

Electric Vehicles I

Session Chair: TBD**Session Vice Chair: TBD****8 - 8:30 am****3666962: Novel, Bio-Based Group V Basestocks for EV Applications: Customizable Performance with Reduced CO₂ Footprint**

Ben Deweert, Oleon, Evergem, Belgium

Strengthening fuel economy, emission control regulations and consumer preferences are steering the automotive industry to switch to electric vehicles to reduce CO₂ and other GHG emissions. OEMs are pushing the boundaries by continuously optimizing electric drivetrain design, performance, and efficiency. Performance characteristics of EV fluids can be enhanced by selecting the right basestock. Specific challenges will be reviewed like lowering fluid viscosity and decreasing the additives treat rate. The base oil must therefore largely carry the technical EV requirements by itself. Multi-purpose basestocks like Group V oils can address the industrial criteria. At the same time, the awareness for the carbon intensity of products and materials is also increasing. By designing new Group V base oils from renewable, sustainably sourced building blocks, these fluids can contribute to a further reduction of the total carbon intensity of electric vehicles, as confirmed by Life Cycle Assessments.

8:30 - 9 am**3659666: Advancing EV Fluid Development with Next-Gen Base Oil**

Babak Lotfi, ExxonMobil, Baytown, TX

Over the last several years electric vehicle (EVs) design has rapidly evolved. The electric motor which is the key component in the EV drive-unit that differentiates EVs from conventional internal combustion engine-based vehicles, posed new fluid requirements e.g. thermal management in addition to conventional tribological properties.

This work demonstrate how next-gen PAO molecules can help to advance EV fluids formulation. The next-gen PAO bring a balance of low viscosity and low volatility (high flash point) that is first in class and not achievable by incumbent molecules like Gr III/+ and conventional PAO. The lower viscosity formulation is achieved by next-gen PAO. Testing results exhibit superior energy efficiency and cooling properties of next-gen PAO fluids, in a gear-box and an e-motor, which can result in extending driving range in electric vehicle.

9 - 9:30 am**3669418: Next Generation Basefluids for Electrical Vehicles - Optimizing the Performance Balance**

David Gillespie, Croda, Inc., New Castle, DE

The requirements of next generation gear fluids for electric vehicles will require fluid optimization in both the additive package and basefluid technology. High efficiency of the electric motor means any efficiency losses in the gear system including the fluid are under scrutiny whilst thermal management of both the motor and battery pack continue to be essential along with safety aspects such as low electrical conductivity and high electrical breakdown voltage values. Here, next generation group V fluids are evaluated for their efficiency and cooling ability whilst also tested for other critical parameters such as oxidative stability, fluid and material compatibility and wear performance.

9:30 - 10 am

3664452: Do Esters Make Sense for Fluids in Electric Vehicles ?

Matthias Hof, Emery Oleochemie GmbH, Monheim, NRW, Germany

Driven by the intent to reduce emissions by limiting the use of fossil fuels alternatives to the internal combustion engine (ICE) are being developed. Electric mobility is evolving as the new dominating alternative drivetrain.

The change of the existing drivetrain technology to a full electric or hybrid drivetrain will require a new set of automotive fluids to be used. Currently most OEMs are using existing fluids with minor adaptations to meet new requirements related to the exposure to electric fields and temperature control. All major lubricant, additive and component companies are now engaged in the development of fluids specifically designed for the usage in the new vehicle generations in the future. This paper looks at the suitability of ester technology in future fluids for electric vehicles. Data will be presented how the chemical structure of ester shapes the physical and chemical properties and what impact the structure has on the dielectrical and thermal profile.

10 - 10:30 am - Break

1B

Southern Hemisphere II

Lubrication Fundamentals I - Contact Models I

Session Chair: Q Jane Wang, Northwestern University, Evanston, IL

Session Vice Chair: TBD

8 - 8:30 am

3640353: The Lubrication at the Piston-Ring and Liner Interface as a Subject of Trade-Off Between Competing Factors

Polychronis Dellis, ASPETE, Athens, Attiki, Greece

Lubricant flow in piston-rings and liner of ICEs has been challenging due to complexity contributing or obstructing effective, low emissions and efficient operation. Increasing efficiency and enhancing load capacity has led to extensive study that combine different conditions of speed, load, temperature, and geometrical aspects with varying lubricant properties. Example: experimental data showed that viscosity variation alters cavitation initiation and shapes that result to different shapes on the surface of the ring. Friction losses over a cycle is a factor that needs to be investigated constantly. More data showed that friction peaks at boundary regions show the effect of squeeze film and its dependence on HTHS, speed, load, temperature, and ring geometry. This study also showed that hydrodynamic losses-mainly due to viscous shear at the diverging wedge of the ring, when an effective trade-off is achieved, can be optimized towards recent lubricant trends and sophisticated additives.

8:30 - 9 am

3658966: Flow Around a Contacting Asperity Modeled in the Macro-, Micro- and Nanometer Scales

Shuangbiao Liu, Henry Soewardiman, Nicole Dorcy, Jannat Ahmed, Yip-wah Chung, Q Jane Wang, Northwestern University, Evanston, IL; Stephen Berkebile, US DEVCOM ARL, Aberdeen Proving Ground, MD

Mixed lubrication problems involving asperity contacts have often been studied assuming a continuous medium, or continuum. However, the behavior of fluid flow around contacting asperities, where the gap between surfaces is extremely thin, requires investigation on the discrete molecular level. This work studies the three-dimensional flow at the corner of a fully flooded wedge, in which one surface moves at a constant velocity and the other remains stationary, with three computational methods involving three different scales: computational fluid dynamics, micro elastohydrodynamic lubrication modeling with the

Reynolds equation, and molecular dynamics. The flow fields are simulated; the flow statuses at the fluid-wall interface are examined; and the wall slip conditions are defined. From this work, the wall-slip behavior is quantified and the influence of the aforementioned scales on mixed lubrication is revealed.

9 - 9:30 am

3669142: Micro –Hydrodynamic Lubrication of Rough Thermoplasts in Parallel Sliding – The Role of Asperities, Cavitation, and Elasticity

Dilek Bulut, Norbert Bader, Gerhard Poll, Leibniz University of Hannover, Hannover, Germany

Traditionally, in order to include asperities or other deviations from perfectly flat surfaces when simulating hydrodynamic lubrication, the real roughness profiles have been transformed into abstracted parameters such as flow factors which then are used to modify the terms of Reynolds equation. These approaches obviously have their limitations. Therefore, it is reasonable to attempt to work with real 3-D scans of surface topography.

In a previous paper, the Reynolds-Solver of Elmer was fitted with a mass-conserving cavitation algorithm, and an iteration routine based on the force balance method was implemented. The validity of this approach was shown numerically and experimentally. In the current work, the numerical method is extended to include the micro surface features with elastic deformations. The simulations are compared with the optical experiments. The role of micro surface features, elastic deformations and cavitation is investigated via the simulations based on 3-D scans.

9:30 - 10 am

3668941: A Fully Conservative Thermo-Elastohydrodynamic Lubrication Model for Counterformal Contacts

Suhaib Ardah, Daniele Dini, Imperial College London, London, United Kingdom; Francisco Profito, Polytechnic School of the University of São Paulo, São Paulo, Brazil

The current contribution proposes an integrated and fully conservative finite volume framework to solve the coupled TEHL problem for counterformal contacts. The fluid flow behavior is predicted by solving the generalized Reynolds equation with the p- θ Elrod-Adams mass-conserving cavitation model and the energy equation for a viscous compressible fluid with proper boundary conditions for the fluid-solid interfaces. Advanced partitioned fluid-structure interaction (FSI) techniques are employed to handle strong nonlinearities exhibited by the coupled system of equations while simultaneously accelerating the solution convergence. The application of a body-fitted curvilinear coordinate system is explored to solve the energy equation from its strong conservation form. The performance of the model in terms of accuracy and computational effort will be evaluated against CFD-based TEHL models, while experimental validation will be assessed from infra-red thermal maps and other experimental data.

10 - 10:30 am – Break

1C

Southern Hemisphere III

Commercial Marketing Forum I

Session Chair: TBD

Session Vice Chair: TBD

8 - 8:30 am - Open Slot

8:30 - 9 am

3668939: Oil Filtration Systems: Remote System Monitoring & Purification of Lubrication Oil Reservoirs

Tom Lisy, Ken Kaihlanen, Oil Filtration Systems, Boerne, TX

Hydraulic and lubrication oils become contaminated with solids and water through normal use. As part of their reliability program, plant personnel pull samples periodically and send them to a lab for analysis. Although the reports are usually accurate, it often takes several days to get them back, and this delay can slow down the response time to critical contamination levels and contribute to system degradation. Utilizing sensors and a PLC, the oil condition in critical hydraulic and lubrication oil systems can be continuously monitored in-situ, and when contamination levels above set parameters are detected, a filtration/dehydration system can come on automatically. When contamination levels are reduced to pre-set parameters (particulate and water), the system automatically shuts off. This technology is particularly useful in remote facilities where operators are not frequently available. Vacuum dehydration & barrier filters are used to purify oils and extend their useful life.

9 - 9:30 am

3647758: Biosynthetic Technologies: Estolides - High Performance Sustainable Base Oils for Lubricant and Metalworking Formulations

Matthew Kriech, Biosynthetic Technologies, Indianapolis, IN

Biosynthetic Technologies strives to deliver innovations for a sustainable future. As such, we offer products that are bio-based, biodegradable yet deliver superior performance characteristics. In this session we'll discuss our currently product line of sustainable base oils / estolides that are made from organic fatty acids found in various bio-derived oils. In this session, we provide in depth information on estolide hydrolytic stability, oxidative stability, seal compatibility and other performance characteristics. In addition, we share our knowledge on a modified hydrolytic stability test to monitor the extensive stability of estolides versus traditional lubricant esters over a long duration of time under real world applications. This 30 minute session will be a MUST for anybody looking to develop a high performance EAL product line!

9:30 - 10 am - King Industries

10 - 10:30 am - Break

1D

Southern Hemisphere IV

Tribotesting I

Session Chair: TBD

Session Vice Chair: TBD

8 - 8:30 am

3641067: Study of Friction and Lubrication in Wire-Drawing Process

Marie-Louise Schlichting, Marc Masen, Amir Kadiric, Imperial College London, London, United Kingdom; Stijn De Pauw, Hendrik Van Hoecke, Marc Derdeyn, NV Bekaert SA, Ingelmunster, Belgium

Steel wires are used in various engineering applications, from car tires, oil platform anchorage ropes to champagne corks. A commonly used process to produce steel wires is wire drawing where a wire is pulled through a series of conical dies to reduce its cross-sectional area. At the wire-die contact the wire is subjected to high frictional forces. The underlying friction and lubrication conditions have an impact on the wire quality as well as the total energy consumption in the drawing process. However, these tribological interactions at the wire-die contact are poorly understood due to complex process conditions

such as high pressures, high speeds, and the use of unconventional lubricants such as soaps. This work investigates friction and lubrication behaviour under conditions pertinent to wire-die contacts using lab tribometers and wire-drawing set-ups and typical soaps and wire steels. Presented results offer new insights into the tribological interactions at the wire-die interface.

8:30 - 9 am

3642543: The Assessment of Tribological Effects of Nanofluid Flow on Heat-Exchanger Materials

Gustavo Molina, Fnu Aktaruzzaman, Mosfequr Rahman, Valentin Soloiu, Georgia Southern U, Statesboro, GA

Nanofluids, the suspensions of nano-size powders in cooling or lubricant fluids, are an active field of tribology research. But while the tribology of nanofluid lubricant is being actively studied, there is little knowledge on the effects of nanofluid cooling mixtures, as nanopowders in water and ethylene glycol, on typical heat-exchanger material surfaces. The authors discuss their pioneer research work on the testing of such effects, and their development of tribology testing and wear-assessment methodologies. More relevant results of testing nano-alumina fluid tribological action on typical materials (aluminum, copper, and stainless steel) are presented and assessment methods (roughness changes, weight-removal, and microscopy) are discussed. New proposed assessment methodologies and their integration with other critical nanofluid tests (as the heat-transfer measurements) are discussed.

9 - 9:30 am

3642999: An in-situ study of lubricants and their thermal properties

Peter Renner, Yan Chen, Hong Liang, Texas A&M, College Station, TX

In electric-mechanical systems like electric vehicles, a lubricant's thermal performance is essential for efficiency. During operation, it is difficult to measure directly the dynamic thermal behaviors of the lubricant. As such, this research introduces an alternative approach to measure fluid film thickness experiencing shear at different temperatures using electrochemical impedance. Polyalphaolefin (PAO) and mineral oil were the lubricants used in this research. It was shown that the thermal properties of the lubricants are dependent on temperature. Additionally, the dynamic thermal conductivity of the PAO was lower than that of the mineral oil. This research showed a new method to measure the dynamic thermal properties of a lubricant.

9:30 - 10 am

3643909: Influence of Structural Depth of Laser-Patterned Steel Surfaces on the Solid Lubricity of Carbon Nanoparticle Coatings

Timothy MacLucas, Lukas Daut, Maria Agustina Guitar, Sebastian Suarez, Frank Mücklich, Saarland University, Saarbrücken, Germany; Philipp Grützmacher, Carsten Gachot, TU Wien, Vienna, Austria; Volker Presser, INM - Leibniz Institute for New Materials, Saarbrücken, Germany

The ability of carbon nanoparticle coatings to provide effective solid lubrication in ambient conditions has been demonstrated in numerous studies. When coated, the recesses of textured surfaces can serve as lubricant reservoirs, forming a solid lubrication system capable of maintaining lubricity over significant periods of time. To optimize the performance of such systems, we examine the influence of the structural depth of line-patterned steel surfaces coated with multi-walled carbon nanotubes (CNT) and carbon onions (CO) on their respective potential to reduce friction and wear. The results show that regardless of particle type, the shallower the coated structure, the lower its coefficient of friction. Furthermore, CNTs reach a minimum COF of just below 0.20 thus lubricate more effectively than COs. Additionally, CNTs show a strong tendency to remain in the contact and the immediate proximity during friction testing, whereas the majority of the CO coating is removed.

