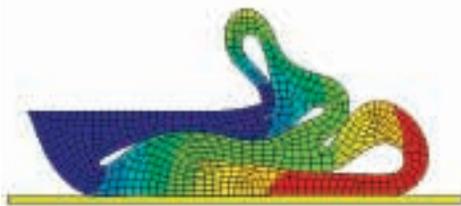


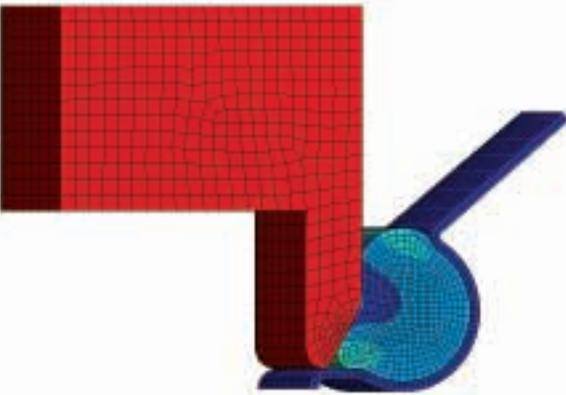
Stretching Your Elastomer Understanding

Accurate nonlinear analysis leads to a better material selection process that enables innovation and faster time to market.

By Siddharth Shah, Product Manager, ANSYS, Inc.



Large deformation analysis of an elastomeric-based automotive door seal



3-D analysis of an O-ring elastomer seal employed in a valve cavity

Elastomers, or rubbers, are a category of engineering materials that are used in many critical applications and have properties that are very distinct from commonly occurring solid materials. They exhibit a highly elastic nature, allowing them to be stretched to many times their original length and, upon release, quickly return to their original shape. This ability to significantly deform and, as a result, conform between complex adjacent surfaces makes them very attractive for use in seals, sealants, gaskets and shock-absorbing applications.

For a good seal, the elastomeric part needs to maintain sufficient pressure against the sealing surface so that a leak is prevented. Since they are often expected to function at extreme conditions, it is critical to determine whether sufficient pressure can be maintained.

Elastomers have the following characteristics:

- Ability to undergo large deformations and sustain strains in the range of 500 percent
- Highly nonlinear load-displacement or stress-strain relationship
- Nearly or fully incompressible — can undergo very little volumetric change under stress or cannot be compressed significantly under load
- Exhibit high energy absorption under cyclically varying load, providing excellent damping properties
- Highly dependent on temperature, operating frequency and duration of use

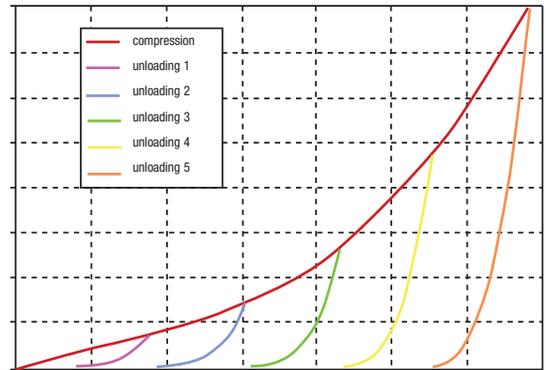
Elastomers have a wide range of applications and come in an even wider range of material types. Diverse and often conflicting design requirements make material specifications difficult. Selecting a material is often a complex process, with the final choice dependent on a series of trade-offs and intangible factors. A material is often selected based on familiarity and experience that takes years to develop. As a

Hyperelastic
Neo-Hookean
Mooney-Rivlin
Polynomial
Ogden
Arruda-Boyce
Gent
Yeoh
Ogden (Foam)
Blatz-Ko
Anisotropic
User

Material models available with ANSYS mechanical tools

result, as newer elastomeric materials are made available, a continuous learning process is necessary.

Simulation can help augment the understanding of an elastomer’s performance by providing deep insight that may not be available through physical testing. With software tools, it is possible to study many prototypes rapidly, accelerating the understanding of the material. In this way, engineers are provided with a means to make better material choices and develop a more effective selection process.



Pressure vs. deflection loading curve for a typical gasket material

Simulation

With any finite element analysis, the accuracy of the material properties used is critical. However, because of the highly nonlinear and nearly incompressible attributes of elastomers, their mathematical characterization assumes a central role in ensuring the quality of any analysis. Complex mathematical models, often referred to as hyperelastic material models, are required to accurately describe elastomer behavior under loading conditions.

Most elastomeric specimens need to be tested in a lab to extract their stress–strain behavior. The goal is to acquire the stress–strain curves of the material in the desired operating state and then find the matching material model to mimic that behavior. It is highly recommended that more than one set of test data — such as uniaxial tension, biaxial tension and shear test data — be used to identify the correct model for the material.

ANSYS Mechanical Technology

To fully rely upon a simulation tool for the material selection process, the software needs to be accurate and have an established record of excellent correlation with experimental results. The mechanical suite of software from ANSYS has repeatedly proven to have all of the necessary features to perform quick and accurate simulations of elastomeric components.

