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Summaries

I- Session 1: Introduction Lectures

I 01

Matthias Kröger, Robert Teichert, Yongzhen Lin**,** Technische Universität Freiberg, Freiberg, Germany

Scaling of radial seals

Standard seals are required in almost all conceivable machine solutions for common nominal diameters. A common practice here is to transfer an initial original design of one diameter to a large number of other diameters. In this way, the seal manufacturers can implement an adapted scaling of the series, which ensures the safe function of the individual size.

This work investigates radial shaft seals in three dimensions to check the different designs. Differences in the contact size and the radial load are observed. On the experimental side, oil and grease lubrication has been investigated. For the investigated seal type differences in the friction characteristic are observed.

I 02

Matthias Graf, Thomas Ebel, Tobias Lankenau, Kathrin Ottink, Hochschule Emden/Leer, Emden, Germany

Towards additively manufactured dynamic rod seals

In a recently started DFG-funded research project, the suitability of additive manufacturing methods and materials for the production of dynamic rod seals is investigated. Initially, a range of methods was defined, which shall be considered in the next phases of the project. For one of those methods, Fused Filament Fabrication (FFF), commercially available TPU-materials were analyzed. A set of potential materials has been defined and analyzed with respect to different criteria.

These criteria comprise the processability, the static stiffness of the material, and the tribological properties.In a systematic process, the capability of the materials has been evaluated and compared with a commercially available reference sealing material to find the most promising approaches. With these findings, a fully coupled FSI (fluid-structure interaction) simulation model was de-veloped and parametrized to predict the behavior of 3D-printed seals under working conditions.

A- Session 2: Alternative Energy

A 01

Anna Berger, Andreas Mierzwa, Frenzelit GmbH, Bad Berneck, Germany

Sealing Solutions for Hydrogen Applications

The effect of climate change on humans and nature is leading to an increased importance of alternative sustainable energy sources that create lower emissions. Hydrogen is an essential element of the transition to renewable energy, due to the possibility of "green" production and the many diverse application possibilities.

However, Hydrogen is an extremely challenging medium, which requires efficient sealing solutions. Currently, there are hardly any official norms, approvals or confirmations for gaskets in hydrogen applications available. As the number of hydrogen applications is increasing rapidly, gasket specialist Frenzelit has developed a test procedure, to prove the suitability of Frenzelit gasket materials for hydrogen applications.

A 02

Lucian Pasieka, Agim Gashi, Eugen Seitz AG, Wetzikon, Switzerland

Static seals for hydrogen at high pressure

A 03

Marius Hofmeister, Alea Frische, Mathias Grunewald, Manuel Reddemann, Carolin Grütering, Lars M. Blank, Reinhold Kneer, Katharina Schmitz, Instiute for Fluid Power Drives and Systems, Aachen, Germany

Tribological properties of PTFE sealing materials with regard to bio-hybrid fuels

Bio-hybrid fuels are carbon-neutral and can be produced based on sustainable raw material sources. Therefore, they represent a promising alternative to conventional fuels. However, the use of bio-hybrid fuels in automotive systems is challenging due to deviating fluid properties compared to conventional fuels. This applies especially to the compatibility of bio-hybrid fuels and sealing materials used in the automotive industry.

One reliable way to prevent failure of seals is the use of PTFE materials, which, in turn, introduces new tribological challenges. For this reason, this contribution focuses on these challenges for radial shaft seals, which arise from the special characteristics of PTFE materials and bio-hybrid fuels.

A- Session 3: Rotary Shaft Seals I

A 04

Susanne Hahn, Simon Feldmeth, Frank Bauer, University of Stuttgart, Institute of Machine Components (IMA), Stuttgart, Germany

On the prediction of the lubrication condition of grease sealing rotary shaft seals

The so called "tear-in" tests were developed to evaluate a correlation between the tear-in of a grease dam in a tribological system and the lubricity of the grease. They were carried out with a rheometer as equivalent system and 23 greases. The grease sample was sheared in the gap between a rotating and a stationary plate with a linearly increasing shear rate. The motion of the grease within this gap was observed optically with a high-speed camera. In addition, the shear stress was measured and evaluated. The results of the tear-in tests correlate well with functional tests using a rotary shaft sealing system.

A 05

Tim Schollmayer, Stefan Thielen, Bernd Sauer, Oliver Koch, Technische Universität Kaiserslautern, Institute of Machine Elements, Gears, and Transmissions, Kaiserslautern, Germany

Characterization of radial shaft seal performance in contaminated environments

Radial shaft sealing (RSS) systems in both the automotive and industrial sectors are sometimes exposed to contaminated environments. There is currently no standard for testing dynamic seals in a defined contaminated setting. In this contribution, an attempt at standardizing the investigation of the influence of dirt on a RSS-system is presented. Results of investigations with NBR and FKM based seals are presented as well.

