79th STLE Atlanta

Annual Meeting & Exhibition | May 18-22, 2025

Preliminary Program As
of March 27, 2025

2025 STLE Annual Meeting Program At A Glance

Preliminary as of 1-15-2025

All Sessions and Events will take place in the Hyatt Regency Atlanta unless otherwise noted.

Sunday, May 18, 2025

Registration
6:30 am – 6 pm – Grand Hall Foyer

Education Course Speakers Breakfast
7 – 7:45 am – Centennial II

Education Courses - 8 am - 5 pm (Times vary by course.)
Basic Lubrication 101 – Hanover Hall A/B
Electric Vehicles 101 – Hanover Hall C/D
Metal Removal Fluids – Hanover Hall E
Advanced Lubrication 301 – Hanover Hall F/G
Artificial Intelligence/Machine Learning – Courtland
Bearings – Dunwoody

Course F&B Breaks – Hanover Hall Foyer

4:30 – 5:45 pm - Section Leader Training – Greenbriar

Student and New Member Networking Reception -
6:00 – 7:30 pm – Regency V

Monday, May 19, 2025

Registration
6:30 am – 6 pm – Grand Hall Foyer

Monday Speakers Breakfast
7 – 7:45 am – Centennial II

Technical Sessions - 8 am - 10 am
1A – Artificial Intelligence/Machine Learning I – Hanover Hall A/B
1B – Commercial Marketing Forum I – Hanover Hall C
1C – Wear I – Hanover Hall D
1E – Rolling Element Bearings I – Hanover Hall F/G
1G – Materials Tribology I – Regency Ballroom V
1I – Electric Vehicles I – Regency Ballroom VII
1J – Non-Ferrous Metals I – The Learning Center

10 – 10:30 am - Beverage Break in Centennial Foyer

Opening General Session - 10:30 am – 12 Noon
Keynote Presentation: ***TBA***
Centennial Ballroom

12:00 pm – 1:40 pm - Lunch on your own

Commercial Exhibits and Student Posters -
12 pm – 5 pm – Grand Hall

Technical Sessions - 1:40 pm – 5 pm
2A – Artificial Intelligence/Machine Learning II – Hanover Hall A/B
2B – Commercial Marketing Forum II – Hanover Hall C
2C – Wear II – Hanover Hall D
2D – Metalworking Fluids I – Hanover Hall E
2E – Rolling Element Bearings II – Hanover Hall F/G
2F – Sustainability in Motion I – Courtland
2G – Materials Tribology II – Regency Ballroom V
2I – Electric Vehicles II – Regency Ballroom VII
2J – Non-Ferrous Metals II – The Learning Center

3:00 – 4 pm - Exhibitor Appreciation Break – Grand Hall

Networking Reception
5:30 – 7:00 pm – Grand Hall

Tuesday, May 20, 2025

Registration
6:30 am – 5:30 pm – Grand Hall

Tuesday Speakers Breakfast
7 – 7:45 am – Centennial II

Commercial Exhibits and Student Posters -
9:30 am – 5:30 pm – Grand Hall

Technical Sessions - 8 am – 12 Noon
3A - Artificial Intelligence/Machine Learning III – Hanover Hall A/B
3B – Commercial Marketing Forum III – Hanover Hall C
3C – Condition Monitoring I – Hanover Hall D
3D – Metalworking Fluids II – Hanover Hall E
3E – Rolling Element Bearings III – Hanover Hall F/G
3F – Sustainability in Motion II – Courtland
3G – Materials Tribology III (Tribute to Prof. Yip Wah Chung) – Regency Ballroom V
3H – Aerospace I – Regency Ballroom VI
3I – Electric Vehicles III – Regency Ballroom VII
3J – Rheology I – The Learning Center
3K – JAST- STLE Early Tribology Symposium I - Dunwoody

10 – 10:40 am - Beverage Break in Exhibit Hall – Grand Hall

President's Awards Luncheon/Business Meeting -
12 - 2:00 pm – Centennial Ballroom

