Collaborative engineering programme helps manufacturers optimise hydraulic cylinder sealing systems

Freudenberg-NOK Sealing Technologies is working with its customers to help them reduce the manufactured cost of hydraulic cylinders, whilst optimising the performance and service life of their production equipment.

According to the company – which runs the business operations of Freudenberg Sealing Technologies (FST) in the Americas – large-scale manufacturers, such as those found in the agriculture and construction industries, often find that they are faced with the difficult task of upgrading entire sections of expensive equipment to keep production running smoothly.

Under the Freudenberg Perfect Cylinder Program, experts at the company work with distributors to re-engineer cylinder components for hydraulic systems and pair them with the appropriate sealing technology to maximise system efficiency on existing machines, whilst eliminating the need for costly equipment replacement.

Commenting on the programme, John Plut, Director, Fluid Power Partners, North America, Freudenberg-NOK, said: ‘We are known for our sealing products, but our expertise can reach beyond that to assist our customers in new ways.’

‘With the Freudenberg Perfect Cylinder Program we can substantially reduce cylinder costs by collaborating at the engineering level to help create an enhanced system of cylinders and seals.’

Plut says that once the cylinders have been re-engineered they are be paired with sealing products from Freudenberg’s catalogue of products to create an optimised sealing system that uses high performance seals whilst still saving customers as much as 40% on total material and production expenditures.

The recently launched imperial-sized Guivex® series of guide bands is one of the company’s latest sealing innovations in this technology.

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When you hear the term ‘research and development’ (R&D) it most likely invokes images of test laboratories, research papers and patents as well as feelings of innovation and deduction.

R&D plays a critical part as an investment in technology and future capabilities, which is transformed into new products, processes and services – providing companies the ability to remain competitive and create value for their customers, not only for immediate use, but for long-term sustainability.

The current research environment is fast-paced with the shelf-life of innovations decreasing as a result of competition from China, academic research and start-up companies.

According to PriceWaterhouseCoopers, in 2018 companies such as Amazon, Alphabet Inc and Volkswagen spent the most on innovation and improvements, with funding dedicated to R&D exceeding $15 billion.

Pharmaceutical, semiconductor and software/technology companies generally tend to spend the most on R&D, to maintain extreme growth and meet their consumers’ needs.

Centre stage

Why such a great investment?

One of R&D’s major roles is to assist management in tackling uncertainty, through the power of knowledge, which is why research departments rely on tools and processes that provide the most precise and accurate input.

This is where numerical simulation takes centre stage, especially for design engineering and manufacturing companies such as Saint-Gobain Seals.

Design work for any complicated system usually involves computation with complex geometries and challenging material/interaction behaviour. Because analytical calculations are usually only possible for simple geometries and simple system behaviour, it then becomes essential to apply numerical modelling and simulation for applications where quantitative assessment is required.

The finite element method (FEM) is a numerical technique for solving problems in engineering and mathematical physics. It helps to determine and make possible, calculations that relate to real component geometries. In addition to FEM for geometric resolution, accurate constitutive models that are used to study materials and interactions are essential to accurately simulate real-world systems.

The usefulness of the FE method was first recognised at the start of the 1940s by Richard Courant, a German-American mathematician, who was able to apply it to a range of problems. However, it was not until several decades had passed that the approach was applied generally in fields outside structural mechanics.

Modelling complex material behaviour of rubber and rubber-based components also started in the 1940s, but also did not immediately undergo significant development into simulation software.

This is because of the difficulties associated with non-linearity and computation resource requirements. It is only during the last couple of decades that researchers have started to find solutions to such problems.

The recent development of robust solvers on software platforms and availability of computation resource have helped bring together FEM and advanced material modelling, to make numerical simulation what it is today and have an impact in R&D.

Application areas

Where are simulation processes used?

These days specialised robust solvers on software platforms are growing in popularity and help to realise numerical simulation in technical fields such as solid mechanics, fluid mechanics and chemistry for a variety of applications.
of industries that require precise data in challenging applications, in the aerospace, automotive, marine, and oil and gas sectors, and in life sciences.

Simulation helps engineers to understand component and system behaviour, compute interested design quantities and design components for complex applications that may need to operate under extreme conditions.

These conditions could range from very low temperatures (for example, cryogenic) found in space; very high temperatures in commercial aircraft engines, and in oil and gas subsea drilling equipment; and very high-pressure in oil and gas, industrial and ultra-high performance liquid chromatography (UHPLC) systems.

Saint-Gobain Seals has conducted simulations for a number of projects:

- **space applications**: control valves, feedlines and manholes (Figure 1);
- **aerospace applications**: jet engines and gearboxes (Figure 2);
- **oil and gas applications**: butterfly valves, ball valves, couplers and loading arms (Figure 3);
- **life sciences applications**: UHPLC pump seals and components for respiratory equipment (Figure 4);
- **industrial applications**: swivel joints and compressors (Figure 5); and
- **automotive applications**: piston seal rings and transmission bearings (Figure 6).

**Benefits**

How are simulation processes used to benefit companies and their customers?

In the case of Saint-Gobain Seals, simulation helps in four critical ways, which are summarised below.