Apart from the choice of lubricant, the environment of most RSS can essentially be described by the temperature in the sump, the sliding speed as well as the surface and thermal conductivity properties of the shaft and the conditions on the air side of the seal. When debris contaminated air and water is present on the air side of the seal, the features of the shaft and the RSS can be changed by dirt ingress and the sealing mechanisms can be disturbed. Such conditions can for example occur in machines, which operate in extremely dirty environments. To investigate the influence of dirt on the air side of the sealing system, a standardized test environment for endurance tests under contaminated conditions was developed. Hereinafter test bench experiments were conducted, to describe the wear behavior and dirt migration through the sealing system.

Experimental results from test runs under varying conditions (sliding distance, particle size of contaminant, shaft speed collective), were conducted for NBR and FKM seals. Wear, progress of dirt ingress through the dust and main lip as well as contamination of the grease and oil were determined in staggered experiments from 7.500 – 20.000 km of sliding distance.

A clustered representation of the results is proposed, in order to identify different impacts on the sealing system and to allow for a performance comparison between such systems.

A 06

Sumbat Bekgulyan, Simon Feldmeth, Frank Bauer, University of Stuttgart, Institute of Machine Components (IMA), Stuttgart, Germany

Influence of dynamic eccentricity on the pumping rate of rotary shaft seals at sub-zero temperatures

In this paper, the influence of dynamic eccentricity and low operating temperatures on the pumping rate of elastomeric rotary shaft seals is analysed experimentally. For this purpose, function tests and pumping rate measurements were carried out at different dynamic eccentricities up to 0.3 mm (0.6 mm TIR) and oil sump temperatures between +40 and -20 °C with rotary shaft seals made of nitrile rubber (NBR) and fluoro rubber (FKM) in combination with synthetic polyalphaolefin oil FVA PAO1. The function tests and the pumping rate measurements show the application limits of the rotary shaft seals under the combination of dynamic eccentricity and low oil sump temperature.

A 07

Simon Feldmeth, Christoph Olbrich, Frank Bauer, University of Stuttgart, Institute of Machine Components (IMA), Stuttgart, Germany

Influence of Lubricants on the Thermal Behaviour of Rotary Shaft Seals

The thermal behaviour of rotary shaft seals is affected by the fluid which has to be sealed. The fluid lubricates the sealing contact and determines the frictional heat generated there. Addition-ally, the fluid influences the heat transfer to the environment. Both aspects were experimentally analysed by measuring the friction torque and the temperature on the air side near the sealing contact during test runs with 16 different lubricants. The measurement results show that the fluid affects the heat generation much more than the heat transfer. In general, the friction torque is higher for more viscous fluids. However, several exceptions restrict this finding.

A- Session 4: Rotary Shaft Seals II

A 08

Philipp Fricker, Matthias Baumann, Frank Bauer, University of Stuttgart, Institute of Machine Components (IMA), Stuttgart, Germany

Correlation between Wetting Properties and the Susceptibility to Wear of Rotary Shaft Sealing Systems

Modern lubricants (e.g. polyglycols, esters) cause problems when sealed with rotary shaft seals. The wear of rotary shaft seals strongly depends on the wetting properties of the respective friction partners. The paper shows, how the susceptibility to wear of rotary shaft sealing systems can be estimated by a combined consideration of the wetting properties of the sealing components, the lubricants viscosity and the pumping rate of the sealing system. Investigations were carried out using polished steel counter faces made from eight different alloys, together with FKM rotary shaft seals and eleven chemically different lubricants (mineral oils, polyglycols, poly-α-olefins, esters and silicone oils).

A 09

Laura Stubbe, Sarah Staub, Konrad Steiner, Stefan Thielen, Oliver Koch, Bernd Sauer, Technische Universität Kaiserslautern, Institute of Machine Elements, Gears, and Transmissions, Kaiserslautern, Germany

Cost-efficient evaluation of elastomer-lubricant incompatibility under tribological loads equivalent to radial shaft seals

Within this investigation, the contact temperature of radial shaft seals (RSS) was experimentally determined under different operation conditions, oil sump temperatures and various lubricants. These results were compared to contact temperature measurements in the tribological equivalent system of the RSS, which is the ring-cone-tribometer. In this system, a circular elastomer plate slides on a shaft steering cone under lubrication. These tests were carried out under identical boundary conditions.

For this purpose, a test cycle was developed and ran for both test benches. The measured temperatures were additionally calculated theoretically using the common calculation methods according to Engelke and a semi-analytical method from MEGT. The results indicate that it is possible to measure the contact temperature in the tribological system and that the temperatures correspond very well with the measured temperatures in the radial shaft seal system. The results of the calculation methods also show a high degree of agreement and are valid for both systems.