Technical Sessions - 2 pm – 5 pm
4A - Artificial Intelligence/Machine Learning IV – Hanover Hall A/B
4B – Commercial Marketing Forum IV – Hanover Hall C
4C – Condition Monitoring II – Hanover Hall D
4D – Metalworking Fluids III – Hanover Hall E
4E – Rolling Element Bearaings IV – Hanover Hall F/G
4F – Sustainability in Motion III – Courtland
4G – Materials Tribology IV (Tribute to Prof. Yip Wah Chung – Regency Ballroom V
4H – Aerospace II – Regency Ballroom VI
4I – Electric Vehicles IV – Regency Ballroom VII
4J – Rheology II – The Learning Center
4K – JAST- STLE Early Tribology Symposium II – Dunwoody

3 – 4 pm Exhibitor Appreciation Break – Grand Hall

5:15 – 6:15 pm – Bonus Program: Career Pathways Panel – Centennial Ballroom

Wednesday, May 21, 2025

STLE Fun Run/Walk
6:30 am – ***Participants will meet at the front entrance of the Hyatt.***

Registration
6:30 am – 5:00 pm – Grand Hall Foyer

Wednesday Speakers Breakfast
7 – 7:45 am – Centennial II

Commercial Exhibits & Student Posters -
9:30 am – 12 Noon – Grand Hall

Education Courses - 8 am - 5 pm (Times vary by course.)
Basic Lubrication 102 – Embassy Hall A
Sustainability – Embassy Hall B/C
Metalworking Fluids 200 – Embassy Hall D
Advanced Lubrication 302 – Embassy Hall E/F

Technical Sessions - 8 am – 12 Noon
5A – Lubrication Fundamentals I – Hanover Hall A/B
5B – Commercial Marketing Forum V – Hanover Hall C
5C – Contact Mechanics I – Hanover Hall D
5D – Tribochemistry I – Hanover Hall E
5E – Environmentally Friendly Fluids/Synthetics I – Hanover Hall F/G
5F – Tribotesting I – Courtland
5G – Materials Tribology V – Regency Ballroom V
5H – Aerospace III – Regency Ballroom VI
5I – Electric Vehicles V – Regency Ballroom VII
5J – Gears I – The Learning Center
5K – Power Generation I - Dunwoody

10 – 10:40 am - Beverage Break – Grand Hall

12:00 to 1:40 pm - Lunch on Your Own

Technical Sessions - 1:40 pm - 5 pm
6A – Lubrication Fundamentals II – Hanover Hall A/B
6B – Commerical Marketing Forum VI – Hanover Hall C
6C – Fluid Film Bearings/Seals I – Hanover Hall D
6D – Tribochemistry II – Hanover Hall E
6E - Environmentally Friendly Fluids/Synthentics II – Hanover Hall F/G
6F – Tribotesting II – Courtland
6G – Materials Tribology VI – Regency Ballroom V
6H - Artificial Intelligence/Machine Learning V – Regency VI
6I – Engine and Drivetrain VI: Engine Oil, HEV, and Water-Based – Regency Ballroom VII
6J – Gears II – The Learning Center
6K – Power Generation II – Dunwoody

3 – 3:40 pm Beverage Break – **Foyers**

5:15 – 6:15 pm – Bonus Program: Discussion Roundtables, an Ideation Event – Centennial Ballroom

Thursday, May 22, 2025

Registration
6 :30 am – 1 pm – Grand Hall Foyer

Thursday Speakers Breakfast
7 – 7:45 am – Centennial II

Education Courses - 8 am - 5 pm
Electric Vehicles Course – Regency Ballroom VII

Technical Sessions - 8 am – 12 Noon
7A – Lubrication Fundamentals III – Hanover Hall A/B
7B – Commercial Marketing Forum VII – Hanover Hall C
7C – Fluid Film Bearings/Seals II – Hanover Hall D
7D – Biotribology I – Hanover Hall E
7E – Surface Engineering I – Hanover Hall F/G
7F – Tribotesting III – Courtland
7G – Materials Tirbology VII – Regency Ballroom V
7H – Nanotribology I – Regency Ballroom VI
7I – Grease I – The Learning Center