10 - 10:30 am - Break

Surface Engineering I

Session Chair: Sougata Roy, University of North Dakota, Grand Forks, ND

Session Vice Chair: Ali Beheshti, George Mason University, Sterling, VA

8 - 8:30 am

3648360: Additively Manufactured Inconel 625 Subjected to Surface Strength Improvements-Part II: Elevated Temperature Fretting Wear Analysis

Manisha Tripathy, Ali Beheshti, George Mason University, Fairfax, VA; Lloyd Hackel, Curtiss- Wright Surface Technology, Livermore, CA; Keivan Davami, The University of Alabama, Tuscaloosa, AL

Inconel 625 is a nickel-based superalloy with excellent mechanical properties and corrosion resistance at high temperatures highly used in harsh environments as joints, seals, valves, etc; which are subjected to fretting loads. While fatigue and corrosion properties of additively manufactured (AM) Inconel 625 have been studied, knowledge on its wear, contact, and friction properties is limited. This part of the study evaluates the fretting wear properties of AM Inconel 625 with its wrought counterpart at high temperatures up to 700°C. The samples were manufactured by metal powder bed fusion technology using different process parameters; whose surface properties are further strengthened using shot peening (SP), ultrasonic peening (UP), and laser peening (LP), respectively. SP and LSP showed significant changes in the surface roughness parameters compared to the as-built AM sample and wrought Inconel 625 sample with improvements in friction and wear properties at high temperatures.

8:30 - 9 am

3669511: Additively Manufactured Inconel 625 subjected to Surface Strength Improvements-Part I: Surface Integrity and Microstructural Characterization

Ali Beheshti, Manisha Tripathy, George Mason University, Fairfax, VA; Keivan Davami, University of Alabama, Tuscaloosa, AL; Lloyd Hackel, Curtiss Wright Surface Technology, Livermore, CA

Surface enhancement processes like laser peening (LP), shot peening (SP), and ultrasonic peening (UP) are being extensively used in harsh environment applications for decades now to improve the mechanical and surface behavior of parts. With the rapid growth of the metal additive manufacturing industry, it becomes necessary to rigorously study the additively manufactured components trying to achieve comparable or even superior properties with reference to their conventional counterparts. The first part of this study showcases a detailed microstructural and surface property comparison between additively manufactured and traditionally manufactured Inconel 625 with LP, SP, and UP processes. Surface morphology and mechanical properties as well as advanced characterization techniques like XRD, EBSD, and TEM were employed to collate the changes due to the different types of peening processes

9 - 9:30 am

3646318: A Comprehensive Characterization of Laser Sintered Polyamide-12 Surfaces

Kieran Nar, University of Sheffield, Sheffield, United Kingdom

There are a number of factors which influence the resultant surface topography of polymer Laser Sintered (LS) components and consequently affect their functional performance, particularly when subject to dynamic contact. The scope of this research was to comprehensively characterize the surface topography of LS Polyamide-12 specimens and to specifically understand how resultant roughness is a function of applied energy density; XY location across the powder bed; part surface orientation; measurement technique and roughness descriptor. Results showed that the roughness profiles of top and bottom surfaces of cube-shaped LS PA12 samples were distinct in both size and shape. Moreover, micro-CT analysis provided insight into how the sub-surface microstructure was affected by part orientation and applied energy density. This work provides a benchmark for future Polymer Powder Bed Fusion (PBF) studies, specifically when characterizing the friction and wear properties of resultant samples.

9:30 - 10 am

3667955: Investigating the Tribomechanical Behavior of Hot Rolled and Additively Manufactured NiTi Alloy

Sougata Roy, Hyunsuk Choi, University of North Dakota, Grand Forks, ND

Nitinol is an alloy containing Ni and Ti can present two unique properties— shape memory effect and superelastic effect. For aerospace applications, superelastic effect of Nitinol alloy can be leveraged due to its ability to accommodate large elastic strain in load bearing applications. In this study, the tribo-mechanical behavior of superelastic 55NiTi alloy was investigated. Reciprocating friction and wear tests on 55NiTi alloy samples fabricated via conventional hot working and laser directed energy deposition (DED) based AM technique were conducted. Tribological tests were performed in unlubricated conditions against AISI 52100 balls at room temperature to 300C. Wear tracks were analyzed using a set of microscopy and white light interferometry techniques to understand the key wear mechanisms as a function of temperature and fabrication routes. The findings are expected to reveal the benefits and challenges of fabricating NiTi alloy using AM route from tribo-mechanical perspective.

10 - 10:30 am - Break

1F

Northern Hemisphere A1

Seals I: Rotary Rod Seals

Session Chair: Hongmei Zhao, Lubrizol, Wickliffe, OH

Session Vice Chair: Jing Yang, Texas A&M University, College Station, TX

8 - 8:30 am

3641477: Friction of Rod Seals at Pre-Defined Thin Lubricant Films analyzed with a New Measurement Procedure

Oliver Feuchtmüller, Lothar Hörl, Frank Bauer, University of Stuttgart, Stuttgart, Germany

The film thickness and lubrication conditions in the sealing gap of a reciprocating rod seal are of great interest due to their influence on friction, wear, and leakage. However, it is still a challenge to analyze the friction of rod seals in direct relation to the film thickness, shear rate, apparent viscosity and contact area. Thus, conclusions on the tribological mechanisms in the sealing gap are restricted. We developed a measurement procedure for analyzing friction at pre-defined shear rates. Therefore, thin lubrication films in the nanometer-range are produced and measured using ellipsometry. One unique feature is that practical-relevant sealing rings and various lubricants can be analyzed and compared. Results from a recent study including sealing rings with different geometry, surface topography and material are presented and discussed. The novel procedure and the empirical results can be used for optimizing modern sealing solutions.

8:30 - 9 am

3643939: Wear on Rotary Shaft Seals: Tribological Correlation Between Wear at Sealing Edge and Wear of Shaft

Lukas Merkle, Matthias Baumann, Frank Bauer, University of Stuttgart, Stuttgart, Germany

Elastomeric rotary shaft seals are a common seal type for automotive and industrial applications. The wear mechanism of these sealing systems is not fully understood and not predictable so far. If a lip seal fails, it causes high maintenance costs and environmental damage. In order to investigate the wear mechanism, an empirical test series is conducted with shaft seals on plunge ground shafts. Various tribological conditions are considered, including operating conditions relevant to practice. For a complete acquisition of the system condition, all shaft surfaces are measured 2- and 3-dimensional before and after the test runs. The wear of the sealing edges is evaluated with a recently developed laser line triangulation

method on the complete circumference of the sealing rings. Results show large amounts of wear, depending significantly on the operating conditions. We discuss the wear mechanisms and the correlations of wear effects in the tribo contact area of the sealing system.

9 - 9:30 am

3646391: Modeling of Mixed Friction on Rotary Shaft Seals under Consideration of Real Measured Surface Data

Jeremias Grün, Simon Feldmeth, Frank Bauer, University of Stuttgart, Stuttgart, Germany

Rotary shaft seals are machine components subject to high dynamic loads. They are used in complex applications where their lubrication conditions change rapidly. This study deals with numerical analysis of the lubrication condition of rotary shaft seals under different operating conditions. Measured surface data of rotary shaft seals serve as input for the numerical analysis. A mixed-EHL model involving a deterministic asperity contact model provides an investigation of the flow and solid contact. The approach presented aims at numerical determining different parameters for characterizing the sealing behavior of rotary shaft seals under different operating conditions. The dynamic lubrication gap height, hydrodynamic pressure, contact pressure, pumping rate and frictional torque quantify the lubrication condition. The results of the mixed-EHL model provide a realistic insight into the lubrication of rotary shaft seals in different operating conditions considering measured surface data.

9:30 - 10 am

3646402: Approach to the Description of Macro Lead Formation by Means of Kinematics Simulation

Georg Haffner, Matthias Baumann, Frank Bauer, University of Stuttgart, Stuttgart, Germany

Rotary shaft seals together with the shaft counterface form a tribological system. The interactions between these components determine the lifetime and the sealing function. In some cases, surface structures on the shaft counterface can create an unintended axial fluid flow through the sealing contact. This unbalances the sealing system and causes either dry run or leakage and therefore seal failure. These surface structures are called lead. Axially periodic and thread-like surface structures are called macro lead. The formation of macro lead is caused due to unfavorable grinding and dressing parameters in the manufacturing process. The functional interactions between manufacturing parameters and the formation of macro lead now has been investigated by means of a kinematic simulation tool. We present simulation results and give an overview about the functional relationship between manufacturing and resulting surface characteristics.

10 - 10:30 am - Break

1G

Northern Hemisphere A2

Grease I

Session Chair: TBD

Session Vice Chair: TBD

8 - 8:30 am

**3647897: High Performance Greases Toolbox: Synthetic Basestock Effect
A Study of the Influence of Synthetic Base Fluids on High Performance Greases**

Luca Salvi, ExxonMobil Chemical, Baytown, TX; Joe Kaperick, Afton Chemical Corporation, Richmond, VA

As demands on equipment productivity and reliability increases, it becomes more important to understand the impact of the base fluid in improving the performance of lubricating greases under more severe

conditions including higher loads and broader operating temperatures. This study was carried out to look at the performance of lithium complex greases produced with high vis metallocene PAO. Grease variations incorporated AN and EP polymer. A performance additive package was used in each of the base greases and were benchmarked against a mineral oil formulation. Performance of the base greases, as well as fully additized finished greases, were evaluated in a comprehensive study including a wide range of testing to evaluate high/low temperature performance, seal compatibility, and ability to protect against oxidation, wear, extreme pressure, and corrosion. Testing included evaluation against NLGI GC-LB and the new HPM specs. Impact of consistency is included comparing NLGI 1 and 2 greases

8:30 - 9 am

3648467: The Churning Mechanism in Grease Lubricated Rolling Bearings: Identification and Characterization

Sathwik Chatra K R, SKF, Houten, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Utrecht, Netherlands; Jude Osara, University of Twente, Enschede, Netherlands

The running process of a grease-lubricated bearing can be separated into two phases: the churning phase and the bleeding phase. The churning phase is characterized by a very transient high-temperature profile while the bleeding phase has a steady low-temperature profile. During the churning phase, the grease will experience high levels of shear resulting in degradation. Churning duration and intensity are grease-dependent. Here, we classify greases into “good/peak-type churning” greases and “poor/plateau-type churning” greases. The grease property responsible for this behavior is microstructural flexibility. Churning also consists of two phases: channeling and clearing. During the channeling phase of churning, a grease channel is created, and during the clearing phase, excess grease from the raceways is removed via side flow caused by over-rolling. The clearing phase is the longer of the two. Experimental results from lithium greases in 6204 DGBB bearings verified observed mechanisms.

9 - 9:30 am

3647990: A Model to Study Lubricating Grease Rheology: Exploring Molecular Dynamics Simulations

Femke Hogenberk, Sissi de Beer, Jude Osara, University of Twente, Enschede, Overijssel, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Utrecht, Netherlands

In the initial phase of bearing operation, the rollers in a bearing form a channel through the grease. For “good” channeling greases, this is formed easily. For “poor” channeling greases, it takes much longer, leading to increased degradation of the grease structure. Currently, it is unclear why a certain grease would be a good or poor channeling grease. This complex phenomenon is difficult to characterize due to experimental limitations. Here, we explore a potential solution via molecular dynamics modeling of grease. Simulations are performed to study the viscosity and the storage and loss moduli. The effects of fibre density, length, flexibility, and temperature are investigated. A Dissipative Particle Dynamics (DPD) thermostat represents the grease base oil in this study. Optimal fibre dimensions and equilibration time are obtained. This work provides the basis for future investigations into and experimental verification of the various effects of grease parameters on channeling.

9:30 - 10 am

3646574: Scale Up of a Preformed Polyurea Thickener for Grease.

Lauren Huffman, John Cuthbert, Kevin Capaldo, Bruce Hook, Dow Chemical, Midland, MI

Lithium based greases are the most common, but as electric vehicles become more popular, lithium availability is declining and prices are rising because of the demand of lithium for batteries. Other grease thickeners will need to fill in the gap left by lithium, and polyurea is a good candidate for many applications. However, polyurea based greases formed in-situ necessitate the handling of isocyanates which can be difficult and dangerous to work with and require special engineering controls to do safely. This presentation is on the scale up of a solid pre-formed polyurea based thickener for grease, which eliminates the need for a grease manufacturer to handle isocyanates. The efficiency and performance of the thickener will be covered.

Biotribology I

Session Chair: TBD

Session Vice Chair: TBD

8 - 8:30 am

3668367: A Multiphysics Modeling Approach to Wear and Lifetime Prediction of Dual Mobility Hip Implants

Nia Christian, C. Fred Higgs III, Rice University, Houston, TX

Dual mobility hip implants are thought to offer an increase in patient flexibility and range of motion over single mobility hip implant designs, however there have been concerns about increased wear in dual mobility designs due to the increase in moving parts. Due to the use of polyethylene in the acetabular cup, accurate modeling of the wear process in dual mobility designs plays a crucial role in joint lifetime prediction. While many studies using mechanical hip simulators have been done to approximate wear in dual mobility hips, these studies use highly simplified input kinematics instead of real data from patients with artificial hip implants. In this work, a mixed lubrication modeling framework, able to scale to relevant timescales for physical activity for a hip implant, has been constructed using patient specific movement data in an effort to predict implant wear differences amongst patients with different gaits and physical activity levels.