In ANSYS software, there is a wide choice of material models backed by robust element technology sufficient to cover all possible combinations of natural and synthetic elastomers. To further enhance accuracy of simulations — such as predicting the damping behavior of elastomers — the hyperelastic material models can be freely combined with any of the viscoelastic material models.

Property Attributes

Error Norm for Fit:

Yeoh 3rd order

Material Constant C10 MPa	0.77062
Material Constant C20 MPa	-0.20633
Material Constant C30 MPa	0.19605
Incompressibility Parameter D1 1/MPa	0.
Incompressibility Parameter D2 1/MPa	0.
Incompressibility Parameter D3 1/MPa	0.

Screenshot of curve fitting setup (top) and samples of uniaxial, biaxial and shear fitted data using the Yeoh 3rd order curve fitting model available in the Engineering Data tool in the ANSYS Workbench platform (bottom)

To aid in identifying the right material model for stress–strain data, software from ANSYS provides a very efficient and lucid curve fitting tool. This tool, available in Prep7 as well as in Engineering Data, can account for much of the experimental stress–strain data of the material under consideration and then quickly compare different material models. The tool then automatically makes available the various mathematical constants that can be used by the material models.

Additionally, it is critical for simulation to account for contact between elastomeric components. Often the components contact themselves as well as adjacent surfaces that are made of materials other than rubber. The robust, automatic, surface–surface contact capability with mechanical software from ANSYS accounts for this nonlinearity. This capability is not only robust, but is automatic, quick and straightforward to use. ■

Cook Compression: World's First Compressor Valve with Elastomeric Elements

Cook Compression designs and manufactures inlet–discharge valves and capacity–control equipment for industrial reciprocating gas compressors in refineries and petrochemical plants. In the industry, they have built a reputation for long life and efficiency. Historically, metals have been the primary material of choice for valve elements. In the early 1970s, Cook Compression pioneered engineered thermoplastics as valve element materials.

Customers continue to demand a longer mean time between failures (MTBF) for their valve elements. This has been the main driving force behind the investigation of alternative materials. Today, Cook Compression is analyzing elastomeric materials for use in reciprocating compressor valves using nonlinear FEA.

A compressor valve must open and close with each stroke of the compressor (300 to 1500 rpm), forming a gas–tight seal when closed and allowing gas to flow through the valve when open. Since elastomeric materials have no strength, applying them in environments in which differential pressures exist is challenging. To make things more complex, these valves also operate at differential pressures that cycle between zero and some value. Since compressor valves are aerodynamic devices, shapes that promote efficient gas flow are desirable in order to reduce pressure losses as well as the load/power on the driver equipment.

Meeting the needs of dynamic differential pressure loading using an aerodynamic shape made from a material with no inherent strength is not an easy task. First, designers model the parts in 3-D with Solid Edge™ software and evaluate them for ease of manufacture. At this stage, designers then conceptualize shapes that promote efficient flow, with consideration of negative parameters relevant to compressor

valve design — such as fixed clearance, ease of repair in the field and the robustness of the design to handle plant process upset conditions.

Once shapes are determined, elastomeric materials are selected on the basis of their mechanical properties and their resistance to chemical attack. Candidates passing this last criterion get evaluated using nonlinear analysis in ANSYS Structural software to provide insight into the deformation and stresses at operating temperature and pressure. Shapes can be adjusted based on the analysis output, and the design evolution continues until a shape is deemed worthy of a field trial.

There are millions of polymers that can be evaluated. Physically testing them all would be costly at best and impossible at worst. Being able to create a systematic method for polymer selection and then having the capability to perform nonlinear FEA provides insight

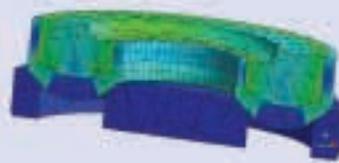
into how the polymer behaves under operating conditions, which in turn provides feedback about how to improve the selection process. In short order, many polymers and polymer families can be eliminated, leaving only the

most promising candidates. Having a reliable simulation model makes analysis fast and accurate.

In the Cook Compression analysis, physical measurements of the prototypes matched the simulation–predicted deflections within 0.002 inches. As a result, the world's only compressor valves with elastomeric valve elements are operating successfully in a number of locations. More work is being conducted to expand the operating envelope, and elastomeric designs are greatly increasing the MTBF with lower valve pressure drops than their thermoplastic and metal counterparts.



Cook Compression manufactures complete compressor valve assemblies such as this one.



Deformation contours for the prototype compressor valve

“The nonlinear capability of ANSYS Structural software has proven to be an invaluable tool in quickly evaluating shapes and elastomeric polymers for use in compressor valves. Time to market is reduced, and the accuracy of the FEA results provides the necessary confidence to spend money on prototype production.”

Kevin Durham, Director of Valve Engineering
Cook Compression