10 – 10:40 am - Beverage Break - Foyers

12 noon to 1:40 pm – Lunch on Your Own

Technical Sessions - 1:40 pm - 5:00 pm
8A – Lubrication Fundamentals IV – Hanover Hall A/B
8B - Environmentally Friendly Fluids/Synthetics III – Hanover Hall C
8C – Fluid Film Bearings/Seals III – Hanover Hall D
8D – Tribology of Biomaterials I – Hanover Hall E
8G – Materials Tribology VIII – Regency V
8H – Nanotribology II – Regency Ballroom VI
8I – Grease II – The Learning Center

3 – 3:20 am – Beverage Break – Foyers

1A Hanover AB

AI and Machine Learning I

Session Chair: Nick Garabedian, Datin Company, Karlsruhe, Germany
Session Vice Chair: Prathima Nalam, SUNY at Buffalo, Buffalo, NY

8:00 - 8:40 am
4205188: A Machine Learning Tool to Correlate Lubricant Properties with Formulations
Tianshi Fang, Oyinkansola Romiluyi, Sravani Gullapalli, Shell Global Solutions (US) Inc, Houston, TX; Grace Uche, Shell Information Technology International Inc, Houston, TX

In the development cycle of commercial lubricants, industrial regulations mandate the measurements of a number of properties: for instance, viscosities, NOACK, and sulfur content. During the early stages of a development cycle, a large number of candidate formulations often need to be individually assessed. This large number of property measurements can be expensive and time-consuming. Shell has been deploying machine learning and AI to tackle this challenge. A machine learning model was developed and trained with Shell's extensive database of at least a decade of historical blends. It accurately predicts a set of common performance properties using the component concentrations in a formulation. With the data-driven insights extracted from the historical data, this model helps formulators quickly screen through candidate formulations and thus accelerate the development cycle. Upon this model, a more advanced tool was established to make informed recommendations of possible formulations.

8:40 - 9:00 am
4202491: Using Artificial Intelligence to Predict Toxicity and Improve Performance of Lubricants
Siegfried Lucazeau, NYCO, Paris, France

The rise of Artificial Intelligence is now giving formulation engineers powerful tools to meet latest performance, regulatory and environmental requirements.
QSARs correlate molecular descriptors with biological activity whilst QSPRs correlate them with physical properties. Combined with 3D modelling, these models are able to predict toxicity on antioxidants or phosphate esters, and frictional performance on ester base fluids. Eventually, such statistical learning models are able to identify and select the safest and more sustainable additives and the best esters from a frictional point of view, amongst thousands of molecules potentially. Practical examples of statistical and 3D models predicting toxicity and performance will be shown. This work also shows that Artificial Intelligence does not only evaluate the properties of molecules quickly and easily, it also identifies the main structural drivers for them, thus opening the door to computer aided design for lubricants.

9:00 - 9:20 am
4199876: Application of AI to Property Prediction of Transesterified Oils for Biodiesel and Biolubricant Formulation
Guillermo Díez Valbuena, Jorge Díez Peláez, Eduardo Rodríguez Ordóñez, Alejandro García Tuero, Antolín Hernández Battez, University of Oviedo, Gijón, Asturias, Spain

The diversity in chemical composition of the various feedstocks utilized for the production of biodiesels and biolubricants presents a challenge in assessing their viability prior to experimental testing. Consequently, a number of predictive models have been developed and studied in

literature, with varying degrees of success. The aim of this study is to investigate the potential of artificial intelligence in predicting the properties of transesterified oils for use in biodiesel and biolubricant formulations. This research will focus on commonly used methodologies, along with recommendations and guidelines for developing reliable and generalizable models. Additionally, the physicochemical properties of transesterified bio-oils will be analyzed to identify which are correlated with their fatty acid methyl ester distribution and which, according to the collected data, are not. A database of over 700 examples of transesterified bio-oils from the literature will support this analysis.