8:30 - 9 am

3668774: Structural Insights Into the Interaction Between Hyaluronan and Phospholipids

Tooba Shoaib, Wei-Ren Chen, Changwoo Do, Oak Ridge National Lab, Knoxville, TN; Justin Silberman, UFL, Gainesville, FL; Rosa Espinosa-Marzal, University Of Illinois at Urbana-Champaign, Urbana, IL

Interactions between molecules in the synovial fluid and the cartilage surface play a vital role in the formation of adsorbed layers, which mediate low friction via boundary lubrication. Here, the association between phospholipids and hyaluronan has been of particular interest. Phospholipids are found both as vesicles in the synovial fluid, and in the form of lamellar structures on the cartilage's surface, while HA is found abundantly in the synovial fluid. Both phospholipids and the HA can influence the lubrication behavior of the articular surface synergistically, yet studies on their self-assembly and resulting structures are limited. We will study the interactions between HA and lipids by scrutinizing the structural arrangements of HA-lipid mixtures via SANS experiments. Preliminary data from DLS for a mixture of HA and DPPC in tris buffer showed the solution to be highly polydisperse. By combining USANS and EQ-SANS we will cover the length scales observed by DLS (up to ~300 nm).

9 - 9:30 am

3668230: The Dynamic Fluid Equilibrium of Articular Cartilage During Activity

Steven Voinier, David Burris, University of Delaware, Newark, DE

Articular cartilage longevity is directly related to its ability to continually withstand its mechanical environment. The biphasic material leverages fluid within the tissue to promote lubricity and support load. However, loading the porous tissue leads to fluid exudation, reducing preferential support. Recently, Moore et al. demonstrated that activity, via sliding cartilage tissue under load, promotes tissue rehydration to combat exudation. When the exudation and rehydration rate equate, the tissue sustains a dynamic fluid equilibrium at a sample-specific fluid strain. In this study, we demonstrate that the dynamic equilibrium is independent of the sliding speed at physiological conditions, indicating that the rehydration mechanism is hydrodynamic in origin, but is limited by fluid uptake through the interface. Additionally, the equilibrium

fluid strain increases linearly with load, resulting in a less favorable mechanical environment that could increase disk of tissue damage.

9:30 - 10 am

3645584: Exploring the Biotribological Characteristics of Surface Functionalised PEEK for Focal Cartilage Resurfacing

Robert Elkington, Andrew Beadling, Richard Hall, Michael Bryant, University of Leeds, Leeds, United Kingdom; Hemant Pandit, Chapel Allerton Hospital, University of Leeds, Leeds, United Kingdom

Current use of hard biomaterials such as CoCr or ceramic to articulate against the relatively soft, compliant cartilage surface increases contact pressure by up to 500% which promotes erosion of the mating cartilage leading to pain and loss of function. Biomimetic soft lubrication strategies have been developed by grafting hydrophilic polymers onto substrates to form a gel-type surface. Polymer brush graftings mimic the natural biphasic and hydration lubrication modes of friction dissipation in synovial joints, showing a promising potential for use in cartilage repair. PEEK surfaces functionalized with highly hydrophilic anionic SPMK were assessed for their wettability, nanomechanical properties and graft density. Cartilage pin-on-plate testing with gait-like dynamic loading cycles demonstrated that SPMK grafted surfaces reduce friction by an order of magnitude compared to untreated biomaterials and exhibit behavior auxiliary to rehydrating cartilage to preserve its natural function.

10 - 10:30 am - Break

1J

Northern Hemisphere E1

Wear I

Session Chair: TBD

Session Vice Chair: TBD

Session Starts at 8:30am

8:30 - 9 am

3637599: Innovative Next-Generation Anti-Wear for New Industry Challenges

Christelle Chretien, Solvay, Bristol, PA

Growing demand for fuel economy, energy alternatives and durability, push the development of alternative solutions for components and additives for lubricants. In this context, Solvay has chosen new technology paths to develop sustainable anti-wears with enhanced performances and milder classification. The objective of this talk is to present an update on the development of next generation anti-wears especially based on a polymeric technology platform demonstrating performances of high potential.

9 - 9:30 am

3642599: Lubricity Improvements of N-Butanol Mixing in Ultra-Low-Sulfur Diesel: A Wear, Friction and Viscosity Study

Gustavo Molina, John Morrison, Valentin Soloiu, Cesar Carapia, Georgia Southern University, Statesboro, GA

Recent studies show that N-Butanol is a suitable alternative fuel for diesel engines. This study shows that N-Butanol in ULSD (ultra-low sulfur diesel) can also mitigate the wear effects of low-Sulphur-content in diesel fuels. Tribological studies of N-Butanol in ULSD mixtures by viscosity measurements, pin-on-disk tribometry and a crankcase lubricant interaction with oils are presented: Viscosity for the tested mixtures (of up to 35% of added N-Butanol) does not decrease below the recommended by standard ASTM D-975.

A unique wear minimum shows in tribometer testing for the 25% N-butanol in ULSD mixture, a wear reduction of 43% as compared to that of pure ULSD; the tribometer friction force evolution data supports that there would be a lubricity improvement around such dilution ratio. Finally, good compatibility of the NButanol/ULSD blend when mixed in engine oil is also successfully tested.

9:30 - 10 am

3642540: Wear Effects of Mineral Oil Dilution by Biodiesels: Is Viscosity Change or Methyl Ester Composition the Driving Factor?

Gustavo Molina, Emeka Onyejizu, Valentin Soloiu, Georgia Southern University, Statesboro, GA

The dilution of IC engine-oils by unburned biodiesels can substantially increase wear. Tribometer research shows varied levels of lubricity and viscosity degradations, which are very dependent on biodiesel feed-stock origin and composition, but it is not yet clear which one is the driving factor increasing the tribometer wear. Tribological studies are discussed of wear and lubricity testing by mixing individual methyl esters (as typical components of biodiesels) in SAE 15W40 mineral oil.

10 - 10:30 am - Break

1K

Northern Hemisphere E2

2D Materials + Superlubricity - Materials Tribology and Nanotribology I

Session Chair: TBD

Session Vice Chair: TBD

8 - 9 am

3669344: Mechanism of Graphite Lubrication Under High Mechanical Load

Martin Dienwiebel, Carina Morstein, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Solid lubricants are used in applications where liquid lubricants reach their limits. One of the well-known solid lubricants is graphite, showing distinct lubrication properties in normal atmosphere but severe wear and friction in vacuum. The most common explanation for the good lubrication properties of graphite is the deck-of-cards-model or lattice shear model postulated by Bragg et al. [1]. Up to this day, this model is highly debated. Our research aims to shine light onto the mechanisms, properties, and limits of graphite lubrication under high mechanical load (> 1 GPa). Experiments were conducted in a microtribometer under reciprocating linear sliding. The sliding track and graphite layers were analyzed by confocal microscopy, SEM, FIB, and HR-TEM. Additionally, detailed MD simulations were performed under different amount of water. We show that the lattice shear model is not valid for highly loaded contacts. Instead, low friction is caused by a turbostratic microstructure.

9 - 9:30 am

3669354: Role of Environment on the Shear Driven Structural Evolution of MoS₂ and Impact on Aging

Tomas Babuska, Tomas Grejtak, Lehigh University, Bethlehem, PA; John Curry, Michael Dugger, Sandia National Laboratories, Albuquerque, NM; Alexander Kozen, Sam Klueter, University of Maryland, College Park, MD; David Ramos, Florida A&M University, Tallahassee, FL; Kylie Van Meter, Brandon Krick, Florida State University, Tallahassee, FL

Due to prolonged storage in the presence of water and oxygen (aging) MoS₂ can degrade due to oxidation impacting the tribological properties such as initial friction and coating life. Practically, coatings are tested in lab air, resulting in different microstructures than inert environments due to interactions with H₂O and O₂. This work studies the effects sliding in lab air has on the evolution of the surface microstructure of MoS₂ coatings and the implications for aging resistance. TEM shows that sliding in air

and dry N₂ both result in a basally oriented surface. XPS taken on sheared and as-deposited regions show that sliding in lab air increases the amount of MoO_x at the surface. Interestingly, sliding in air allows for lower initial friction and shorter run-in to low friction before and after aging compared to an as-deposited surface. This work suggests that testing coatings in lab air before storage significantly improves the tribological properties after storage in H₂O and O₂.

9:30 - 10 am

3669363: Robust Vibration-Activated Lubricity

Arnab Bhattacharjee, David Burris, University of Delaware, Newark, DE; Nikolay Garabedian, Karlsruhe Institute of Technology, Karlsruhe, Germany; Brian Borovsky, St. Olaf College, Minnesota, MN

Friction can be reduced or eliminated when the contact interface is subjected to an external vibration; we refer to this phenomenon here as vibration-activated lubricity. According to prior literature, vibration-activated lubricity is limited to oscillation amplitudes and frequencies that depend strongly on case-specific experimental variables such as the instrument resonance frequency, sliding speed, and slip length of the tribo-pair. This study aims to overcome these limitations and clarify their origins. Specifically, we used a quartz crystal microbalance (QCM) to directly oscillate the sample at a fixed frequency and at oscillation speeds that exceeded the sliding speed by orders of magnitude. Under these direct oscillation conditions, vibration-activated lubricity persisted for alumina probes ranging from 50-1500 µm in diameter, loads from 20 µN - 5 mN, speeds from 5 µm/s - 1 mm/s, gold and MoS₂ samples, and two instruments – a custom microtribometer and a commercial AFM.

10 - 10:30 am - Break

1L

Northern Hemisphere E3

Power Generation I

Session Chair: TBD

Session Vice Chair: Salvatore Rea, Lanxess Corporation, Perkasie, PA

8 - 8:30 am

3644441: Demonstration of the Benefits of SAE 30 Monograde Stationary Gas Engine Oil

Zoe Fard, HollyFrontier Lubricants and Specialties, Mississauga, Ontario, Canada

Stationary gas engines are typically lubricated with SAE 40 monograde stationary gas engine oils (SGEOs). Despite the historic preference of gas engine OEMs for SAE 40 oils, several gas engine designs are capable to run safely on SAE 30 oils. This study evaluates the benefits of an SAE 30 monograde SGEO in comparison with SAE 40 monograde SGEOs with the focus on two main areas. First, to demonstrate and quantify the effect on the fuel consumption rate, and second to demonstrate the faster lubrication of hard to reach points (e.g. valve guide) in the engine during start up. The current industry recognized fuel efficiency test methods for passenger car and on-road diesel engine sectors are not suitable for evaluating the fuel efficiency performance of a gas engine oil because of the significant differences in fuel type, engine operating conditions, and oil formulations. This work, therefore, describes comparative studies of three different SGEOs in a fully instrumented MAN gas engine.

8:30 - 9 am

3647478: Gas Engine Oils with Enhanced Solvency Based on Novel Base Oil Blends

Thomas Norrby, Jinxia Li, Nynas AB, Nynashamn, Sweden; Franz Novotny-Farkas, Lubex Consulting OG, Schwechat, Austria; Christoph Schneidhofer, Jasmin Pichler, AC2T, Wiener Neustadt, Austria

Stationary gas engines are frequently employed to provide back-up electrical grid support, especially in combination with intermittent power generation from sources like wind and solar. The lubrication

requirements of the gas engine oil (GEO) are similar to other ICE engine oils but have additional challenges in matching fuel quality with GEO lubricity and thermal and oxidative stability. In this study, we investigate how the base oil selection with respect to solvency and thermal stability can be a design factor for novel GEO formulations with improved properties. Post-test run oil analyses were performed, and we show how blends of highly refined naphthenic base oils on combinations with paraffinic Group II and III base oils can provide improved cleanliness through better base oil solvency. This work was funded by the project COMET InTribology1, FFG-No. 872176 (project coordinator: AC2T research GmbH, Austria).

9 - 9:30 am

3668946: The Three Rs: A Sustainable Approach to Turbine Lubricant Maintenance

Matthew Hobbs, EPT, Calgary, Alberta, Canada

Sustainability and maintenance go hand-in-hand. By definition, something must be maintained for it to be sustained. To ensure sustainable power generation, turbine maintenance is, therefore, imperative. Despite its recognized importance, existing oil maintenance programs are often reactive instead of proactive in scope. Indeed, most programs target physical contamination without addressing the chemical causes of costly oil-related failures. This approach, inherently, treats turbine oils as consumables. For power generation to move towards true sustainability, however, oils must be regarded as assets to be proactively cared for rather than reactively replaced. Early sustainability programs highlighted the value of "The Three Rs" (Reduce, Reuse, Recycle). A different set of Rs are similarly effective with respect to making oil maintenance more sustainable: Rethink; Remove; Restore. By building on these pillars, turbine users can make meaningful contributions towards sustainability.

9:30 - 10 am

3646311: Power Plant Lubrication Reliability

Anshuman Agrawal, Minimac Systems Pvt Ltd, Pune, Maharashtra, India

An uninterrupted power supply is all that is needed to meet our lifestyle in the growing competitive world and the same is the goal of any power plant that is to maximize uptime by reducing the failure of the critical equipment involved in power generation like turbines, generators, boiler feed pumps, mills and many more. In a typical thermal power plant, the most challenging areas of lubrication maintenance are the Coal handling plant, Boiler, Turbine, and the Governing system where maintaining the cleanliness level of Lubricating fluid is of utmost priority. With this technical paper, we attempted to present the challenges associated with lubrication maintenance in a power plant and some important measures to achieve equipment Reliability. Our focus is to minimize downtime and maximize uninterrupted power generation.

10 - 10:30 am – Break

1M

Northern Hemisphere E4

Rolling Element Bearings I

Session Chair: TBD

Session Vice Chair: TBD

8 - 8:30 am

3637818: In-Situ Measurement of the Oil Film Meniscus at the Entry and Exit of a Rolling Bearing Contact

William Gray, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, United Kingdom

This work describes the use of ultrasonic sensors, instrumented to take measurements of the presence and thickness of the lubricant film at the contact entry and exit of a full-size wind turbine gearbox

cylindrical roller bearing. As ultrasonic waves can propagate through solid and liquid media, direct access to the lubricated surfaces is not required and measurements are truly in-situ, unlike more conventional methods. Results show that lubricant viscosity is the greatest determining factor for healthy lubrication, with less viscous oils being unable to develop a meniscus of adequate length. Bearing rotation rate was also crucial, with higher velocities being able to develop a more stable, repeatable meniscus at the contact inlet. Load was found to predominantly affect the outlet meniscus. This work shows the potential of ultrasound to be used as a lubricant monitoring tool in industrial bearings, helping to avoid premature failure due to inadequate lubricant supply.