- **Customer confidence in products**: accurate simulation reduces repeated testing, which reduces costs for customers and decreases time to market.
- **Design improvements and knowledge base**: accurate simulation has helped the company’s engineers design more effectively with computations and decrease trial-and-error, thus, the iteration cycle. Engineers were also able to better understand system behaviour in order to provide expertise when communicating with customers – displaying their technical leadership in this field.
- **Informed decision-making**: accurate simulation decreases trial-and-error practices, therefore product/material development can be interpreted in a more reliable manner to enable faster selection and direction.
- **Safety**: accurate simulation provides a way to understand safe opportunities and alternatives by looking closely at how certain challenging conditions can affect the performance of a seal or polymer parts in core systems.

**Tools**

What type of simulation tools are used?

In the past, companies relied on trial-and-error methods, simplified analytical calculation, or qualitative/comparative finite element analysis (FEA) of simple systems with simple material and interaction properties. However, today there are better ways to implement accurate computations for unprecedented large complex systems, using several simulation platforms.

Saint-Gobain Seals uses the modelling and simulation package SIMULIA, and multi-physics, cross-platform FEA software COMSOL to handle complex geometries (2D and 3D) and interactions (for example, contact, transportation of chemicals, reaction, friction, wear and adhesion).

Advanced material constitutive models are also developed and used to simulate viscoelastic, plastic, creep, relaxation and large deformation behaviour, which are typical in polymer sealing applications.
The company also conducts many mechanical tests (compression, tension, creep, relaxation for polymer materials under a large range of temperatures) to extract material parameters for accurate quantification.

The types of simulation with which it works covers solid mechanics, including buckling and modal analysis; fluid mechanics; heat transfer; and various combinations (or multi-physics).

### Growth

Through R&D companies can grow by designing new products and improving their existing ones to support customers.

Numerical simulation is just one tool in R&D’s range of resources, which Saint-Gobain Seals has invested in along with increasing laboratory space and skilled research and design engineering team members.

**Recently Published Papers**

- M. Jarray, D. Souchet, A. Fatu and Y. Henry, Priime Institute, University of Poitiers, France: ‘Sealing performance solution by means of a liquid-gas interface tracking approach: Application to viscosseals’, *Tribology International*, Volume 119, March 2018, pages 329–336. In this work, the authors present details of a numerical approach to predict the sealing performance of a viscoseal under laminar regime, by tracking the lubricant–gas interface using a method based on volume of fluid (VOF). The results are compared with experimental data presented by Stair and Hale (W.K. Stair, C.F. Fisher Jr. and L.H. Luttrull in ‘Further experiments on the turbulent viscososeal’, *ASLE Trans*, 13 (1970), pp. 311–317). Special care is given to the lubricant–gas interface advection, where a compressive second-order interface reconstruction scheme is used to produce a sharp interface. The computational time is reduced considerably by using a coupled pressure–velocity algorithm, employing a pseudo-transient under-relaxation scheme and by imposing a periodic boundary condition, based on the viscoseal geometry. Whilst – to the authors’ knowledge, this is the first time that this approach is being used to predict the sealing performance of the viscoseal, this interface tracking technique shows a high accuracy across the range of tested parameters.

- F. Cangioli, S. Chatterton, P. Pennacchi, Politecnico di Milano, Milan, Italy; L. Nettis, Baker Hughes, a GE Company, Florence, Italy; and L. Ciuchicchi, Baker Hughes, a GE Company, Le Creusot, France: ‘Thermo-elasto bulk-flow model for labyrinth seals in steam turbines’, *Tribology International*, Volume 119, March 2018, pages 359–371. Over the last few decades, the increasing demand on efficiency and performance for steam turbines has resulted in OEMs operating machines near the critical conditions of their structural and thermal capabilities. This paper introduces a new thermo-elasto bulk-flow model for labyrinth seals. It includes the bulk-flow model for estimating the dynamic coefficients, heat-transfer model for evaluating the temperature distribution in the rotating and stationary parts, and a structural-mechanics model for calculating the radial growth. By considering a staggered labyrinth seal – installed in the balancing drum of a steam turbine – different operating conditions, such as the boundary pressure, rotational speed and inlet pre-swirl ratio and the stability of the seal are investigated in this study.

- Y. Hu, X. Menga and Y. Xie, State Key Laboratory of Mechanical System and Vibration, Shanghai Jiaotong University, Shanghai, China (and School of Mechanical Engineering, Shanghai Jiaotong University): ‘A new efficient flow continuity lubrication model for the piston ring–pack with consideration of oil storage of the cross-hatched texture’, *Tribology International*, Volume 119, March 2018, pages 443–463. In this paper, a new efficient flow continuity lubrication model for the piston ring–pack is established by taking the oil storage of the cross-hatched texture into account. To fully consider the influence of the cross-hatched texture and plateau roughness on lubrication and oil transport, a two-dimensional two-scale mass-conserving homogenised mixed lubrication model is developed. To solve this model efficiently, the recently proposed Fischer–Burmeister–Newton–Schur (FBNS) algorithm is adopted. The oil available to lubricate each ring is determined by conducting oil transport analysis. The trapped oil in the texture is calculated as an “extra oil supply” to the inlet of the contact. The developed model has great potential in aiding understanding and optimisation of the honed cylinder-liner surface, say the researchers.

- N. Morris, M. Mohammadpour, R. Rahmani, P.M. Johns-Rahnejat and H. Rahnejat, Wolfson School of Mechanical,