9:20 - 9:40 am
4205646: Leveraging Machine Learning in the Design of Novel Ionic Liquids
Pawan Panwar, Mitchell Johnstone, Mays Neiroukh, Subha Kumpaty, Paul Michael, Milwaukee School of Engineering, Milwaukee, WI

Ionic Liquids (ILs) have gained significant attention for their versatile applications, yet discovering new ILs through traditional experimental methods is resource-intensive and slow. To address this, our study introduces a contemporary method for generating unique ILs, leveraging machine learning to ensure desired chemical properties and novelty in the resulting ILs. We employed the Generative Chemical Transformer (GCT) model, integrating Transformer and Conditional Variational Autoencoder (CVAE) architectures to produce novel ILs. Using data from the National Institute of Standards and Technology, we obtained properties of 450 ILs, yielding 3315 data points with SMILES strings, temperature, pressure, and properties like density and viscosity. The trained GCT model generated 30,000 ILs, facilitating the creation of valid ILs with predefined attributes, thus accelerating the discovery process.

9:40 - 10:00 am
4202175: Predictive Insight for MoS_2 Thin Film Synthesis from Machine Learning Algorithms
Dayton Vogel, Tomas Babuska, Alexander Mings, Steven Larson, John Curry, Michael Dugger, Sandia National Laboratories, Albuquerque, NM

MoS_2 materials have been exemplified as surface coatings to minimize surface-environment interactions and promote ultra-low friction environments. One challenge to these solid lubricants is increased friction, often resulting from interactions with ambient chemical species such as H_2O, O_2, and N_2. Experimental work has identified the primary tribological challenges in MoS_2 coatings to be minimizing initial friction and oxidation. This work leverages the combination of existing experimental data and machine learning models for prediction of optimized deposition parameters. Gradient boosted regression trees and artificial neural networks have been utilized to identify keys deposition parameters from the wide parameter space sampled during thin film synthesis. Current models have highlighted the impact of target conditioning and film thickness for properties of wear rate and the initial friction coefficient, identifying a unique role of indirect control parameters.

10:00 - 10:30 am - **Break**

Commercial Marketing Forum I

Session Chair: TBD

8:00 - 8:20 am
4306254: ExxonMobil: Alkylated Naphthalene: A Booster and a Base Stock
Manish Patel, ExxonMobil Chemical Co., Spring, TX

Lubricant markets continue to push for extended fluid life while extending equipment life and improving operational efficiency. The focus for OEMs is better engine performance, longer oil life, and smaller sump size to increase efficiency. To help achieve these goals, Synesstic™ alkylated naphthalene AN5 & AN12 can be incorporated into the base oil blend as a booster. Synesstic™ base stocks enhance thermo-oxidative stability, augment additive performance, extend fluid operating life, increase blend stability, improve compressor oil life, and improve engine cleanliness. Compared to esters, this performance is achieved with the added benefits of enhanced seal compatibility and hydrolytic stability.
This presentation will demonstrate how Synesstic™ AN5 and AN12 Group V base stocks can work as boosters to improve performance, meet lubricant industry needs, and expand base oil formulation flexibility.

8:20 - 8:40 am
4304261: Kao Chemicals: Impact of the Additive Selection on the Handprint of Metalworking Applications
Sabine Wohlfahrt, Kao Chemicals Europe, Emmerich, Germany; Oskar Vögler, Carbon Minds GmbH, Cologne, Germany

In the evolving landscape of metalworking, sustainability and efficiency are paramount. Our innovative KAO Metalworking Toolbox leverages cutting-edge surfactant technology and quality. Our surfactant range covers emulsifiers (AMIDET and KAO FINDET MB / AKYPO® ROX), co-emulsifiers (AKYPO® and FOSFODET) and solubilizers (AKYPO® LF) used as key ingredients for advanced metalworking and cleaning formulations. Especially AKYPO® ether carboxylic acids significantly enhance metalworking fluid performance. This presentation will explore the critical role of AKYPO® in extending the lifetime of metalworking fluids, thereby reducing the operational footprint. We will shade light on the savings created by AKYPO® technology by assessing the life cycle of a metalworking fluid. Join us to discover how our state-of-the-art solutions contribute to a more sustainable future in metalworking, promoting efficiency without compromising quality.