8:30 - 9 am

3646294: In-Situ Measurement of Roller Skew and Lubricant Film Change Within a Rolling Element Bearing

William Gray, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, United Kingdom

Rolling element skew, where a rolling element pivots about an axis normal to the roller-raceway contact, causes an increased frictional force between a roller end-face and flange and reduces bearing life. Ultrasonic reflections are very sensitive to bearing contact conditions, meaning they can be used to observe and time a contact passing over a sensor location. Additionally, the same reflections are sensitive to the lubricant thickness within the contact centre, with micron changes altering the reflection amplitude. In this work, ultrasonic sensors are instrumented across the axis of a cylindrical roller bearing test rig. The change in contact time across the axis is used to calculate roller skew, and results are presented with the corresponding change in film thickness. Results show that as a roller skews, the lubricant film thickens on one half of the roller and thins on the other. This occurs for all viscosity oils and greases tested.

9 - 9:30 am

3645188: Grease Performance in Ball and Roller Bearings for All-Steel and Hybrid Bearings

Piet Lugt, Marco Van Zoelen, Charlotte Vieillard, SKF Research and Technology Development, Houten, Netherlands; Frank Berens, SKF France, St-Cyr-sur-Loire, France; Robert Gruell, Paul Meaney, SKF Germany, Schweinfurt, Germany; Gerwin Preisinger, SKF Austria, Steyr, Austria

Grease life in hybrid bearings is longer than that in all-steel bearings. This will be shown in this paper by means of grease life tests with a large number of greases for both Deep Groove Ball Bearings (DGBB) and Cylindrical Roller bearings (CRB). The results show that grease life for hybrid bearings is always larger than that for equivalent all-steel bearings and that this varies between a factor 2 and 9 depending on the grease type that is used. For cylindrical roller bearings grease life does not increase with decreasing speed below a minimum value. However, also at these relatively low speeds, hybrid bearings give a longer grease life than all-steel bearings.

9:30 - 10 am

3645644: Analyzing Ball Bearing Capacitance Using Single Steel Ball Bearings

Steffen Puchtler, Julius van der Kuip, André Harder, Eckhard Kirchner, TU Darmstadt, Darmstadt, Germany

A precise modeling of the capacitance of rolling element bearings is of increasing significance over the last years, e.g. in the context of bearing damage estimation in electric drives. The complexity of a steel bearing as an electrical network makes reliable validation of calculation models under realistic operating conditions nearly impossible. A way to reduce complexity in yet realistic conditions is the use of hybrid bearings with a single steel rolling element. This helps to measure only one current path through the bearing at a time and thus, gives a much clearer picture of the contact capacitance of rolling elements in and out of the load zone. The usage of different materials comes with different thermal expansion coefficients and different elasticities, which cause a significant change in load distribution. For the first time, this work considers both of these effects in calculation and validates them with corresponding experiments using single steel ball bearings.

10 - 10:30 am – Break

2A

Southern Hemisphere I

Electric Vehicles II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3669482: Additives for Improving Efficiency and Durability of Drivetrain Lubricants for Electric Vehicles.

Alexei Kurchan, Jacob Wegbreit, Croda Inc., Princeton, NJ

Future developments of electric vehicles will continue to focus on increasing single-charge range while controlling manufacturing and raw materials costs. Longer driving ranges can be achieved through progress in battery technology combined with improvement in the efficiency of the electric motor and drivetrain. Development of dedicated lubricants will provide for minimizing frictional and churning energy losses. Formulating drivetrain lubricants for electric vehicles present a unique challenge of minimizing energy losses, controlling corrosion of electrical components, coatings, and insulation compatibility, as well as maintaining excellent anti-wear, fatigue, and oxidation stability. These unique requirements drive development of new baseoils and additives. We will present our work on development of novel additives allowing formulation of lubricants with improved wear protection, friction, and traction characteristics in mixed and elastohydrodynamic lubrication regimes.

2 - 2:30 pm

3669347: Polymeric Additives as an Optimum Solution for Performance and Compatibility Challenges in E-drive Fluid Design

Peter Moore, Dmitriy Shakhvorostov, Stefan Wieber, Andreas Hees, Roland Wilkens, Evonik Oil Additives, Horsham, PA

An overview of the critical electric axle lubricant requirements and how tailor-made viscosity index improvers contribute to the full formulation performance in optimization of e-axle efficiency, electric conductivity, reduction of copper corrosion, thermo-oxidative stability, heat transfer, and low temperature performance. Tests used current industry standard ASTM and ISO methods, state-of-the-art methods for EV applications, and a modern E-drive gear box. Comb-like polymers in the fluids allowed use of a wider range of base stocks, which enabled the formulations to achieve significant reduction of gear box losses (>10%) as well as boosting heat transfer at relatively low temperatures. Targeted functionalization of polymers provided additional features, such as dispersancy and film-forming, with insignificant increases in electrical conductivity. Functionalization of polymers also helped withstand detrimental effects associated with the fluid aging (deposits and thickening).

2:30 - 3 pm

3648063: The Performance of Low Viscosity and Ex-High VI Engine Oils with MoDTC under Hybrid Electric Vehicles

Kenji Yamamoto, Shinji Iino, Yukiya Moriizumi, ADEKA Corporation, Arakawa, Tokyo, Japan

Electrified ICE equipped vehicles such as HEV and PHEV are considered to be important to reduce the CO₂ emission for coming decade or using synthetic fuels made with renewable energy. Hybrid electric systems which operate its engine under low temperature more frequently, the effect of ultra-low viscosity engine oil for FEI would be significant. However, high temperature performance cannot be sacrificed because it is elevated as high as conventional ICE during long driving and high load operation. As it becomes more important to reduce engine friction under wide range of temperature, Ex-high VI engine

oils are being considered. In this study, the FEI performance is evaluated with the latest GF-6 and Ex-High VI formulation, under several types of engines with different displacements, including those for HEVs. MoDTC formulated Ex-high VI engine oil demonstrated significantly improved fuel economy performance than the latest GF-6 formulations under both conventional ICE and HEV systems.

3 - 4 pm - Break

4 - 4:30 pm

3669304: A Study of the Effects of Foam and Defoamer Performance in Electric Vehicle Fluids

Safia Peerzada, Stefanie Velez, Munzing Chemie GmbH, Bloomfield, NJ

Green, eco-friendly, and sustainable technology has become the future of the automotive industry causing a significant increase in the effort to develop Electric Vehicle Fluids. These lubricants exhibit different foaming tendency compared to traditional automotive fluids due to the difference in system chemistry, which requires different defoamer chemistry and test methods to simulate real world application. During use of the fluid, the defoamer functions to minimize foam buildup, which is undesirable for reasons such as reduction of lubrication and heat removal. A study of foam tendency in Electric Vehicle fluids using new lab foam test methods will be reviewed. Furthermore, the performance of various defoamer chemistries will be studied to understand the most optimal defoamer type for Electric Vehicle fluids.

4:30 - 5 pm

3663659: Impact of High Speed Operation on Lubricant Aeration in an Electric Drive Unit

Cole Frazier, Marshall Hudson, Caroline Mueller, Southwest Research Institute, San Antonio, TX

Compared to internal combustion engines, drive motors used in electric vehicles typically spin at much higher speeds. Current vehicles contain motors running up to 20,000 RPM, with trends moving towards faster speeds. Electric drive lubricants must perform in these high-speed environments – protecting gear interfaces and cooling components. The degree to which air is entrained in the lubricant as it makes contact with rotating components at 15,000+ RPM is currently not well quantified. Air entrainment in the lubricant can cause poor heat transfer and reduce wear protection. In the experiment described herein, the phenomenon of air entrainment was investigated. An electric drive unit was run in a laboratory setting with high speed data acquisition. Air entrainment was then measured across various operating conditions. Results showed an increase in air entrainment with both increasing speed and temperature, along with differentiation between fluids of varying aeration performance.

5 - 5:30 pm

3647009: How New E-Fluid Formulation Enable Efficiency and Better Performance Under High Speed Conditions

Torsten Murr, Shell Global Solutions Germany, Hamburg, Hamburg, Germany

For a number of years fluids for BEV s are available in the market. This first generation of fluids was able to satisfy the basic requirements on gear/ bearing protection, material compatibilities and fulfilling electrical requirements.

An obvious next generation of BEV Fluids in looking for further efficiency gains which reads direct into a more extended driving range. Based on this the presentation discusses the following topics: * Reflecting trends on adaption of ultra low viscosity fluids for BEV, * Efficiency Driveline testing with low and ultra low viscosity fluids

* Formulating high performing fluids for electric racing, * Safety risks and characteristics of ultra low vis formulation in realistic operating conditions

5:30 - 6 pm

3669345: Enabling Next Generation E-Fluids for Mobility, Electronics and Energy

Kai Wirz, Evonik Corp., Richmond, VA

Evonik provides innovative solutions for rising technologies in mobility, electronics, and energy. Applications including power electronics, e-drives, and battery thermal management benefit from a strong history in lubricants and metalworking fluid additives. Evonik Interface and Performance is one of the leading partners in specialty additives for critical performance enhancing effects, such as corrosion inhibitors, defoamers, friction modifiers, wetting agents, and lubricity enhancers. E-Mobility is changing the landscape of fluids and the related additives in order to meet demanding performance requirements. E-fluids for electric motors and batteries require additives that provide efficiency enhancing effects that serve the special requirements, for example in thermal management and lubrication. Evonik Interface and Performance offers a broad range of solutions for these applications, strong customer focused development and service for these demanding applications.

2B

Southern Hemisphere II

Lubrication Fundamentals II – Contact Models II

Session Chair: Gerhard Poll, Leibniz University Hannover, Hanover, Germany

Session Vice Chair: TBD

1:30 - 2 pm

3646378: Numerical Study of the Validity of the Reynolds Equation in the Nanoscale

Andrea Codrignani, Kerstin Falk, Michael Moseler, Fraunhofer Institute for Mechanics of Materials IWM, Freiburg, Germany

In this work we aim to extend the validity of the traditional Reynolds equation in order to include typical aspects of nanoscale lubricant flows such as shear thinning, near wall effects and the partial slip of the first layer of lubricant at the liquid/solid interface. To achieve a proper description of these phenomena, we analyzed the flow of a mineral oil base (hexadecane C₁₆H₃₄) in a representative geometry of a lubricated contact (i.e. both parallel and converging-diverging channels) and we carried out a comprehensive parametric molecular dynamics study in order to analyze the influence of mild to severe operating conditions. As results we proposed a model to describe the occurring of slip at the nanoscale which is based on the local and the operating conditions of the system. The implementation of this model into the Reynolds equation results in an extension of the applicability of the latter and hence in a more computationally efficient way to describe lubricated nanosystems.

2 - 2:30 pm

3648103: Numerical Simulation of Contacts Working Under Mixed Lubricating Conditions

Ruchita Patel, Zulfiqar Khan, Adil Saeed, Bournemouth University, Bournemouth, Dorset, United Kingdom; Vasilios Bakolas, Schaeffler Technologies AG & Co. KG (Schaeffler Group), Herzogenaurach, Germany

Mixed lubrication offers significant asperity contact in severe loading conditions, which can initiate surface pitting and scuffing failure. Over the years there has been an increased interest in modelling and analysis of mixed lubrication regions, to avoid severe damage on the surface. However, a few researchers have addressed the problem by using Reynold's equation, which assumes that a minimum thickness of lubricant film always exists between the contacts. Therefore it's uncertain that Mixed Lubrication (ML) can be modelled with the Reynolds equation. The current research presents a theoretical and mathematical background of asperity contact in mixed lubrication including CFD results which are compared with numerical simulation results with multilevel methods in lubrication. This paper discusses scientifically proven Mixed Lubrication theory based on numerical simulation of EHL models (Reynolds' equation) and is unique in addressing the roughness interaction within the Mixed region.

2:30 - 3 pm

3664184: Lubrication-Contact Interface Conditions and Novel Mixed/Boundary Lubrication Modeling Methodology

Shuangbiao Liu, Q Jane Wang, Yip-wah Chung, Northwestern University, Evanston, IL; Stephen Berkebile, US DEVCOM ARL, Aberdeen Proving Ground, MD

Under severe conditions, solid contacts take place even when parts are lubricated. Precise mathematical conditions are needed to describe the interior interface between fluid lubrication and solid contact zones. In order to distinguish the conditions for this interface from conventional lubrication boundary conditions, they are named lubrication-contact interface conditions (LCICs). In this work, mathematical LCICs are derived with local flow continuity from the continuum mechanics point of view and pressure inequality across the interface. Numerical implementations are developed and tested with problems having simple geometries and configurations, and they are integrated into a new mixed/boundary elastohydrodynamic lubrication (EHL) solver that uses a new method to determine solid-contact pressures. This solver is capable of capturing film-thickness and pressure behaviors involving solid contacts.

3 - 4 pm – Exhibitor Appreciation Break

4 - 4:30 pm

3664197: Analyzing Transient Mixed Elastohydrodynamic Lubrication Considering Lubrication-Contact Interface Conditions

Shuangbiao Liu, Nicole Dorcy, Q Jane Wang, Yip-wah Chung, Northwestern University, Evanston, IL; Stephen Berkebile, US DEVCOM ARL, Aberdeen Proving Ground, MD

In order to design tribological interfaces to meet required fatigue/wear lives and avoid scuffing, pressure and film thickness distributions are needed among other performance characteristics. Transient mixed EHL analyses involving asperity contacts were conducted to obtain these distributions in circular contacts with various asperities under pure rolling, simple sliding, and rolling/sliding conditions. An axisymmetric finite element model was built to quantify the effect of an asperity in the microscale on surface vertical displacement. This model simultaneously solves the Reynolds equation for lubrication regions, the zero-gap equation for the other locations during numerical iteration, and the load balance equation, particularly with the enforcement of complete interface conditions between lubrication and solid contacts. Transient EHL under unidirectional and reciprocating motions are analyzed to support laboratory tests and to facilitate understanding of engineering problems.