A 10

Koji Watanabe, Kazunari Seki, NOK corporation, Kitaibaraki, Japan
Hikaru Tadano, Dr.-Ing. Fabian Kaiser, Freudenberg Sealing Technologies GmbH & Co. KG, Weinheim

Formation of Macro Lead using plunge grinding – a kinematic approach

Plunge grinding is considered to produce lead free surfaces for the usage with rotary shaft seals. The term “lead” summarizes all surface structures, which create a rotation dependent pumping effect. Since lead influences the complex tribological system “rotary shaft seal”, it is essential that the process “plunge grinding” manufactures surfaces without lead.

A kinematic simulation model of the manufacturing process “plunge grinding” was developed to understand and visualize the complex interactions between the manufacturing parameters and the macro lead parameters on the surface. Additionally, an approach for the stochastic influence on the surface is also presented to investigate parameters for lead free surfaces. The model has been validated by the measurement of plunge ground parts with the same manufacturing parameters.

A 11

Abdelhak Azzi, Samuel Maquinghen, Poclain Hydraulics, Verberie, France

Radial shaft seals failures investigation

The purpose of this study is to use root cause failure analysis method to investigate and resolve reliability related problems of radial shaft seals in order to help designers and manufacturers to improve the product validation process. Previous studies have revealed that lifespan and performance of hydraulic motors are significantly affected by the reliability of the sealing solution. The key point for achieving lifetime of radial shaft seal improvement is to deeply understand seals applications duty cycle, which leads to specific failures modes.

In this paper, the factors relating to life of radial shaft seals are investigated and discussed. The application of root cause failure analysis method used on field data, experimental tests and numerical simulations aimed at reproducing of a defect, accelerating test and estimating the lifespan of a seal have been presented. Obtained results show a good agreement between on field data and experimental tests, as well as the strong impact of operating conditions on the radial shaft seal lifespan.

A- Session 5: Applications in Practise

A 12

Roy Ovink, Bas van der Vorst, Mickael Sansalone, SKF B.V., Houten, Netherlands

Digital twin for rubber seal manufacturing

This paper describes the latest improvements carried out in terms of material char- acterization and modelling techniques for uncured rubber required for the develop- ment of digital twins of seal compression and injection moulding processes. Much of this work was focused on obtaining the right parameters to be used in the required dynamic viscosity model as well as in the used curing kinetics model.

Moulding simulation results show very good agreement with results like pressure values and melt front displacement obtained experimentally. Based on these results, a new analytical approach was developed giving a rapid indication of the maximum allowable filling or compression time, thus allowing to prevent underfill and scorch in the seal manufacturing process.

A 13

Franz Schmeink, Flender GmbH, Voerde, Germany

Sealing solutions for industrial gear units

Industrial gear units drive working machines in many different applications and uses. The environmental conditions are just as different as the operating ones. Indoor and outdoor assembly, dust, moisture, aggressive gases and liquids on the one side corresponds with speeds, oils and (oil-) temperatures, geometrical issues, manufacturing tolerances and installing positions and place highest demands on the shaft-sealing. Flender is now expanding its range of configurable seals for industrial gearboxes, taking into account the application-specific and gearbox-related boundary conditions in a way that is easiest to act. The aim:

Besides the robustness against contamination, knowledge about dealing with the gear unit conditions is just as important - so extensive tests on seal and gearbox test benches show the performance and specific properties of the seal variants under different environmental and operating conditions. These are incorporated into the gearbox configurator as differentiation criterion, but before that, they are compared with the results of systematic evaluations with regard to field experience with the extensive Flender gearbox fleet – the result: With just a few inputs you can take into

reducing wear and increasing service life. Optimized lip seals and seal systems ensure reduced heat generation and longer service life.
In addition, it has now been possible to integrate a wear-free seal for environments with high contamination loads as standard: Tacolab - a seal that is even tight when stationary.

account Flender's extensive application experience and the configurator generates suggestions and options for the optimum seal.

A 15

Silvio Schreymayer, Thomas Schwarz, Michael Fasching, Michael Liebminger, Aldara Naveira Suarez, Tomas Östberg, Erik Råwall, SKF Sealing Solutions Austria GmbH, Judenburg, Austria

Investigation of hydraulic fluid condition on seal performance

This work investigates the impact of various hydraulic oil conditions on the performance of hydraulic rod seals - fresh, different aging conditions and cleaned with a special oil regenera-tion. Oil aging was introduced by so-called heavy-duty tests applying elevated temperature and pressure conditions to the oil and the seals.

This test procedure accelerates aging of the hydraulic fluid by oxidation and particle formation. The test program was done with a commercial hydraulic oil grade and polyurethane rod seals on a hydraulic seal test rig. The aged oil was treated with the newly developed Double Separation Technology (DST) and tests were after-wards repeated with same procedure.

