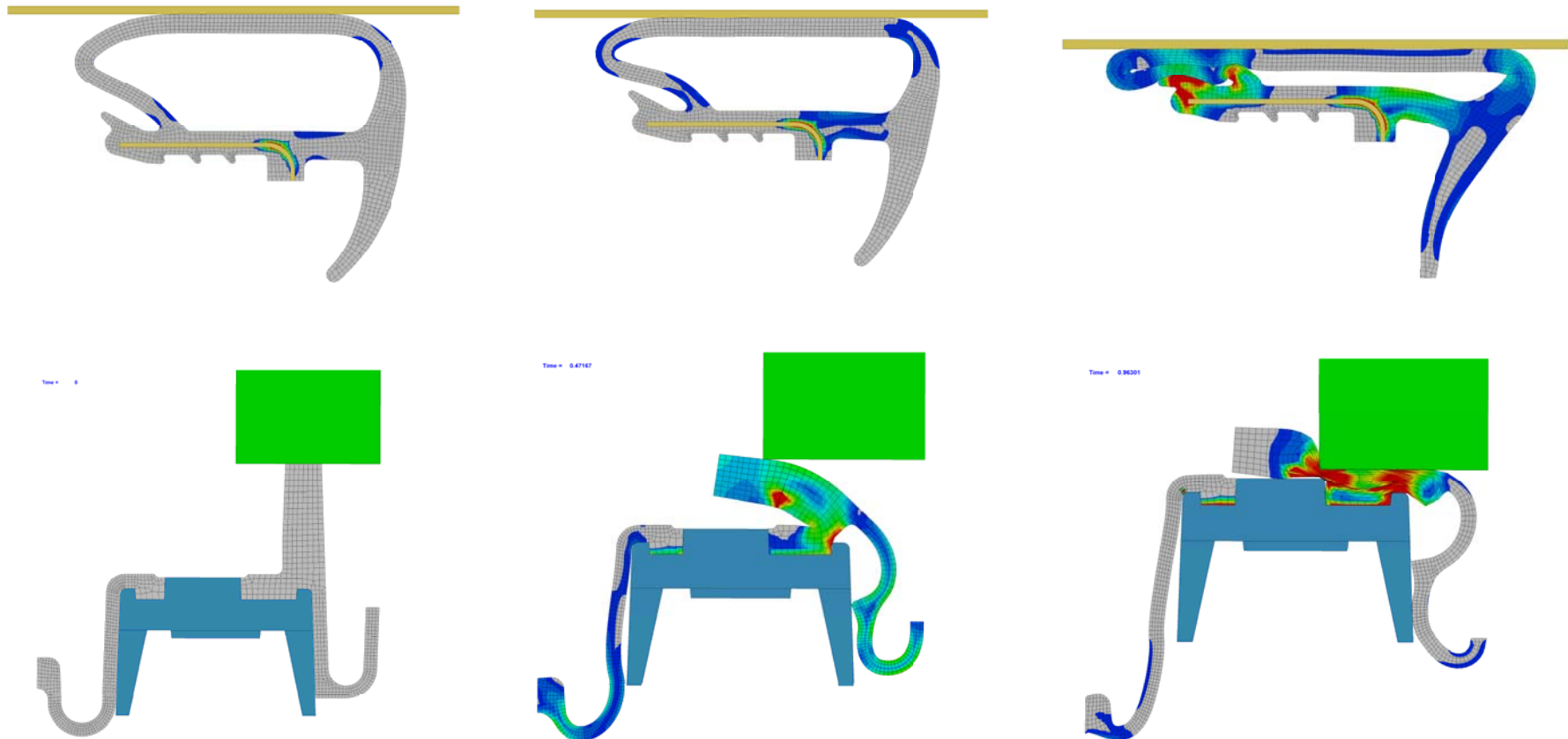


Figure 5: Open O-Ring seal compaction and high-stiffness rubber latch mechanism crush to failure simulation

One of the key utilities of elastomeric materials is their ability to withstand high crushing loads and then spring back to their original shapes. They might be considered the first “superplastic shape memory alloy”. In these simulations, the work was benchmarked against a standard nonlinear elastomeric code using a Mooney-Rivlin material model and then moved forward to a more complex formulation. The last simulation was used to determine the crush load response of a hard rubber in an automotive gear shifting mechanism.