4:30 - 5 pm

3669192: Thermal Investigations into EHL Contacts –Determination of Solid Body Temperature at Lubricant Interface

Norbert Bader, Haichao Liu, Dilek Bulut, Gerhard Poll, Leibniz University Hannover, Germany, Germany

Elastohydrodynamically lubricated (EHL) contacts are found in numerous machine elements. To increase efficiency and reduce energy consumption better understanding of friction generation is necessary. It is dominated by lubricant rheology. As temperature is drastically changing lubricant behaviour the knowledge of local temperatures is important. In this work we present results from experiments with a twin-disc experiment where the local contact temperature was measured via infrared camera. Using a numerical method, the radiation components of the elements of the lubricating gap (film, surfaces) could be determined independently. Combined with simulation results the influence of each element's temperature and the individual heating behaviour could be shown. Furthermore, in the simulations it could be investigated how physically sound rheological models can yield good agreement with experiment. This work contributes to better understanding and improved prediction of friction generation.

5 - 5:30 pm

3640731: Tribology for the Soul – How the Science of Tribology Can Help Companies (and People) Succeed

Michael Holloway, 5th Order Industry, Highland Village, TX

Friction, wear, and lubrication is typically considered the stuff of machines. Drawing a comparison between a bearing or gear set to the human condition is ripe for consideration. Humans require analogies, comparisons, similes, and poetic content to make sense of their world. While a world built on logic seems utopian it is not realistic, maybe never; we still use comparisons to understand and communicate. When examining a machine, the dynamics of a department, the working of a company or even a relationship, they all experience failure as well as a means to succeed. This presentation draws comparisons between the world of tribology and leadership as well as human interaction with the objective to learn how to utilize tribology to make your company and life run smoother.

2C

Southern Hemisphere III

Commercial Marketing Forum II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm - Clariant Corporation

2 - 2:30 pm - Kao Corporation USA

2:30 - 3 pm - The Lubrizol Corporation

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm - ANGUS Chemical Company

2D

Southern Hemisphere IV

Tribotesting II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3650703: Prediction of Retention of Fuel economy Capability in Aged Fully Formulated Fuel Economy Engine Oils containing Soluble Molybdenum Friction Modifiers using Laboratory Scale Bench Tests and Correlation with the Field Performance

Sanjay Kumar, Y Rao, David Hall, Chidambaram C T, Jencen Arivannoor, Vinod D, Vinith Kumar, Gulf Oil International, Chennai, Tamil Nadu, India

Molybdenum containing fuel economy engine oils lose their friction reduction capabilities over usage. In Sequence VI engine tests, an aging stage is included in which oil is aged within the engine before evaluation of fuel economy. The efficacy of friction modifier containing oils is currently estimated in a laboratory on a Linear Reciprocating Friction Tester. This study deals with a laboratory study to predict the effect of aging on the long-term fuel economy of friction modifier containing engine oils based on retention of its coefficient of friction values. The Aging of the oil sample in the laboratory was achieved through an oxidation test. Aging in the field was carried in a field trial. The aged samples were evaluated

on the Friction Tester to determine the coefficient of friction. Six friction modifier containing oils were evaluated. The study shows that aging effect can be predicted in laboratory scale bench tests and that the results correlate well with field performance.

2 - 2:30 pm

3644378: Electrical Impedance Spectroscopy to Study Sooty Engine Oils

Thomas Kirkby, Tom Reddyhoff, Imperial College London, London, United Kingdom; Mark Fowell, Volvo Group Trucks Technology, Göteborg, Sweden; Joshua Smith, Jacqueline Berryman, Infineum UK Ltd, Abingdon, United Kingdom

Electrical impedance spectroscopy (EIS) is a powerful tool used to determine electrochemical properties; however, it is underutilized in the field of lubricant monitoring. Soot is a problem in engines and can influence additives, leading to wear. Hence, a novel EIS probe was designed to monitor bulk properties of engine oils. Engine oils with specific additives removed were studied to identify the additive influence on resistance and capacitance. Results were compared with used sooty engine oils obtained from real-world field testing from heavy-duty diesel engines. This revealed that a higher soot content exhibited a lower resistance and higher capacitance than clean engine oils. High frequency reciprocating rig (HFRR) tests were also used to correlate bulk lubricant properties with friction and wear data, enhancing the understanding of the interactions between soot and different additives. This paves the way for EIS to be applied in both lab-based and online testing of engine oils.

2:30 - 3 pm

3645314: Adhesive Wear Performance of Specialty Bearing Steels

Daulton Isaac, Mathew Kirsch, Alexander Fletcher, AFRL Turbine Engine Division, Wright Patterson Air Force Base, OH; Hitesh Trivedi, UES Inc., Dayton, OH

In an effort to understand the parameters influencing a particular steel's tendency to scuff, a campaign has been undertaken in recent years to investigate this phenomenon in a wide array of steels. This most recent batch of bearing steels evaluated for their adhesive wear performance includes two high nitrogen stainless steels (HNS): CRONIDUR 30 and XD15VDW, powder metallurgy (PM) steels: T15 and CPM-REX76, and a carburizing stainless steel CX13VDW. HNS have excellent corrosion resistance but poor adhesive wear or scuffing resistance. PM steels are known for having favorable hot hardness. High chromium cobalt free CX13VDW is tested for comparison with Pyrowear675 (P675). Based on current and previous adhesive wear testing results, suggestions will be made as to the possible features of a steel that promote favorable scuffing resistance.

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm

3645609: Novel Compatibility Test of Seal Materials and Lubricants Under a Dynamic Stress Collective

Ameneh Schneider, Optimol Instruments, München, Germany

The ISO 1817 standard ("Rubber, vulcanized or thermo-plastic - Determination of the effect of liquids") is a method by which the resistance of vulcanized or thermo-plastic elastomers to liquids is tested. Sealing's damages caused by tribological-dynamic issues can often be observed in machineries. These damages result among others also from the counter surface, the lubrication and type of lubricant, the sliding speed as well as the temperature. Braun described the challenges of static test very well. This work represents added value to static compatibility test with conditions near to applications.

4:30 - 5 pm

3677562: Novel Method for Evaluating Lubricants in HD Bearing Interfaces

Michael Moneer, Peter Lee, Carlos Sanchez, Southwest Research Institute, San Antonio, TX

A methodology for evaluating friction and wear performance of lubricants against main bearings was developed. Modeled after a block-on-ring test configuration, this bench top test undergoes dynamic

speeds and loads under fully lubricated conditions in an effort to simulate the real system. Main bearings from heavy duty diesel engines were machined to fit the test geometry which presents an opportunity to evaluate new bearing materials and coatings in addition to lubricant formulations. Test results have shown to be effective in ranking the performance of material pairs and lubricants. This new method presents the opportunity for screener testing when developing new oil formulations as well as bearing materials and coatings.

5 - 5:30 pm

3647051: How Can We Evaluate the Frictional and Wear Performance of Shock Absorbers on the Lab-Scale: A New Tribological Approach

Emmanuel Georgiou, Dirk Drees, Lais Lopes, Michel De Bilde, Falex Tribology, Rotselaar, Belgium

Component testing is typically costly and time-consuming, and thus inappropriate for R&D activities. Researchers are inevitably forced to perform tribological analysis in simplified test rigs that do not always simulate the actual contact. For example, pin-on-disk tests under dry conditions are sometimes used to characterize shock absorbers. However, in the actual application the contact pressure is much lower (area contact), and the contact always operates under a thin layer of lubrication. It is essential to develop tribological methods that generate the same wear mechanisms as in the components. These methods should also provide additional information (e.g. friction evolution) that can assist in the further development and optimization. Having the above in mind a new test method was developed to directly test shock absorber components and to provide a meaningful relative ranking of both the wear resistance and frictional performance.

5:30 - 6 pm

3664941: Evaluation of cryogenic Pin-on-Disk Test to Improve Sliding Friction Interaction of Cryogenic Solid-Lubrication

Wonil Kwak, Yongbok LEE, Korea Institute of Science and Technology, Seoul, Republic of Korea

In the interaction of solid lubrication, the friction mechanism can determine the effect on the bearing performance of cryogenic fluids (liquid nitrogen) through tribometer experiments. In this study, friction mechanism analysis was performed considering the coupling of bearing friction characteristics and fluid dynamics by the dynamic interactions between the bearing components. In addition, in order to improve friction performance in a cryogenic environment, a pin-on-disk test was conducted according to various composite materials. The purpose of this study is to understand the correlation between parameters affecting the improvement of solid lubrication performance in cryogenic fluid environments and diagnostic parameters for predicting the lifetime. In particular, this paper proposes a dimensionless friction coefficient classification factor that can satisfy an appropriate wear rate and predict its lifetime for the operating stability of ball bearings.

2E

Southern Hemisphere V

Surface Engineering II

Session Chair: Auezhan Amanov, Sun Moon University, Asan, Republic of Korea

Session Vice Chair: Suvrat Bhargava, TE Connectivity, Middletown, PA

1:30 - 2 pm

3677795: Effect of Ultrasonic Needle Peening on Subsurface of Bronze casting alloy Caused by Fretting Wear

Seunghyon Song, Auezhan Amanov, Sun Moon University, Asan, Republic of Korea; Insik cho, Mboria, Asan, ChungNam, Republic of Korea

Bronze casting alloy is widely used for manufacturing engine bushing and bearing owing to the high corrosion, cavitation, and wear resistances. In this study, the samples made of NAB was subjected to ultrasonic peening technology with the aim of improving the fretting wear by eliminating casting defects such as voids, pores, etc. from the microstructure. The fretting wear behavior of the unpeened and peened bronze casting alloy samples fretted against SAE 52100 steel ball was evaluated using a high-frequency fretting machine. Cross-sectional microstructural evolution of the underneath fretting-induced wear and subsurface layer of the unpeened and peened samples were comprehensively discussed.

2 - 2:30 pm

3663198: Post-Thermal Spray Coating Surface Modification for Sliding Wear and Adhesion Strength

Auezhan Amanov, Sun Moon University, Asan, Republic of Korea; Stephen Berkebile, US DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

In this study, the effect of ultrasonic nanocrystal surface modification (UNSM) on wear and adhesion strength of two different Cr_2O_3 and Cr_3C_2 coatings was investigated. The objective of this study is to find an optimum coating for the application of a high-pressure common rail injection system, which operates under fuel-lubricated sliding conditions. The effect of UNSM treatment on the coefficient of friction (COF) and specific wear rate (SWR) was more pronounced to the Cr_3C_2 coating than Cr_2O_3 one against SAE 52100 steel, Si_3N_4 and Al_2O_3 in F24, dodecane and ethanol. The improvement in COF and SWR of the coatings was attributed to the reduction in surface roughness and formation of nanostructured layer having lower shear strength with good lubricating properties. The scratch-induced adhesion strength of the UNSM-treated coatings was found to be higher in comparison with the as-sprayed coatings due to the changes in microstructure and hardness.

2:30 - 3 pm

3669371: Development of Self-Lubricating Metal Alloys Using Laser Metal Deposition

Manel Rodriguez Ripoll, Hector Torres, AC2T research GmbH, Wiener Neustadt, Austria

This work presents the development of self-lubricating metallic alloys for laser deposition processes, as they offer a great flexibility and efficiency compared to traditional subtractive manufacturing processes. However, the extreme thermal conditions during deposition and the rapid cooling times pose great challenges in the alloy design. These challenges are illustrated using self-lubricating iron and nickel-base alloys incorporating lubricious soft metals and metal sulfides. The self-lubricating laser deposited alloys can control friction from room temperature to 600 °C in ambient air. In vacuum conditions, they can effectively reduce friction down to 0.25 without the aid of an additional lubricant against martensitic stainless steel at 300 °C. This overall tribological performance makes the presented self-lubricating alloys potential candidates for high temperature forming and space applications.

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm

3669286: A Study on the Influence of Spray Parameters on Adhesion of Cr3C2-NiCr Plasma Coating on Steel Substrate

Cuong Pham, Hanoi University of Industry, Hanoi, Viet Nam

This paper investigates the effect of spraying parameters including plasma current, powder feed rate and stand-off distance on the adhesion strength of Cr3C2-NiCr coated on 16Mn steel substrates by plasma spraying technique. The experiments were carried out according to the central composite design (CCD) method. Adhesion strength was measured in two directions perpendicular and parallel to the sample surface using a tensile compression tester. Quadratic polynomial regression models were developed to predict the adhesion strength of the coating in both directions. Results showed that the sprayed parameters significantly affected adhesion of the coating in both directions, in which the plasma current was the most influential parameter, followed by the stand-off and powder feed rate, respectively. In addition, optimization were performed to find out the spray parameters at which the adhesion of Cr3C2-NiCr coating to 16Mn steel reached highest value.

4:30 - 5 pm

3668698: Enhancing the Tribology of TWAS-Coated Cylinder Bores by Using the Triboconditioning(R) Process

Boris Zhmud, David Chobany, Applied Nano Surfaces Sweden AB, Uppsala, Sweden; Eduardo Tomanik, USP, Sao Paulo, Brazil

Despite the proliferation of e-mobility applications, the internal combustion engine (ICE) is going to be with us for decades to come in hybrid electric vehicles run on hydrogen and e-fuels. Hence, the development of low friction powertrains remains an important task. Advanced surface finishing and coating methods, such as thermally sprayed coatings and mechanochemical surface finishing, help improve fuel economy and reduce emissions.

