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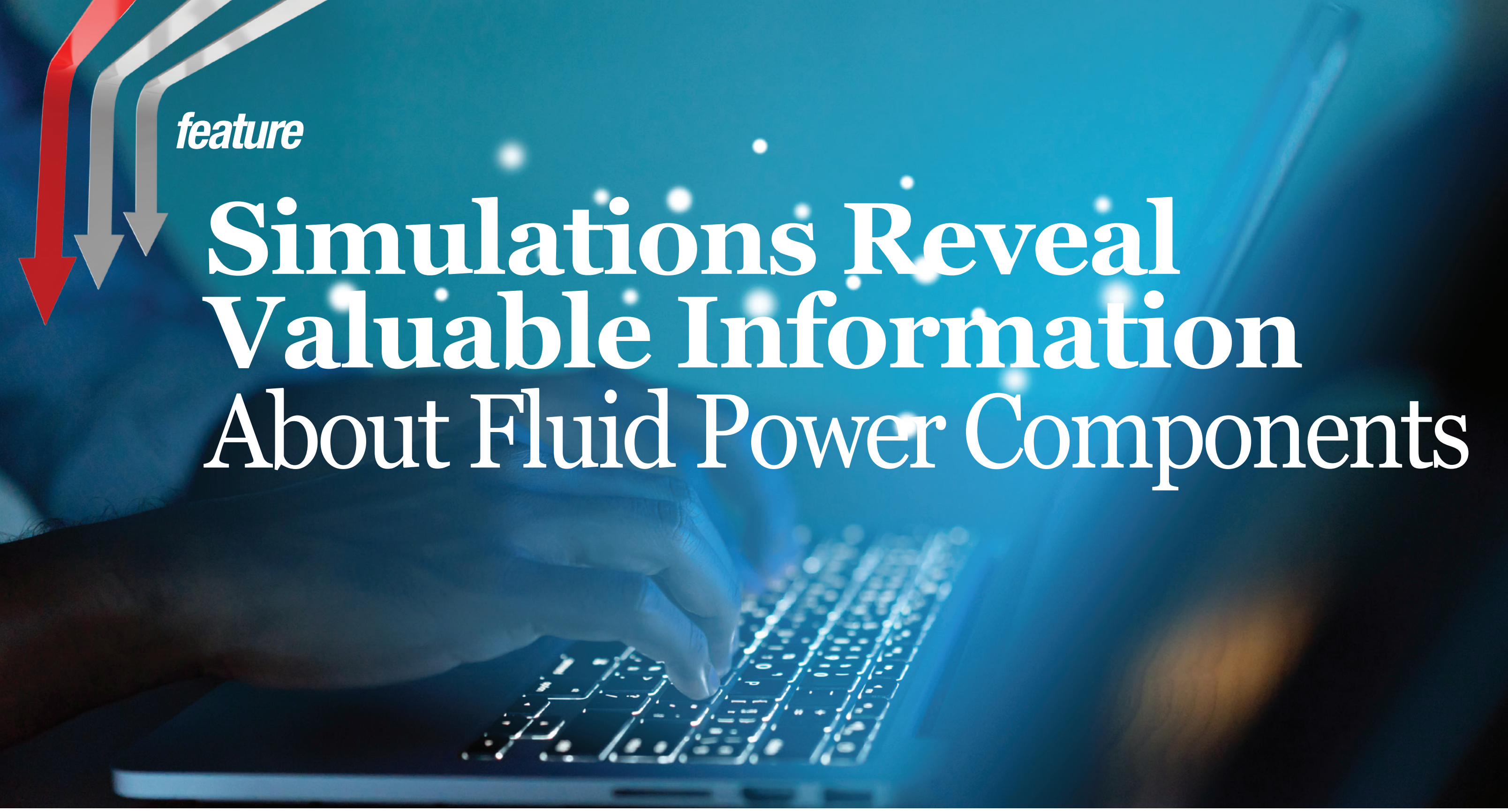
Simulations Reveal Valuable Information About Fluid Power Components



By Alan Astbury, Trelleborg Sealing Solutions

To achieve optimal efficiency, fluid power applications and their sealing components need good friction characteristics and long life to reduce maintenance. Engineering simulations can help original equipment manufacturers (OEMs) succeed in an environment where the demands for efficiency are increasing. Good simulations and the experts to interpret them can result in better sealing and material recommendations, leading to faster prototyping, predictive maintenance, and a more efficient fluid power system.