A- Session 6 : Automotive / E-Mobility

A 16

Kenya Yoshioka, Tim Leichner, Max Freiberger, Freudenberg Sealing Technologies GmbH & Co. KG, Weinheim, Germany

Dynamic dirt deflectors for friction reduced shaft seals

Passenger vehicles are increasingly used in severe environment such as unpaved and flooded roads due to globalization of the market. Fuel-efficient is also required to reduce CO2 emissions. Therefore, oil seals are required to have robustness against dust and muddy water from outside and to reduce friction torque.

In this study, non-contact deflectors as part of the oil sealing system were examined. Goal is to improve the effect of prevention for ingress of muddy water while keeping the friction torque as low as possible. Protection without increasing friction is only possible with a non-contact sealing system, for which labyrinths are particularly suitable.

A 17

Christoph Schüle, Martin Franz, **Christoph Wehmann,** Sergio Amorim, Trelleborg Sealing Solutions Germany GmbH, Stuttgart, Germany

Axial seal for high-rpm application and poor lubrication

The electrification of drivetrains brings big advantages for users of vehicles and the surrounding environment. However, component suppliers will experience drastic reductions of product variety due to reduced complexity of electrified drivetrains. Current estimations are suggesting that the automotive market alone, aside from all other transportation equipment, will demand in the range of 11 million new pure electrically driven light vehicles by 2025.
A major technology in electric vehicles is the electric drive unit, a combined electric motor and gearbox that fits within the traditional axle/differential space. The motor and gearbox are directly coupled but while the gearbox requires efficient lubrication, it is essential that the motor remains dry and so a highly reliable sealing solution is required between these two components.
Electric motors run most efficiently at high speeds and so the seal requirements are very different from those for a transmission input on a combustion engine vehicle – the speeds are a lot higher; the duty cycle is much more varied and there is a reversing requirement. (The main pain points with regards to the seal are the fact that rotary seal and bearings are limiting factors for the electric motor performance, friction and torque of the seal cause high power losses and active cooling of sealing and bearing might have a need of complex cooling setup with for example additional oil pumps.)

A 18

Bas van der Vorst, Jeroen Lenten, Mickael Sansalone, SKF, Houten, Netherlands

Responding to sealing challenges in Electric Vehicles (f

Recent developments in electric driveline technologies require that seal testing capabilities, seal virtual predictive platforms and, most importantly, sealing solutions be upgraded to cope with the challenging high-speed levels and specific lubrication conditions present in Electric Vehicles (EV). Since the EV global market is also very dynamic, related sealing product specifications and test requirements also constantly varying.
This paper discusses a strategy to develop sealing solutions able to properly perform in the severe and diverse conditions related to EV applications. It requires test equipment that not only fulfils the test requirements but also rapidly adapts to changes ensuring that products can be properly developed and validated. Here parameters such as seal reverse pumping ability, friction and temperature are discussed, which are key in responding to the challenges related to Electric Vehicle applications.

A 19

Jan Gölz, Magna PT B.V. & Co. KG, Untergruppenbach, Germany

Validation cycles for electrical systems from a Seal's perspective – Discussion of LV124 compared to established seal test sequences

One significant challenge are validation cycles for electrical systems or components. Compared to established approaches on sealing system validation, some test cycles are much more severe regarding thermal loads. This can lead to sealing system failures in the respective test run, provoked by non-representative failure modes. To avoid incorrect conclusions on the sealing systems' performance, it is mandatory to review the test parameters critically.

To review the thermal loads within this paper, test cycles from the standards LV 124 for electrical components, DIN 3761 for radial shaft seals and ISO 1817 for oil compatibility testing are compared. The latter two are established validation cycles for sealing systems with elastomeric seals. Equivalent test temperatures and test durations are calculated and the resulting thermal loads are compared. Afterwards some examples of sealing system failure modes in LV 124 cycles are shown and discussed.

A- Session 7: Materials and Surfaces

A 20

Matthias Baumann, Jannik Röttger, Frank Bauer, Thomas Bergs, University of Stuttgart, Institute of Machine Components (IMA), Stuttgart, Germany

Formation of Micro Lead in Cylindrical Plunge Grinding

Lead, especially micro lead, on ground shaft sealing surfaces has been an ongoing issue in sealing technology for many years. Now that suitable lead measuring methods have finally been developed, the scientific focus has shifted from the measurement of lead and its influence on the sealing function to the formation of lead. Experimental investigations have been carried out to analyse the influence of the process parameters on the formation of micro lead during external cylindrical plunge grinding. The results show that micro lead occurs using industrial common parameters. The influence of the grinding tool specification, the dressing and the grinding parameters on the micro lead structures are described and discussed.