TWAS (twin wire arc spraying) thermal spray coating technology is used by a number of car manufacturers for aluminum engine blocks. However, conventional carbon-steel TWAS coatings tend to have poor corrosion resistance. The use of stainless steel may address that problem but undermines the tribological properties increasing the risk of scuffing. The present study shows how the Triboconditioning(R) process implemented as the finish honing operation can be used to enhance the tribological properties of TWAS-coated cylinder bores.

5 - 5:30 pm

3669312: Tribological Test of Tungsten Disulfide Solid Lubrication Exposed to Simulated Space Environment

Ayaka Takahashi, AIST, Tsukuba, Ibaraki, Japan

Solid tungsten disulfide film can be use as a longer endurance lubrication than proven space lubricant at high vacuum with elevated temperature. Other space environmental properties also need to be evaluated in order to make tungsten disulfide to be option for space use. High-level radiation applied irradiation to the surface of tungsten disulfide coated on a SUS316L stainless steel substrate. It was confirmed that the coefficient of friction was low even after high-level radiation irradiated.

2F

Northern Hemisphere A1

Seals II: Mechanical and Elastomeric Seals

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3669268: Machine Vibration and Noise Effects on the Dynamics of Mechanical Face Seal

Itzhak Green, Georgia Institute of Technology College of Engineering, Atlanta, GA

Mechanical face seals are ubiquitous in many applications, such as centrifugal, submersible pumps, drill-bits (for oil and water), and turbopumps. Often vibration and noise are inevitable because of a constant changing environment which can be persistent and forceful. In critical applications if a seal fails it may have significant or even catastrophic consequences. While the exact root-causes and sources of machinery vibration is very difficult to ascertain, the current analysis uses some general common causes of noisy seal operation, and provides markers to be observed for diagnosis. Results show that under some design parameter, the seal response exhibits a rich spectral content that stems from various transient phenomena that include half-frequency whirl, synchronous steady-state response, and a rich spectral content.

2 - 2:30 pm

3645972: Numerical Transient Study of Two-Phase Flow in Inward Pumping Grooved Mechanical Seal

Abdel Salem Medjahed, Antoinette Blouin, PPrime Institute, Chasseneuil-du-Poitou, France; Noel Brunetiere, CNRS, Chasseneuil du Poitou, France; Balint PAP, Safran Transmission System, Colombes, France

This work studies the behavior of a mechanical seal in a two-phase environment (atmosphere on low pressure side and sealed fluid on the other side) in transient regime. One face of the studied seals contains inward pumping spiral grooves used to pump the external low pressure fluid and prevent leakage. The location of the boundary interface between the inner and outer fluids is then studied through numerical analysis. To determine the location of the boundary interface between the two fluids at each time step, a transport equation coupled with the transient Reynolds equation is solved using the finite element method. The model is then used to study the impact of the operating conditions including seal misalignment on the boundary location. In addition, several grooves geometries are used in the computation to find the best seal design.

2:30 - 3 pm

3647075: Measurement of Oil Film Thickness in Reciprocating Rubber Seals Using the Ultrasound

Rob Dwyer-Joyce, Xiangwei Li, Scott Beamish, Juanjuan Zhu, University of Sheffield, Sheffield, United Kingdom

Elastomeric seals function by allowing a finite leakage to lubricate the interface; but not so much to cause economic or environmental hazard. In this study, reflected ultrasound has been used to study the film formed by a rubber O-ring in reciprocating sliding. Measurements are challenging because the materials of seal and counterface are acoustically dissimilar so the measurement range when an oil film is interposed is small. Oil films were measured under varying speeds (2, 4, 6 and 8 Hz) and loads (10, 15 and 20 N). Central film thickness measurements were found to be in the range of 1.8 – 7 μm , which were comparable with predictions from the iso-viscous EHL models of Hamrock and Dowson and Nijenbanning et al. Measured contact size and oil film profiles were comparable with Hertzian simulations. Finally, the oil film along the reciprocating path was measured using an array of ultrasound sensors; this mapped the oil film formation covering the length of a reciprocating stroke.

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm

3645600: 3D Printed Surface Textured Seals with Superior Friction Properties

Markus Brase, Matthias Wangenheim, Leibniz University Hannover, Garbsen, Germany

The friction behaviour is an important property of dynamic seals. Surface texturing is an effective method to control the friction level without the need to change materials or the lubricant. However, the conventional production of surface textured seals is complex and expensive, in particular in the prototyping phase, when a variation of surface textures needs to be evaluated. Therefore, this study introduces novel 3D printed seals with surface textures. The textured seals are manufactured by using a Stereolithography printer. The textures are applied to the seal surfaces in the form of deterministic dimples. The geometry of the round dimples is defined by the diameter, distance, and depth. Based on the 3D printed seals, friction tests are performed to validate the positive effect of the 3D printed textures on friction.

4:30 - 5 pm

3647448: Bio-inspired pneumatic sealing disc of fluid-driven pipeline robot

Chunmei Yue, China University of Petroleum, Beijing, China

Pipeline inspection gauge (PIG) is a kind of pipeline robot used for pigging and internal inspection in the underwater oil and gas pipeline. However, the PIG is often stuck in the aging pipelines owing to the stacked objects and the limitation of its passive control. In this study, as for the elastomer material of the

PIG's sealing disc, a new type of sealing disc was designed combining with bio-inspired and soft robot technology to achieve its active control. First, the designed sealing disc was fabricated using 3D printing technology and multi-step molding, and the active control of it was realized by inflating the air chamber joints. Then the structure factors and material factors were studied and optimized using numerical simulation method to get the best performance structure. This study proposes an actively controlled bio-inspired pneumatic sealing disc of the PIG, provides a new idea to solve its blocking problems.

5 - 5:30 pm

3648363: High Temperature Sealing Advancements Utilizing Non-Contacting Gas Seal Technology

Robert McManus, John Crane Inc, Portsmouth, RI

Developments in gas seal technology now provide new technologies to solve challenging sealing applications in rotating machinery. Integrating a corrosion resistant, thermally compliant and pressure stable seal face assembly technology together with a completely non elastomeric design, high temperature gas seals can now be reliably applied in the most challenging applications. Dual gas seals can reliably seal hot and cold hydrocarbon process fluids found in process industries. High temperature gas seals eliminate the complexities and cost of the support system needed to reliably operate traditional single or dual wet contacting seal designs. Dual gas seals supported with an API plan 74 support system operate with zero emissions to atmosphere of the pumped fluid, have lower operating costs and a lower carbon footprint for the seal and support system.

2G

Northern Hemisphere A2

Grease II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3647445: Measuring Flim Thickness in Starved Grease Lubricated Bearings: An Improved Capacitance Method

Pramod Shetty, Robert Meijer, Jude Osara, University of Twente, Enschede, Netherlands; Rihard Pasaribu, Shell, Rotterdam, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Utrecht, Netherlands

Film thickness is a vital parameter that determines grease and bearing life. Measuring the film thickness in a real grease lubricated bearing is done by using the electrical capacitance method. In this paper, a new calibration method will be presented that significantly increases the accuracy of film thickness measurements when bearings are running under starved lubrication conditions. This method is subsequently used to study grease film thickness during the bleed phase as a function of speed for various temperatures. It was found that film thickness increases with speed showing similar behavior to base oil film thickness up to a certain speed. At higher speeds, it becomes almost independent of speed.

2 - 2:30 pm

3647029: How Does Temperature Affect Grease Adhesion and Tackiness?

Emmanuel Georgiou, Lais Lopes, Michel De Bilde, Falex Tribology, Dirk Drees, Rotselaar, Belgium; Erik Willett, Functional Products, Macedonia, OH; Michael Anderson, Falex Corporation, Sugar Grove, IL

Greases are extensively used in diverse applications, from machinery lubrication to demanding field like EV's or wind power. Their performance in the field is directly linked to their ability to adhere onto a surface (adhesion), and to form threads (tackiness) when pulled apart, so that the transfer between moving contacts can be controlled. However, adhesion and tackiness cannot be characterized by a single value as they depend on the contact conditions, surface topography, environment etc. During the last 8 years,

Falex developed a method to quantify adhesion and tackiness of greases, based on indentation/retractions. It also allows to adjust the temperature, retraction speed and applied load. In this work, we attempt to gain a better understanding of the effect and synergism between contact conditions and temperature on the adhesion and tackiness of industrial greases. A temperature range between -20 and 100 °C was investigated.

2:30 - 3 pm

3646282: Calcium Sulfonate Greases – Improving Biodegradable Solution Thanks to 1-Step Process

Guillaume Notheaux, SEQENS, Porcheville, France

In 2021, during 75th STLE meeting, the advantages of the “1-step process” for OverBased Calcium Sulfonate (OBCaS) greases have been unveiled, especially the possibility to choose 100% of the carrier of the final grease. As a result, the first biodegradable OBCaS grease has been launched. For this second lap, keeping in mind the objective of biodegradability, and the new HPM specifications, research has been carried out to improve: - the corrosion preventive properties under dynamic wet conditions, thanks to different co-acid and additives- the behavior under cold environment, thanks to new carriers, - the oxidation stability (RSSOT), thanks to a DoE (Design of Experiment), to select the right blend of AO, and especially a surprising effect, on consistency according to the time of introduction during the process. Since the targeted greases are based on ester for biodegradability, oxidation will be the main key topic.

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm

3649678: Grease Material Properties from First Principles Thermodynamics

Jude Osara, University of Twente, Enschede, Netherlands; Sathwik Chatra K R, SKF, Houten, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Utrecht, Netherlands

Thermodynamics has long been used to derive characteristic material properties. In this study, fundamental thermodynamics is applied to lubricant grease. First-principle formulations of existing and new material properties are derived and experimentally determined. Measurements of the derived properties are performed in accordance with theoretical formulations, with procedures detailed for grease analysts. The potential impact of these material properties on grease performance and degradation is discussed. Properties values for fresh and aged greases are shown to conform with anticipated, observed, and established grease behaviors. The proposed properties can be used in grease performance and degradation analyses, as well as grease selection for bearing and other lubrication applications.

4:30 - 5 pm

3651539: Polyglycols as High Performing Base Oil Components in Modern Greases

Cristina Schitco, Clariant Corporation, Frankfurt, Germany; Stephanie Cole, Clariant, Mount Holly, NC

The industry growth and rise in automation trigger the need for improved quality greases with tailored properties to enhance equipment performance. Simultaneously, there is a significant demand for environmentally friendly greases to meet the worldwide sustainability efforts. The base oils are a significant component in greases and influence several essential properties of the final product. This paper discusses the relevant properties of polyglycols and how these synthetic base oils can meet the requirements of the grease formulators focusing on the following properties: low and high-temperature behavior, material and chemical compatibility, lubrication properties, heat transfer properties, and electrical properties, sustainability aspects. Several grease formulations are shown, and some of the properties mentioned above of polyglycols translate to the final grease properties. This paper describes polyglycols offerings in grease application for both performance and sustainability.

5 - 5:30 pm

3663806: On the Flow Dynamics of Polymer Grease

Josep Farré-Lladós, Jasmina Casals-Terre, UPC - Technical University of Catalonia, Terrassa, Spain;
Lars Westerberg, Luleå University of Technology, Luleå, Sweden

In this paper polymer- and lithium based lubricating greases - both having the same rheology - are investigated using micro Particle Image Velocimetry. The main objective is to determine the reason for the differences in anti-wear and antifriction properties during running conditions as reported in the literature. To this end, low and high driving pressures have been considered in order to generate different ranges of shear rates in the flow. It was found that the observed flow behavior matches well with observations in previous research results, linking the thickener type and deformation characteristics to the flow dynamics and how that in turn affect the grease running properties. For polymer grease it is apparent that the change in flow dynamics is most apparent in regions of high- and low shear rates, which in turn links to the oil bleeding properties of the polymer grease.

5:30 - 6 pm

3688156: Fictitious Grease Lubrication Performance in a Four-Ball Tester

Sravan Josyula, Debdudd Patro, Deepak Halenahally Veeregowda, Ducom Instruments, Groningen, Netherlands

The extreme pressure (EP) behavior of grease is related to additives that can prevent seizure. However, in this study the EP behavior of greases was modified without any changes to its additive package. A Four-Ball Tester with position encoders and variable frequency drive system was used to control the speed ramp-up time. A tenth of a second delay in speed ramp up time had showed an increase in the weld load. Further increase in the speed ramp up time showed that the greases passed the maximum load possible in the Four-Ball Tester without seizure. The mechanism can be related to the delay in rise of local temperature, theoretically attributed to an increase in heat loss. Furthermore, the speed ramp up time increased the corrected load for all greases, resulting in lower friction. This study suggests that speed ramp up time is a critical factor that should be further investigated by ASTM and grease manufacturers, to prevent the use of grease with fictitious EP behavior.

6 - 6:30 pm - Grease Business Meeting

2H

Northern Hemisphere A3

Tribochemistry I

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3644606: Aging Mechanisms of Molybdenum Disulfide: a Fundamental Surface Spectroscopic Study

Filippo Mangolini, Robert Chrostowski, The University of Texas at Austin, Austin, TX; John Curry, Michael Dugger, Sandia National Laboratories, Albuquerque, NM

Molybdenum disulfide (MoS_2) has been used as solid lubricant in aerospace applications because of its low friction response in inert environments. However, exposure to atmospheric conditions and periods of inactivity can cause MoS_2 to “age” into a high friction state. This poses a significant challenge in the reliable use of MoS_2 . Despite the volume of the published literature, our understanding of the surface phenomena taking place during aging of MoS_2 is still elusive. Here, we performed XPS and ToF-SIMS analyses to identify the surface chemical changes occurring in MoS_2 upon aging in variable environments. This work was funded by the Laboratory Directed Research and Development program at Sandia

National Lab., a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the US Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

2 - 2:30 pm

3644588: Tailoring the Surface Reactivity and Tribological Performance of Phosphonium-Based Ionic Liquids by Varying the Anion Chemistry

Filippo Mangolini, Zixuan Li, Hugo Celio, Andrei Dolocan, Nicolás Molina, Jude Kershaw, Oscar Morales-Collazo, Joan Brennecke, The University of Texas at Austin, Austin, TX

Phosphonium phosphate ionic liquids (PP-ILs) are attractive lubricant additives owing to their miscibility in hydrocarbon fluids and excellent tribological performance. Most published studies evaluating the lubricating properties of PP-ILs were performed with high-purity ILs, whose high cost mainly derives from the time-consuming purification required to remove contaminants (e.g., residual halides from the synthesis). Here, we evaluate the dependence of the lubricating behavior of phosphonium-based ILs when used in steel/steel contacts on the relative concentration of phosphate and halide (i.e., bromide) anions. The results of tribological tests and XPS/ToF-SIMS analyses demonstrate that the friction and wear properties of phosphonium-based IL can be tuned by varying the amount of bromide in the IL, while maintaining high corrosion resistance in the presence of phosphate ions. This finding opens the path towards the cost-effective implementation of PP-ILs in tribological applications.