PREDICTING A SEAL'S LIFETIME

At the start of a project, customers want to know the practicality of a sealing design including how long it will function. Engineering simulations are the most effective way to answer questions about the durability of seals. Testing if a system's component will work is generally easy but understanding how long it will last traditionally requires long-term testing. However, this kind of testing is often impractical. Simulation can ease and cut down time needed to prove a component.

One valuable Finite Element Analysis (FEA) simulation that an OEM's sealing partner can perform looks at the reduction of a seal's contact pressure over time in a system to predict when maintenance will be required. In this simulation, experts determine the compression set a seal will experience under specified loading and temperature conditions. Information gained can be extrapolated over decades in a matter of hours to determine a seal's lifetime.

Additionally, a sealing partner can use a method called non-parametric optimization when designing a seal to see where stress can be reduced on the seal under loading conditions. These techniques and simulations enable sealing manufacturers to design a seal with optimized characteristics and provide guidance to OEMs on how to meet material, temperature, and pressure specifications that will maximize the life of a seal. Being able to predict a seal's lifetime offers a higher return on investment for OEMs because it allows for planned maintenance rather than unplanned line stops or in-field stoppages.

A SIMULATION DOMINO EFFECT

In an industry where efficiency is paramount, a component manufacturer can determine a seal's coefficient of friction through an automated physical testing process. This test data can then be used for many valuable simulations.

One example is the assembling of an O-Ring using automation. The coefficient test data tells the OEM the amount of force needed to assemble the O-Ring and what force profile it will generate.

Friction coefficient data can also accurately determine the amount of torque a rotary seal generates. For linear seals, this data gives insight into the force required to move the seal in an application. Often customers want to know what strength spring or what size motor they would need; friction coefficient data helps them size these components.

FEELING THE HEAT

Heat from friction on a seal is another concern affecting efficiency. This is particularly important in rotary applications where the seal continuously maintains contact with the same region of the shaft.

Using coupled thermal-mechanical analysis simulation, experts can predict the heat generated by a seal from friction and the effect this will have on a seal's performance. Additionally, this analysis can show where different amounts of heat are generated. For example, the heat produced at the seal's edge can be many times greater than the temperature of the surrounding fluid. Making sure the material selected is suitable for the temperature range caused by frictional heat helps ensure long seal life.

In addition, when a seal heats up, it typically becomes softer leading to a different loading profile on the hardware. By analyzing the seal's heat generation and how this changes its mechanical properties, experts can determine the best sealing profile for a given application.

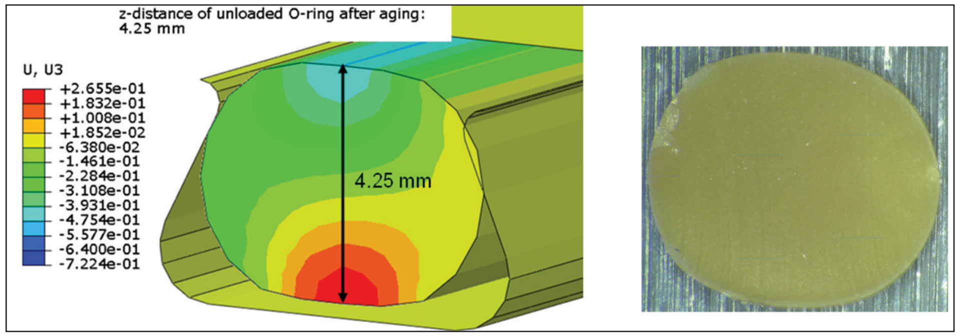
ELASTOMER-SPECIFIC SIMULATIONS

There are two main simulations that offer valuable information for elastomer-specific seal designs: injection molding simulations and non-linear viscoelastic performance simulations.