A 21

Barthel Engendahl, Cora Leibig, Chromatic 3D Materials GmbH, Selfkant, Germany

3D Printing Flexible Materials: From Prototyping to Industrial Manufacturing

This paper introduces additive manufacturing techniques and their relevance in the production of seals and gaskets. Following an economic consideration of the general benefits of additive manufacturing, we will compare the application requirements and material properties of different additive manufacturing materials. We will then present an application example of a cargotrain brake membrane, including the qualification protocol for this safety-critical application. We will also discuss the isotropic material properties unique to our printing process, as well as compression set and changes to tensile properties after aging the material in different media. The paper concludes with an outlook that considers additive manufacturing's benefits in producing other types of seals and gaskets.

A 22

Cornelius Fehrenbacher, Simon Kayser, Simon Haaf, KACO GmbH + Co. KG, Kirchardt, Germany

Thermoset Shaft Seals – A new generation of Radial Shaft Seals

Radial shaft seals used in corrosive media need usually a stainless steel support part. To achieve sufficiently good adhesion between the support part and the elastomer, a complex pre-treatment process is required.
With radial shaft seals using a thermoset support part, the high corrosion protection requirements of some customers can be met.
In addition, a weight saving is achieved and the process time is significantly reduced by eliminating the time-consuming pretreatment process of the stainless steel support part. But there are challenges in using a thermoset support part.
The design of a thermoset support part is discussed and the investigations are described.

B- Session 2: Mechanical Seals

B 01

Peter Waidner, seal-ing – the sealing doctor, Bamberg, Germany

Influence of the installation environment on the operating behavior of mechanical seals

Mechanical seals have significant internal power losses inside the sealing gap on the axial surfaces because of friction conditions. Even with pure liquid friction with a complete hydraulic balance of the sealing gap, friction losses of several kW can occur on high-performance seals. The heat must be dissipated through the seal's components and transferred to the liquid to be sealed for cooling.
In practice on the cylindrical surfaces, carbonization layers might occur in oil seals and evaporation processes might occur in water seals. The cause is to be found in insufficient heat transfer to the liquid to be sealed. Heat transfer is significantly influenced by the geometry of the seal's cavity beside the physical properties of the fluid.

B 03

Florian Koehn, Michael Sedlmajer, Andre Guetlein, Markus Merkel, Joachim Albrecht, Aalen University, Aalen, Germany

Tungsten Carbide-Cobalt: with 3D metal printing to wear-resistant coatings for technical applications

The mechanical protection of component surfaces sliding on each other against wear, as in mechanical seals, can typically be achieved by the deposition of hard coatings. Depending on the kind of application suitable material combinations and deposition techniques have to be selected. In case of cobalt-based tungsten carbide coatings usually physical vapor deposition (PVD) is used. However, a promising approach uses 3D printing to produce such coatings with enhanced adhesion and extreme wear resistivity.Characterizing those coatings in tribological tests under severe wear inducing conditions, it can be found that the coatings are extremely wear resistant. The measured coefficient of friction against tungsten carbide-cobalt highly depends on the surface topography. It is obtained that different surface properties strongly influence the tribological behaviour.

B- Session 3: Reciprocating Seals

B 04

Boris Traber, Olaf Nahrwold, Freudenberg Sealing Technologies, Weinheim, Germany

Condition monitoring of reciprocating seals

This contribution shows the approach from Freudenberg Sealing Technologies: Instead of using indirect machine parameters and modelling the expected lifetime, the seal becomes 'smart' thanks to a special design: The sensing seal provides the same sealing functionality as a conventional one but can additionally become a sensing element by combining different materials to a two-component part. In that way, this seal does not require any external sensor components in the sealing system, which usually impair the sealing function. Measurements on real valves and cylinders show how the progressive wear of a sealing lip can be measured in translatory applications. The correlation of the dimensional change caused by wear to the leak test of the seal shows that the developed sensor seal system is more sensitive than the leakage detection and a measurable signal increase always occurs before, which has also been verified in contact with different fluids.
Possible intervention limits can be set by the user himself or the system can calibrate itself; in consequence the system provides self-learning capabilities. This solution significantly increases the overall system reliability and thus the system efficiency.

B 05

Gonzalo A. Barillas, Andreas Gropp, Mert von Daven, Freudenberg Sealing Technologies GmbH, Schwalmstadt, Germany

Observations on Particle Wiping Behaviour of Hydraulic Wipers

The sealing mechanism of reciprocating seals has been described quite accurate in the litera-ture and validated by several testing procedures. Nevertheless, the behaviour of most of the times not pressurized wipers cannot be described when particles are added into an oil film. To describe the mechanism of particle retraction during rod motion, a series of tests with different parameters have been performed. In this paper, these results will be summarized showing -among others- the effects of particle sedimentation on the wiping mechanism. Also, a numerical approach to explain what particles do in the wiping area will be presented.