8:40 - 9:20 am
4302503: CPChem: Grow with Us - New Opportunities with Synfluid® PAO
Tom Malinski, Spencer Kerns, Chevron Phillips Chemical Company, The Woodlands, TX

Join us for a presentation on opportunities for innovation as we share our growth plans with the expansion of our Belgian plant and highlight the advantages of Synfluid® PAO. This session will explore the strengths of our products, the advantages of upgrading your base oil to synthetic, and the sustainability benefits for the full life cycle of your products. We will highlight our feedstock flexibility and the unique properties you can achieve with products such as our PAO 2.5 cSt. Lastly, we will showcase the Synfluid® PAO Blending Matrix Tool which allows users to calculate a variety of properties from any PAO blend to meet your application challenges and streamline future product development.

9:20 - 9:40 am
4300317: Colonial Chemical: Ether Carboxylic Acids for Industrial Lubricants
Steven Tang, Colonial Chemical Inc, South Pittsburg, TN

Ether carboxylic acids are a unique class of emulsifiers featuring the combined nonionic and anionic surfactant properties. They offer a wide range of performance properties, including emulsification, lime-soap dispersing, corrosion inhibition, lubrication, surface wetting, hydrotroping, and coupling. Especially, they demonstrate outstanding stability against electrolytes and high-water hardness. Ether carboxylic acids have been broadly used in metalworking fluids, hydraulic fluids, metal cleaners, and other industrial lubricants along with other industrial applications in household, Industrial and institutional cleaning, oil and gas, and personal applications. What ether carboxylic acid to choose for a specific application? That is what this presentation aims to address. As a leading global manufacturer of ether carboxylic acids, Colonial Chemical offers comprehensive product coverage in this space to meet ever increasing demand in a wide variety of applications.

9:40 - 10:00 am
4302075: Novel Reliable Technologies: Is ZDDP Still the King of Anti-wear Additives?
Gavin Duckworth, Novel Reliable Technologies, Galveston, TX

ZDDP (Zinc dialkyldithiophosphate) has been and will continue to be a major contributor to anti-wear performance, corrosion protection, and oxidative stability in a variety of applications including engine oils, hydraulic fluids, and grease technologies. We will explore some recent data on anti-wear performance in engine oils and hydraulic fluids applications that have high load, high pressure, and elevated temperatures. The ZDDP manufacturing process is complex and has a direct impact on the performance and quality of the final product. We will explore the subtleties of this process and the impacts to wear, and other behaviors of a finished fluid related to the quality of the ZDDP.

10:00 - 10:30 am – Break

1C Hanover D

Wear I

Session Chair: Xue Han, Cummins, Inc., Columbus, IN
Session Vice Chair: Steven Thrush, US Army DEVCOM GVSC, Warren, MI

8:00 - 8:40 am
4204533: Application of Novel Data-Driven Methods for Wear Characterization in Machine Elements
Mahdi Mohammadpour, Loughborough University, Loughborough, United Kingdom; Sara Sharifzadeh, Swansea University, Swansea, United Kingdom; Tobias Bender, Maxim Burgman, Fatih Yucebilginc, FUCHS USA, Chicago, IL

A key challenge in the post-design testing and optimization is the critical role of visual inspection of tested samples, leading to subjective qualitative and quantitative judgements. This process often leads to defining acceptance criteria for tribo-systems based on inconsistent and highly variable inspections. The presented method offers an objective alternative by integrating a machine learning approach and surface imaging to automate wear identification and quantification in machine elements. The method is based on Convolutional Neural Network (CNN), which analyses obtained

images from the tested gear flank, classifies the wear type and quantifies its extent. This novel approach replaces the current methods of visual inspection and offers a repeatable and quantitative assessment. The proposed method can be transferred to different components and tests including, but not limited to rolling element bearings, gears, slider bearings, valvetrain, other engine conjunctions and seals.

8:40 - 9:00 am
4199771: Accurate Measurement of Particle Velocity using a Double Disc Anemometer in Erosive Wear Experiments
William Cashmore, Getu Hailu, University of Alaska Anchorage, Anchorage, AK; Alexander Blanchard, Marshall Space Flight Center, Huntsville, AL

Accurately characterizing particle velocity ejected from a nozzle in erosive wear experiments is crucial for quantifying erosive wear. Methods like particle imaging velocimetry, laser Doppler velocimetry (LDV) provide precise measurements, but they can be costly. An alternative approach to the abovementioned methods, at a fraction of the cost, is a velocity measurement with a double-disc anemometer (DDA). This paper presents a highly improved DDA design with automated post-processing procedures and result verification. We report an approach and a set of guidelines that significantly enhance particle velocity measurement using a DDA accurately and economically. A new scarring analysis method was conducted to identify the intricacies of how the instrument's geometries affect the velocity calculation. The DDA results were validated using state-of-the-art LDV equipment, with an agreement of ±2.8% on average.