Using injection molding simulation, experts can analyze the entire manufacturing process of the material including how the material flows into the mold and if it fills all the cavities. It can also determine how much the elastomer will shrink once it is removed from the mold and predict the final shape of the product. To achieve the greatest seal efficiency, experts can optimize temperatures and injection pressures during this simulation.

Non-linear viscoelastic performance simulations measure an elastomer's speed of mechanical response over both long and short durations. Using a dynamic mechanical analyzer set at different temperatures, experts can combine the data produced with standard tensile and compression testing to see how elastomers cope with shock loading conditions in both static and dynamic states. This information can also indicate if a sealing system is likely to leak due to a reduction in the sealing force.

Simulating loading conditions over longer periods helps predict the flow of material into extrusion gaps in the sealing system, the stress relaxation or creep. Knowing this type of information helps component partners recommend the best sealing material.



This figure shows the simulation of a change in a 5.33mm O-Ring cross-section after being in an application for 37 years with a comparison to what it looks like in reality. Figures courtesy of Trelleborg Sealing Solutions.

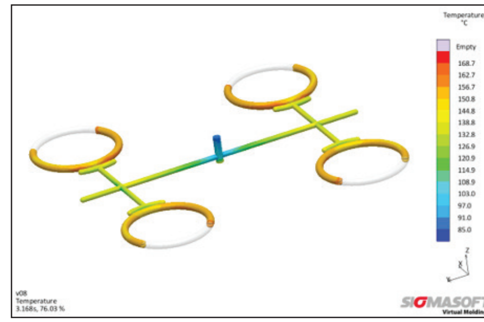
DESIGN AND MATERIAL CONSIDERATIONS

Experts can perform a design of experiment (DOE) that applies a matrix of parameters on a seal under changing conditions. Running the right matrix of simulations based on mathematical methods can determine which parameters have strong, weak, or no effects on a seal.

For example, to control the frictional force generated by a seal on a rod, Trelleborg performed a DOE on a seal and its hardware components. Out of the 19 parameters tested, only four were critical to the frictional force.

This was invaluable information because the customer had a very narrow range in which the seal would work correctly against the hardware. Trelleborg engineers designed a seal with tight tolerances on only the dimensions critical to friction. This contributed to better value for the customer because it left other parts of the seal standard, lowering the overall manufacturing cost. Having more parts designed to standard tolerances also reduced scrap.

When it comes to selecting materials, sealing manufacturers that have proprietary compounds may be able to characterize them using an in-house capillary rheometer. This device measures shear viscosity and other rheological properties and speeds up responsiveness to customers, as materials do not have to be sent away to a third party for testing.



Temperature plots during the injection molding simulation process.

Suppliers that have a capillary rheometer in-house close the loop between simulation and reality, allowing them to revalidate material whenever needed, calibrate material models faster, and if issues arise, reference the full test data on site.

CONCLUSION

In today's world where efficiency is king in fluid power applications, extensive simulations offer payoffs. They enable sealing suppliers to deliver customers high-quality prototypes more quickly and help determine the right solutions – including the critical final choice of material – the first time, expediting overall speed to market.

Alan Astbury is a Simulation Method Developer at Trelleborg Sealing Solutions. He has been with the company for 16 years and has experience in finite element analysis, computational fluid dynamics, and he currently works to develop new simulation techniques. Alan holds a bachelor's degree in mechanical and computer aided engineering and a master's degree in computer aided engineering.