B 06

Seckin Semiz, Cem Tanyeri, Ozan Devlen, Kastas Sealing Technologies, Izmir, Turkey

Development Of a Novel Wiper Seal Test Rig and Validation of Wiper Seal Performances

Although the choice of wiper seal is not paid attention to in applications, the wiper seal is one of the most important elements of the system which isolates the hydraulic or pneumatic system from the external environment. Contamination in hydraulic and pneumatic systems can cause significant damage to metal parts of the cylinder, sealing elements, and other components of the whole system This is the reason why Kastas Sealing Technologies develops a new test bench to perform wiper seal performance tests. This paper provides us with a technical over-view of the design of the wiper seal test rig and performance analysis according to environ-mental effects on the wiper seal.

B 07

Oliver Feuchtmüller, Lothar Hörl, Frank Bauer, University of Stuttgart, Institute of Machine Components (IMA), Stuttgart, Germany

An empirical study on the breakaway friction and squeeze film effects of a polyurethane U-cup rod seal.

The influence of the dwell time and properties of oil on the breakaway friction of a U-cup rod seal was analysed. A logarithmic correlation between the breakaway friction force and the dwell time (in a range from 30 to 104 seconds) was found. We used oils from various viscosity classes (ISO VG 32 …460) and chemical compositions (mineral oil, silicone oil, perfluoropolyether, polyglycol).

An almost linear correlation between the dynamic viscosity and the breakaway friction was found. Among viscosity and dwell time, further properties of oil must have a remarkable influence on the breakaway friction of rod seals. Using ellipsometry, we showed that even a film thickness of approximately 8 nanometres can be squeezed out of the sealing gap during dwell time.

B- Session 4: Static Seals

B 08

FIorian Werner, Oliver Zach, Teadit International Produktions GmbH, Kirchbichl, Austria

Determination of the gasket characteristics at cryogenic temperatures

So far, the knowledge about gasket characteristics in cryogenic conditions is still limited. The determination of gasket factors according to EN13555 would give the possibility to calculate flange connections according to EN1591-1. In this paper the first investigations to determine EN13555 test data at cryogenic temperatures are presented.

The tests were done at a newly developed test machine at temperatures as low as -150 °C. In the tests high performance PTFE gaskets showed superior results in comparison to elastomer bonded fibre gaskets. With the results some of in field applications experienced challenges and failures of non-asbestos fiber gaskets at cryogenic temperatures can be explained.

B 09

Ralf Kulessa, Garlock GmbH, Neuss

Gasket sealability test results in accordance to new test setup concerning Air Quality Control control act ("TA-Luft")

On 1st of December 2021 the new Technical Instruction on Air Quality Control act (German:"TA-Luft") came into action. After six years of preparation by the Ger-man government, the new technical instruction on Air Quality Control act now has approx. 600 pages. The list of changes to previous version does have 144 pages, not only calling out more hazardous substances but also setting new rules for gaskets and flange-connections as well as for stirrers and agitators. Since this Technical Instruction has significant effect to other European Nations as well, because gasketing materials often are specified with regards to this Technical Instruction within customer chemical and petrochemical plants worldwide and across Europe

B 10

Philipp Lambertz, Eike Kottkamp, Malte Schnau, Alexander Riedl, FH Muenster – Center of Sealing Technologies, Steinfurt, Germany

The Smart Flange Joint – Bolt Force Measurement with Foil Sensors

Since precision tools are expensive, flange joints are usually assembled with inaccurate torque wrenches. As measurement equipment is often not made for the rough industrial conditions, it is difficult to monitor bolts over their whole lifespan. That is why a loss of gasket tension can often only be anticipated through frequent maintenance.
To solve these problems, we are developing a new foil sensor. The foil sensor has a thickness that is measured in micrometres and is supposed to be applied within a washer under the bolt head. After successfully measuring the bolt force under laboratory con ditions, we are confident to soon present a sensor for large scale industrial applications.The sensors are manufactured at competitive costs and are not limited to the assembly pro- cesses. Instead, we hope to provide a sensor that enables the plant operators to monitor their flange joints over several years. Thus, we want to develop a warning system against certain irregularities like a drop in gasket tension etc. By collecting data and with the help of artificial intelligence we hope to gain further insights into industrial applications and to increase plant security while decreasing maintenance costs.

B- Session 5: Simulation

B 12

Niklas Bauer, Sumbat Bekgulyan, Simon Feldmeth, Frank Bauer, Katharina Schmitz, RWTH Aachen University, Aachen, Germany

Experimental determination and EHL simulation of transient friction of pneumatic seals in spool valves

The transient sealing friction in pneumatic spool valves plays an important role in the dynamics of pneumatic systems. In order to gain a better understanding of this particular tribosystem, an extensive analysis was conducted, combining experimental measurements on a test rig with an elastohydrodynamic lubrication (EHL) simulation model. This contribution presents a description of the test setup and the test conditions, the parametrization of the simulation model and a discussion of the results. Qualitative agreement between theory and measurement has been found. The results indicate that the viscoelasticity of the sealing material as well as the occurrence of starved lubrication conditions cannot be neglected.