2:30 - 3 pm

3645158: Principle Frictional Properties in Boundary Lubrication by Ideal Nanoscale Gap Using MEMS

Wataru Yagi, Tomoko Hirayama, Kyoto University, Kyoto, Japan

Organic friction modifiers (OFMs) are considered that they have an effect on friction reduction by adsorbing and preventing contact between surfaces. The effects are investigated by many friction tests and the physical property of adsorption layer has begun to be observed by SFA, AFM and NR. However, it has not understood which layers of slip causes the low friction. It is because boundary and fluid lubrication are mixed in real sliding surface on micro scale. The result obtained by macro tribotest means just summation of the friction force produced by these conditions. Their lubrications are required to be separated to measure the friction realized by adsorption layer of OFMs. The ideal friction test requires nanometer-order gap and flat surface. In this study, a film-like specimen ($\sim 5 \mu\text{m}$) was made by MEMS technology. We have developed a "microscopic surface contact tribotester" that realizes parallel of two surfaces in nano-order by applying a load with electrostatic force.

3 - 4 pm – Exhibitor Appreciation Break

4 - 4:30 pm

3644334: Understanding the Boundary Lubrication Tribochemistry of Tetrahedral Amorphous Carbon Coatings by Quantum Molecular Dynamics

Michael Moseler, Takuya Kuwahara, Gianpietro Moras, Fraunhofer Institute for Mechanics of Materials IWM, Freiburg, Germany

Tetrahedral amorphous carbon (ta-C) exhibits high wear resistance and superlubricity under boundary lubrication with organic friction modifiers. Thus, ta-C is increasingly applied as a protective coating in machinery lubricated with oils containing various additives e.g. zinc dialkyldithiophosphate (ZDDP). Unfortunately, the tribochemistry of ta-C coatings interacting with friction modifiers and anti-wear additives is still poorly understood. This contribution reports quantum chemistry calculations that provide a mechanistic understanding of ta-C boundary lubricated by organic friction modifiers [1] as well as by ZDDP [2]. [1] "Mechano-chemical decomposition of organic friction modifiers with multiple reactive centres induces superlubricity of ta-C", T. Kuwahara et al., Nat. Comm. 10, 151 (2019). [2] "Interplay of mechanics and chemistry governs wear of diamond-like carbon coatings interacting with ZDDP-additive lubricants." V.R. Salinas Ruiz et al., Nat. Comm. 12, 4550 (2021)

4:30 - 5 pm

3645199: In Situ Tribochemical Formation of Superlubricious Interfaces in Vacuum and Boundary Lubrication

Takuya Kuwahara, Michael Moseler, Fraunhofer Institute for Mechanics of Materials IWM, Freiburg, Germany; Gianpietro Moras, Fraunhofer IWM, Freiburg, Germany

Superlubricity is a state where the friction between two sliding bodies is almost vanishing (in general, the friction coefficient $\mu < 0.01$). Achieving the superlubricity in industrial applications is crucial since it would significantly contribute to saving of energy and materials resources. In dry and boundary lubrication, the friction is dominated by chemical interactions between two surfaces, and large mechanical energies can induce structural transformations of the surfaces resulting in a drastic decrease of the friction coefficient. Our recent experimental/computational studies revealed that aromatic graphenoid layers form in situ via tribochemical reactions at various sliding interfaces in various environments. Here, we show examples of in situ tribochemical synthesis of superlubricious interfaces, which include ultrahigh vacuum friction of hydrogenated amorphous carbon, water lubrication of diamond, and boundary lubrication of silicon nitride with glycerol.

5 - 5:30 pm

3647723: Dynamic Tribo-Pair of PS400 and DLC for Planet Venus Application

Vasilis Tsigkis, Andreas Polycarpou, Texas A&M University, College Station, TX; Pixiang Lan, ATSP Innovations, Houston, TX

Bearing materials in future missions to Venus will encounter high temperatures (~462 °C) and extremely dense CO₂ atmosphere. Herein, we report on the tribological behavior of PS400 coating (NiMoAl-based alloy) vs. DLC coating at 25, 300, and 500 °C under CO₂ and air environments. We found that at 25 °C DLC provides excellent lubrication and extreme wear resistance. At 300 °C in CO₂, oxygen-containing terminating groups passivated the dangling bonds of the graphitized DLC, and low friction was maintained. However, under air the friction increased significantly. At 500 °C, DLC was worn out and PS400 transfer oxides alleviated the wear in both environments. The unworn and worn surfaces were analyzed using different analytical techniques.

Biotribology II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3651966: Effects of Plant-Based and Dairy Proteins on Oral Lubrication and Mouthfeel

Sorin Vladescu, Connor Myant, Tom Reddyhoff, Imperial College London, London, United Kingdom; Maria Gonzalez Agurto, Guy Carpenter, King's College London, London, United Kingdom; Michael Boehm, Stefan Baier, Motif FoodWorks, Boston, MA; Gleb Yakubov, University of Nottingham, Nottingham, United Kingdom

Meat-based diets represent one of the leading global contributors to greenhouse gas emissions and therefore climate change. Plant-based alternatives to meat, are increasingly perceived as the more sustainable solution. However, to be widely consumed as meat replacements, they must be sufficiently palatable for the broad population. Understanding astringency – i.e. food's property of causing oral mucosa cells to contract following ingestion, often ascribed to a reduction in oral lubrication – is the most promising way of making plant-based food tastier. This presentation will demonstrate how a custom-built, Laser Fluorescence microscope mounted inside a tribometer, was employed to detect both salivary proteins, as well as dairy and plant proteins, and understand their lubrication behaviour and key

underlying mechanisms. This multi-faceted study aims to 'connects the dots' between tribological measurements, physical and chemical phenomena and mouthfeel perception across plant-based foods.

2 - 2:30 pm

3651983: Measurement of Foot Plantar Skin Strain Using Digital Image Correlation Methods for Diabetic Foot Assessment.

Sarah Crossland, Heidi Siddle, Claire Brockett, Peter Culmer, University of Leeds, Leeds, West Yorkshire, United Kingdom; Alexander Jones, David Russell, Leeds Teaching Hospitals NHS Trust, Leeds, United Kingdom

Assessment of diabetic foot ulcer risk is a vital but challenging procedure. Tools to measure plantar pressure exist but these data have limited clinical utility. Plantar shear has promise to better predict ulcer risk, but lacks measurement tools and an evidence base. Two methods using Digital Image Correlation (DIC) were developed to assess plantar foot strains during shod and unshod gait. The unshod method uses a speckle pattern applied to the plantar surface of the foot with transference stamping and imaged through a custom glass walkway.. For the shod method, a plastically deformable insole with speckle patterned upper surface was developed through laboratory studies prior to a pilot study with three participants. In both methods, plantar strains were derived using DIC and segmented into anatomical regions for analysis. A pilot study with six participants was conducted, results show peak strains aligned with areas of high pressure and ulceration particular to each participant.

2:30 - 3 pm

3645981: The Effect of Hyaluronic Acid Concentration in Lubricant and Counter Material, on Friction Behaviour of a Hydrogel Composite

Rahul Ribeiro, Alliance University, Bengaluru, Karnataka, India

A hydrogel composite of polyhydroxyethyl methacrylate (pHEMA) and nanoclay was developed as a potential cartilage replacement material. The percentage of cross-linker was 10% by molecule of monomer. Nanoclay concentration was 1:1 by weight relative to the monomer. For the tribological studies, a lubricant made of simulated body fluid and varying concentrations (in the range found for healthy synovial fluid) of Hyaluronic Acid, was synthesized. The tests were conducted in pin-on-disk configuration. The pHEMA composite with clay was incorporated as the disk. Counter materials were pHEMA without clay and stainless steel 316L. Normal loads of 5N and 10N were chosen. With the stainless steel pin, the coefficient of friction was found to be around 0.34 and when the hydrogel was the pin material, the coefficient of friction was lower at around 0.24. This indicates the possibility of elasto-hydrodynamic lubrication taking place. There was no significant effect of changing the normal load.

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm - Biotribology Business Meeting

2J

Northern Hemisphere E1

Wear II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3669390: Understanding and Mitigation of Knife Mill Wear in Biomass Preprocessing

Jun Qu, Jim Keiser, Oak Ridge National Laboratory, Oak Ridge, TN; Jeffrey Lacey, Vicki Thompson, Idaho National Laboratory, Idaho Falls, ID; George Fenske, Oyelayo Ajayi, Argonne National Laboratory, Lemont, IL; Ed Wolfrum, National Renewable Energy Laboratory, Golden, CO; Peter Blau, Blau Tribology

Consulting, Enka, NC

Relying on shearing between rotary and stationary sharp blades, knife mills can efficiently cut biomass to a desired particle size with fewer fines compared with the more commonly used hammer mills. However, knife blades are susceptible to rapid edge blunting and recession when processing dirty feedstocks. In this study, we first determined the wear modes of a knife mill to be a combination of abrasive and erosive wear, and then selected wear-resistant candidate coatings and surface treatments accordingly. Bench-scale abrasion and erosion tests were used to screen the candidate materials and identified diamond-like-carbon (DLC) coating and iron boriding for actual knife blades. Knife mill testing currently is being conducted using an accelerated wear testing protocol with feedstock containing controlled add-on minerals. The goal is to demonstrate extended tool life as well as enhanced milling performance, e.g., particle size distribution and throughput, for improved economics.

2 - 2:30 pm

3648427: Elevated Temperature Helium Tribology of Inconel 617 Subjected to Laser Shock Peening and Thermal Engineering.

Vasilis Tsigkis, Saifur Rehman, Andreas Polycarpou, Texas A&M University, College Station, TX; Lloyd Hackel, Curtiss Wright Surface Technology, Livermore, CA; Keivan Davami, The University of Alabama, Tuscaloosa, AL; Ali Beheshti, George Mason University, Sterling, VA

Inconel 617 is among the best candidates for utilization in high temperature gas cooled reactor tribo-components. However, the combined effects of sliding contact, and very high temperature material degradation, deteriorates the alloy tribological performance, especially under a helium atmosphere. Laser peening can enhance the properties at the surface and subsurface. We present the tribological behavior of regular laser peened as well as thermally-engineered laser peened Inconel 617 under helium and air atmospheres at 800°C. Regardless of the peening process and post-process treatment types, it is observed that laser peening improves the tribological characteristics of Inconel 617. Interestingly, laser peening followed by helium thermal aging shows highly enhanced tribological behavior. This is attributed to the strengthening effect of the laser peening on the surface oxides providing an excellent and lasting protective and lubricating film under helium exposure.

2:30 - 3 pm

3647034: An Investigation into the Tribological Performance of Wear Resistant PVD Coatings Atop Various Tool Steels Used in Injection Moulding Applications

Roshan Lal, Michael Adams, Zhenyu Jason Zhang, University of Birmingham, Wolverhampton, United Kingdom

Wear is a recurring issue in injection moulding applications where abrasive formulations, high temperature and high pressures are employed. Multiple wear mechanisms can damage a single tooling part during production, so protective coatings are often applied by Physical Vapor Deposition (PVD). Wear resistance is shown as a function of both the coating and substrate properties. Lab-scale testing of TiAlN, AlCrN, diamond-like carbon (DLC) and CrN coatings on various tool steels helped identify substrate-coating systems for optimal performance. Two- and three-body wear mechanisms have been emulated by unique modifications to test equipment (tribometers and force measurement systems) to include particle entrainment at high temperature. Substrate-coating properties have been quantified using nanoindentation and nanoscratch, with different stages of progressing wear characterized using surface replication (Microset 202) and optical techniques (white light interferometry and alicon).

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm

3669385: New Anti-Wear Additives

Nathan Eckert, Nickie Norton, The Shepherd Chemical Company, Norwood, OH

The Shepherd Chemical Company is a family-owned, metal-based, specialty chemical manufacturing company. We have been growing our lubricant additive business significantly over the past several years

(from nearly zero in 2010 to greater than 3MM pounds in 2021). Most of this business has been cultivated through our custom co-development program, where we work with a single customer to develop a proprietary solution for their needs. As the lubricant additive market changes with the increase in hybrid and all-electric vehicles, we feel that our custom co-development program can help usher in the next generation of innovative solutions. In this presentation, we will share a bit about The Shepherd Chemical Company, how we work collaboratively with our partners to develop and deliver custom solutions, and, finally, share some recent anti-wear data on a series of novel, metal-based additives that we hope to introduce to your formulations in the near future.

4:30 - 5 pm

3646934: Is the Miller ASTM G75 Abrasivity Test Obsolete?

Dirk Drees, Emmanuel Georgiou, Lais Lopes, Michel De Bilde, Falex Tribology, Rotselaar, Belgium;
Michael Anderson, Falex Corporation, Sugar Grove, IL

Many standard tests are done with procedures and equipment from decades ago. However, equipment has evolved and so have our insights. Thus, we need to look at these 'older' methods and consider how to update/modify them to obtain relevant and repeatable information for today's applications. ASTM G-75 Miller tests are used to rank the abrasivity of slurries or resistance of materials to slurry abrasion for over 50 years. The standard focusses on aqueous based slurries and standardized samples. This in relation to the simplicity of the method leads people to believe that the method has only a limited use or is becoming obsolete. However, wear problems due to slurry abrasivity phenomena continue to exist in various fields such as food, construction, mining, chemical processing etc. In this work, we present some examples on how a modified ASTM G75 method can be successfully used to investigate modern wear problems in industry.