B 13

Dominik Lorenz, Lisa-Marie Schänzel, Marc-Andre Hodapp, Festo SE & Co. KG, Esslingen-Berkheim, Germany

Component-based modular system modeling of a spool valve

Translational seals are an essential part of spool valves. In order to describe the functional behaviour of such valves block-oriented system models are frequently used. First steps towards a component-based modular system modelling of a spool valve in Modelica are shown in this presentation. The different seals are modelled as components having individual contact states.These discontinuities contribute to the frictional behaviour of the system model. The friction behaviour is implemented by easily replaceable friction models. Advantages of component-oriented vs block-oriented modelling are demonstrated.

B 14

Dirk Möhring, Tim Leichner, Frank Strübing, Gonzalo Barillas, Freudenberg Sealing Technologies GmbH & Co. KG, Weinheim, Germany

Design for contact lubrication of large seals

Structural and fluid engineering simulation tools are suitable for identifying the key design parameters and fluid transport mechanisms and can thereby help optimizing the seal design.
On the structural side, the installation tolerances and kinematic oscillations during operation are small in comparison to the size of the mating parts, but enormous in relation to the section geometry of the seal profile. This requires a very flexible seal lip design, able to follow all movements to avoid high friction forces on one side and contact losses with leakage on the other side.
On the fluid side (grease), it is shown that the non-Newtonian behavior leads to two main schemes: In the region of seal contact with the moving mating part, the grease is oil-like due to high fluid shear rates. The seal geometry is optimized to support the grease film and to transport escaping grease back to the grease side. With optimized design and initial filling with grease, the service life is extended. Furthermore, it is shown that other transport forces such as centrifugal force and gravity play only a minor role in grease transport, while operating conditions such as temperature and the operating conditions, must be taken into account in any case.

B 15

Christoph Wehmann, Ambarish Kulkarni, Feyzan Durn, Murat Gulcur,Trelleborg Sealing Solutions Germany GmbH, Stuttgart, Germany

Modeling the Compression Set of Elastomers to Predict the Lifetime of Sealing Systems by Finite Element Analysis

In many cases, the lifetime of a sealing system is limited by the compression set of the elastomer. Therefore, it would be beneficial to have a numerical procedure which can capture the compression set. This contribution starts with an overview of the existing literature in this field. Next, a method based on previous research work is developed and described. It allows to predict both the decrease of the sealing force and the resulting permanent deformation. This prediction can be done for long time scales. The results of this method are compared to experimental values of a fluorine-based elastomer. Finally, the aging of an O-ring is simulated by the developed method.

B- Session 6 : Materials and Surfaces

B 16

Lukas Merkle, Jeremias Grün, Matthias Baumann, Frank Bauer, University of Stuttgart, Institute of Machine Components (IMA), Stuttgart, Germany

Sealing Systems under Starved Lubrication Conditions

Various operating conditions can cause sealing systems to be insufficiently supplied with oil, resulting in starved lubrication. This paper deals with the experimental investigation of starved lubrication operating conditions. For this purpose, the test rig configuration used is introduced. The influence of starved lubrication on 3 different sealing systems was investigated. In addition to a standard elastomeric rotary shaft seal, a multi-lip initially grease-filled elastomeric rotary shaft seal and a PTFE sleeve with circumferential grooves were employed. The results show that the standard rotary shaft seal is unsuitable for the investigated starved lubrication conditions. The other two sealing systems performed better in comparison and are suitable for operation with a starved oil supply, at least for short durations.

B 17

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Regenerative Thermoplastic Polyurethane for Hydraulic Rod Seals – Time-Accelerated Testing

In a joint research project within the ZIM programme, sustainable high performance TPUs (thermo-plastic polyurethane) for hydraulic rod seal rings were developed by replacing conventional raw materials with regenerative biogenic structural components. Hydraulic rod seal rings were manufactured from these biogenic materials and time-accelerated tested to analyse their extrusion and wear behaviour. This paper shows the developed test methods as well as the results obtained with these. In all tests, various TPU prototypes were used in combination with the hydraulic fluids intended for this purpose (water-based, rapidly biodegradable). The prototype seal rings manufactured of the new developed regenerative TPU compounds were comparable to non-regenerative TPU compounds regarding their functional behaviour.