2K

Northern Hemisphere E2

2D Materials + Superlubricity - Materials Tribology and Nanotribology II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2:30 pm

3642860: Energy Dissipation Studies on a Local Scale

Ernst Meyer, University of Basel, Basel, Switzerland

We study the mechanisms of energy dissipation on a local scale. The probing tip of the atomic force microscope is used for high resolution to observe the molecular structure on the surface. In a second step, the probing tip is used as an active tool to pull the polymer across the surface or to detach it from the surface. A similar experimental setup can be used to study the motion of graphene nanoribbons on metallic surfaces. We do observe ultralow friction, also called superlubricity, which corresponds to ultralow frictional forces due to the incommensurability of the contacting surfaces. S. Kawai, A. Benassi, E. Gnecco, H. Söde, R. Pawlak, X. Feng, K. Müllen, D. Passerone, C. A. Pignedoli, P. Ruffieux, R. Fasel, E. Meyer, Superlubricity of graphene nanoribbons on gold surfaces, Science, 2016, 351, (6276), 957.

2:30 - 3 pm

3669471: Spectral and Frictional Analysis of Alkane Mixtures on Graphitic Surfaces

Behnoosh Sattari Baboukani, Thomas Bui, Medini Rajapakse, Luis Velarde, University at Buffalo, Buffalo, NY; Prathima Nalam, SUNY University at Buffalo, Buffalo, NY

Lubrication significantly affects the service life of metallic components. Graphite, due to its low interlayer shear strength is used as an additive in oil-based lubricants to enhance the load-bearing capacity of the contact. In this study, we employ atomic force microscopy (AFM) to measure nanoscale friction behavior

of highly oriented pyrolytic graphite (HOPG) in a lubricating oil containing linear (n-hexadecane), cyclic (cyclohexane) and the mixtures of a linear and cyclic hydrocarbons. Solvation forces and stick-slip patterns are measured to resolve the structure of the solvation layers at the vicinity of HOPG interface. Further, Sum Frequency Generation (SFG) spectroscopy was employed to measure interfacial interactions and orientations of hydrocarbon molecules with HOPG in presence of solvent mixture. The adsorption enthalpies and structural commensurateness of molecules with the underlying HOPG are considered to understand the impact on the measured friction forces.

3 - 4 pm – Exhibitor Appreciation Break

4 - 4:30 pm

3669467: Molecular Dynamics Investigation of Adhesion Between MoS₂ Coated Scanning Probes

J. Schall, Sathwik Toom, North Carolina A&T, Greensboro, NC; Takaaki Sato, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Yeau-Ren Jeng, National Chung Cheng University, Chiayi, Taiwan

VDW materials such as MoS₂ have been proposed as release layers in the transfer process in flexible electronics devices. Studies of the adhesion mechanics of these materials are needed as processing and function of such devices hinge on the adhesive and mechanical properties. A collaboration with the AFRL Materials and Manufacturing Directorate and U. Pennsylvania has recently succeeded in producing MoS₂-coated scanning probes; allowing adhesion between MoS₂ layers to be probed experimentally in an in situ transmission electron microscope based atomic force microscope. We will present results from molecular dynamics simulations of adhesion between two MoS₂ coated Si probes. Simulations were designed to match the TEM-based AFM experiments in terms of size, number of MoS₂ layers, orientation, and grain size. Results show that there are significant differences in adhesion as a function of MoS₂ grain size. Adhesion and variability in adhesion increases as the grain size is reduced.

4:30 - 5 pm

3647885: MD Simulation on Enhanced Wear Resistance of Nature Rubber Composites by Applications of Carbon Nanotube

Fei Teng, Jian Wu, Benlong Su, Youshan Wang, Harbin Institute of Technology, Weihai, Shandong, China

The carbon nanotube(CNT)can significantly improve the tribological properties of nature rubber(NR). So, alternative CNT/NR composites with different CNT content have been studied by MD simulation at atomic scale for better wear resistance. Results indicate that CNT/NR composite with high CNT content shows high hardness and less deformation in friction process. The worn atomic mass of 15wt.% CNT/NR composite reduced by 51.3% and 53.7% compared to 0wt.% and 5wt.% CNT/NR. The strong binding interaction prevented composite from large deformation and ensured less time for reaching stable dynamic friction state. In the application of aircraft tire, higher COF and better wear resistance are both needed. Therefore, the appropriate blending process to avoid CNT agglomeration and measures to increase the COF of product are needed when the high CNT content is selected for prescription with high wear resistance.

2L

Northern Hemisphere E3

Power Generation II

Session Chair: Matthew Hobbs, EPT, Calgary, Alberta, Canada

Session Vice Chair: TBD

1:30 - 2 pm

3669338: Case Study on Autodegradation of Turbine Oil and Varnish Removal

Jorge Alarcon, Bureau Veritas, Stafford, TX

Although the process of generating varnishes in turbine oils has been determined with great precision, there are some factors that still need to be understood and analyzed. among them is the self-degradation of the oil itself due to the generation of aggressive chemical compounds that turn the oil into its own enemy. Is it possible to determine the level of self-degradation? On the other hand, among the possible corrective actions to eliminate the varnishes are oils or fluids of altra polarity that eliminate or dissolve the varnishes, allowing the oil to return to a less aggressive state for it and for the operation. Many of these products have been presented in the market showing great results, however in very few occasions cases have been presented from the neutral point of view of a laboratory for the evaluation of these products. This real case study shows both points of view, the self-degradation process, and the analysis of these chemicals

2 - 2:30 pm

3646994: Determination of Relative Concentrations of Phosphate Ester Isomers in Turbine Control Systems by Matrix Assisted Laser Desorption Ionization - High Resolution Mass Spectrometry (MALDI-HRMS).

John Duchowski, Johannes Staudt, HYDAC FluidCareCenter GmbH, Sulzbach, Saar, Germany; Gerard Palmer, HYDAC Technology LTD, Witney, Oxfordshire, United Kingdom

One of the approaching regulations dictated by the Registration, Evaluation, Authorization and Restriction of Chemical Substances (REACH) implementation is to replace trixylyl phosphate (TXP; CAS Reg. No.: 25155-23-1) presently employed in many turbine electrohydraulic control (EHC) systems by other phosphate esters deemed of lesser concern to the environment. These other fluids may include triphenyl phosphate (TPP) and/or tri-tertbutyl phosphate (TBP) of various isomers. The REACH regulations dictates that by 2022 TXP be replaced by TPP/TBP such that no more than 0.3 wt% of the former remains in the affected systems. In order to ensure smooth fluid replacement and confirm that that REACH guidelines were met required an adaptation of an analytical procedure based on MALDI-HRMS was required as it was conclusively shown that other MS based methods, such as LC-MS or standard GC-MS would not provide results of sufficient accuracy for positive determination.

2:30 - 3 pm

3669543: Filter Debris Analysis (FDA) of Solid Particles Trapped in Pencil Filter of Servo Control Valve in Steam Turbine Power Plant in Thailand

Surapol Raadnui, KMUTNB, Bang Sue, Bangkok, Thailand

Given the fine filtration used in steam turbine oil today to produce longer life cycles of servo control valve and hence the turbines, over half of the solid particles, which could provide useful insight into turbine control system condition, is caught in the pencil filter, and never end up in a turbine oil control sample. It is generally discarded with the pencil filter. Increasingly, fine filtration is making conventional monitoring techniques less effective at providing reliable indication of solid particles and turbine oil control component wear inside the system and contamination particles from outside. FDA captures this lost information and identifies the specific components that are wearing or contamination related failures, providing improved diagnostic and prognostic information about impending or catastrophic failures.

3 - 4 pm - Exhibitor Appreciation Break

4 - 4:30 pm - Power Generation Business Meeting

Rolling Element Bearings II

Session Chair: TBD

Session Vice Chair: TBD

1:30 - 2 pm

3641055: Towards a Grain-Scale Modeling of Crack Initiation in Rolling Contact Fatigue

Lucas Fourel, Fabrice Ville, Xavier Kleber, Philippe Sainsot, INSA Lyon, Villeurbanne, France; Jean-Philippe Noyel, Etienne Bossy, ECAM Lyon, Lyon, France

Rolling contact fatigue is one of the major failure problems in rolling bearings. It is characterized by microspalling or spalling which are induced by surface or subsurface crack initiation and propagation. Prediction of crack initiation is rather difficult because mechanical phenomena operate at different scales. The accumulation of cyclic plastic energy is considered as a main factor at the meso-scale. A numerical model based on stored energy at Persistent Slip Bands (PSBs) inspired by Tanaka and Mura's dislocation pile-up approach is developed. Voronoi polycrystals and cubic elasticity FEM are used to evaluate the shear stress during a moving contact pressure cycle for different surface conditions. Crack initiation is located at the intersection between PSBs and high misorientation grain boundaries. Crack initiation depth distributions appear consistent with literature.

2 - 2:30 pm

3642431: Prediction of Surface Crack Propagation under Rolling Contact

Bjoern Kunzelmann, Amir Kadiric, Imperial College London, London, United Kingdom; Guillermo Morales-Espejel, SKF, Houten, Netherlands

This study investigates the propagation of surface initiated rolling contact fatigue cracks in rolling-sliding contacts of hard steels. This work combines experimental measurements of crack propagation with numerical simulations of stress fields experienced by such cracks under different contact conditions. A 3D FE model with a specific mesh considers the actual crack morphology observed experimentally to predict the associated stress intensity factors and thus explain the observed crack growth rates. The specific mesh implementation enables the model to resolve the evolution of displacements and stresses near the crack tip during contact over-rolling. The model simulates a contact passing over a crack and includes the effects of surface tractions as well as frictional contact between the crack faces and the effect of lubricant pressurization within the crack. The influence of a range of factors, including contact size, surface topography and fluid entry into the crack are considered.

2:30 - 3 pm

3668690: Fatigue Life Calculation of a Cylindrical Roller Bearing with Surface Damage

Armand Tamouafo Fome, Jan Hendrick Kehl, Norbert Bader, Gerhard Poll, Leibniz University Hannover, Hanover, Germany

Rolling element bearings are widely used in industrial applications. Bearing failure can lead to machine failure or costly repairs. Thus, estimation of bearing life still is a topic of research. Improper handling, impact loads, solid contaminants, or static overload may cause plastic deformation of the raceway. A bearing life model, based on the Ioannides and Harris model using the modified Dang Van criterion, was developed for cylindrical roller bearings to understand such defects. In endurance experiments, a surface defect was generated by impacting a roller and surface of the inner ring. This indentation process was simulated using FEM to obtain the dent geometry and the residual stresses in the deformed area. The different rolling contacts of the bearing including over rolling of dent were then simulated. The stress states obtained from these simulations were used to compute the bearing life using the above life model. The results correlate well with the results of endurance tests.

3 - 4 pm – Exhibitor Appreciation Break

4 - 4:30 pm

3648478: An Investigation of the Effects of Grain Refinement on Rolling Contact Fatigue

Steven Lorenz, Farshid Sadeghi, Purdue University, West Lafayette, IN

In this investigation a grain size dependent, continuum damage mechanics (CDM) framework was conjoined with finite element model to study the effect of grain refinement on rolling contact fatigue (RCF) of non-conformal contacts. The grain size dependent CDM framework enabled the simulation of material degradation as a function of cycle. To establish the CDM critical parameters, torsion stress-life data from open literature of three different grain sizes for the same material was used. In order to assess the effect of grain refinement on RCF, a series of unique Voronoi microstructures were constructed at eight mean grain diameters. FE simulations were devised at three contact pressures per grain size, and results displayed an exponential increase in life as grain size is refined. A predictive fatigue life equation was constructed using this investigation's simulations to evaluate the stochastic RCF performance of non-conformal contacts, given grain diameter and contact pressure.

4:30 - 5 pm

3667586: Fluid Structure Interaction Modeling of Surface Cracks in Elastohydrodynamically Lubricated Line Contact

Kushagra Singh, Farshid Sadeghi, Purdue University, West Lafayette, IN

This paper presents a fluid-structure interaction (FSI) based approach to model surface-initiated cracks in rolling-sliding line contacts operating under elastohydrodynamic lubrication. The lubricant flow behavior is determined by Navier-Stokes equations using a computational fluid dynamics solver. The structural response of the solid is governed by the stress-strain equations solved using the finite element method. The FSI model overcomes the limitations of the classical Reynolds based approach in modeling surface inclined crack geometries and produces fluid solution which is free from Reynolds assumptions. The effect of crack geometry on fluid pressure and structural response is studied by varying the crack length, crack width, crack inclination and crack tip radius. The results of this investigation identify the crack geometries that affect fatigue life of rolling elements in EHL contact and presents novel insights on lubrication of tribocomponents such as rolling element bearings.

5 - 5:30 pm

3647699: Fluid-Solid Interaction Modeling of Point EHL Contacts

Wyatt Peterson, Farshid Sadeghi, Purdue University, Lafayette, IN

Elastohydrodynamically lubricated (EHL) point contacts were investigated using a coupled fluid-solid interaction (FSI) model. A finite element model was used to compute elastic deformation of the solid bodies, while computational fluid dynamics (CFD) was used to model the fluid domain with the Navier-Stokes equations. The current model is not limited by Reynolds equation assumptions, allowing for the investigation of pressure, viscosity and temperature variation across point-contact EHL film thickness. Various slide-to-roll ratios were investigated considering a non-Newtonian fluid with thermal effects to characterize lubricant properties across the EHL film. Cavitation was also considered and cavitation bubble lengths were found to agree with results found in literature. The FSI model developed in this investigation provides new insights on a classical lubrication problem.