B 18

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Interactions between elastomer fillers, strain, surface properties and friction

In elastomeric materials, fillers are very important ingredients. There is a wide variety in terms of materials and sizes of the fillers, depending on the application of the specific compound. In a recent study regarding the simulation of the lubricated friction of a rubber material, it became apparent that the fillers can also have a significant influence on the surface properties of a material in combination with mechanical loading. These interactions can be crucial for the correct prediction of the material behavior. It will be shown, how the fillers influence the surface properties of an elastomer, what the most important parameters are and how this can influence the friction properties of the rubber compound.

B 19

Bernhard Richter, O-Ring Prüflabor Richter GmbH, Großbottwar, Deutschland

Prediction of the functional limits of seals at low temperatures

Proving the required functionality of seals at low temperatures usually involves considerable effort. If the functional test reveals that the required targets are not met, this not only involves costs, but often also jeopardizes or postpones entire development projects. This raises the question of how realistic low-temperature limits can be determined in advance. This presentation will show that this can be done surprisingly well with conventional cold test methods if the type of stress is sufficiently known, using standardized types of stress.

However, the exact nature of the stress can shift the failure limit of the seal at low temperatures up to 20K. And here the use of FE analysis offers new possibilities that are still far too rarely applied. By using appropriate models to simulate viscoelasticity, the limits of seals under the influence of dynamic gap- and pressure-changes could be predicted much more precise, and thus seal housing and loading scenarios could be much better adapted to the potential of available seal materials and seal geometries.

B- Session 7: Simulation II

B 20

Seckin Semiz, Cem Tanyeri, Yoncagul Celik Erez, Ozan Devlen, Kastas Sealing Technologies, Izmir, Turkey

Simulation of Composite Guiding Elements with Analysis Programs

Guiding elements that have an important effect on the long-term trouble-free operation of hydraulic and pneumatic systems, resist the forces perpendicular to the axis in cylinders and are used to prevent metal-to-metal contact. In composite materials, which is one of the most frequently used materials in guiding elements, different parameters such as fiber orientations and reinforcement material ratios greatly affect the quality and strength of the product.

This paper aimed to analyze the transition steps of composite guiding elements from material to product by using the finite element method and simulation studies using Digimat, Moldex3D, and MSC Marc programs. The validation of this simulation study was provided by tests.

B 21

Sylvain Nadiama, Mickael Sansalone, SKF B.V., HOUTEN, Netherlands

Seal virtual optimization for enhanced sustainability

SAMBA is an advanced simulation platform coupling a commercial FEM solver with proprietary analytical equations to predict the behavior of sealing systems in terms of transient dynamics, friction and thermal performance. The modelling method combines viscoelastic material behavior, the heat generated by the seal friction and the heat dissipated inside and outside the sealing system. The equations implemented consider the influence of the tribological, lubrication and heat transfer phenomena, including the temperature dependencies of each variable. The model predictions obtained show very good agreement with experimental test results in terms of temperature, and friction torque. In practice, a real case example shows how the SAMBA prediction capabilities are actively supporting the journey towards cleaner and more sustainable sealing solutions.

B 22

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Benefits and Applications of EHL Analysis in Sealing Technology on the Example of a Hydraulic Step-Seal

High-performance seals excel in keeping systems tight in demanding operating conditions, e.g., in high-velocity, high-temperature, and high-pressure applications. To succeed, special care is taken in the design of the contact interface. A key factor for the longevity of the seal is the formation of a stable lubricant film which fully separates the mating surfaces. The generation of load-carrying fluid films in thin lubricated gaps can be described analytically using the theory of elastohydrodynamic lubrication (EHL). In this study, the application of numerical EHL analysis in sealing technology is presented and discussed on the example of a hydraulic step seal. Relevant aspects of modelling the system and evaluating the results are emphasized. Moreover, the benefits of the EHL analysis to assess characteristic performance criteria such as friction and tightness of a sealing system are outlined.

C- Session 8: Closing Lectures

C 01

Peter Waidner

Tribology of dynamic seals on a nanoscale – where does this lead?

Mechanical seals have been industrially manufactured and used for several decades. Two axially rotating end faces, in which one of the two rings (the seal face) is axially movable to compensate for any axial displacement and wear, slide towards each other at slow to high circumferential speed, forming a minimal sealing and lubrication gap. Under dry, boundary, mixed or liquid friction conditions, a very small lubricating film of much less than one micrometre – often smaller than the measured sum of the surface roughness – forms a major challenge for the materials of the two sliding rings. Decisive for the functionality of the seals is the inter-action between the machine, machine element (the seal) and the fluid to be sealed, which also serves as a lubricant for the seal. The lubricity of fluids depends primarily on their viscosity but also on their wettability of sliding materials. State-of-the-art calculation and simulation methods serve to optimize the stability of the sealing gap even before the detailed design and production – but due to the complexity based on our current knowledge an almost impossible undertaking. All in all, it is the classical consideration of tribology