9:00 - 9:20 am
4200835: A Surface Comparison Methodology for Wear Analysis
Tobias Martin, Q. Jane Wang, Jian Cao, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

There have been several methods used to analyze worn surfaces, including weight comparisons and wear-track cross section measurements. While these methods provide acceptable data for some surfaces, they are not suitable in many other cases. Weight-based methods do not perform well for cases of low-wear, and calculations based on a single or averaged cross-section of the wear track are inaccurate when the wear is inhomogeneous. Area-based image comparisons of surface height profiles between worn and unworn surfaces have been shown to be a promising method applicable to a wide range of worn surfaces. This method is also ideal for simultaneous surface roughness analysis to examine the evolution of surfaces during wear. This presentation will explore the methodology and use of this image-comparison method with white-light interferometry on wear of surfaces with varying degrees of roughness. It will also discuss some drawbacks to the method, such as image alignment, and how to address them.

9:20 - 9:40 am
4205462: Correlation in Filter Debris Analysis
Jacob Simons, POLARIS Laboratories, Indianapolis, IN

Filter Debris Analysis (FDA) is an analytical test that can be used to determine machine condition and system contamination. This is done by extracting debris from filter pleat material, measuring total mass of insoluble particles, and reporting 10 elements in Parts Per Million (PPM) using an acid digestion process. The microscopic debris particles are examined to determine the overall machine, filter, and fluid condition. This work will observe that elements reported in PPM correspond with particle identification and severity by referencing report findings with acid digestion results. Using statistical methods to examine report data, typical values for the measured elements are established. Correlating the presence of quantifiable results with the analyst's interpretation affirms the use of FDA as a diagnostic tool that can be reliably used for maintenance

decisions.

9:40 - 10:00 am - **Available Presentation Slot**

10:00 - 10:30 am - **Break**

1E Hanover F

Rolling Element Bearings I

Session Chair: Travis Shive, SKF USA Inc, Lansdale, PA
Session Vice Chair: Thomas Russell, Exponent, Natick, MA

8:00 - 8:40 am
4184397: Lubricant Levitation in High-Speed Bearings: A Combined Experimental and Numerical Approach
Ujjawal Arya, Farshid Sadeghi, Purdue University, West Lafayette, IN

This study investigates the phenomenon of lubricant levitation on bearing surfaces during high-speed operation, where flow can be significantly affected by lubricant levitation. Experiments were conducted using high-speed rotating setups involving the ball, inner race, and outer race, with a high-speed camera capturing the lubricant film levitation under various operating conditions. The results revealed the occurrence of Aerodynamic Leidenfrost Effect, which causes the lubricant film to levitate over the surface, reducing adhesion at elevated speeds. A numerical model based on compressible Reynolds Equation for air was also developed to simulate this effect, treating the lubricant droplet as a deformable soft elastic body supported by the air-film lubrication pressure. The model's predictions closely aligned with experimental trends and existing literature, offering valuable insights into the critical parameters influencing lubricant adhesion and effectiveness in high-speed tribology.

8:40 - 9:00 am
4206194: CFD Modeling of Bearing Cage Pocket Groove Geometries
Saeed Aamer, Farshid Sadeghi, Purdue University, West Lafayette, IN

This study investigates the effects of bearing cage pocket features on bearing cage friction. A custom test rig with an enclosed oil bath was used to evaluate various cage designs for cylindrical roller bearings. A load cell within the rig was used to measure the cage pocket friction torque of both smooth and pocketed cage designs. A CFD model was developed using Ansys Fluent software simulating the conditions of the experimental setup. The results indicate that a significant reduction in cage friction can be achieved when the surface of the cage pocket is grooved. The validated CFD model was extended to analyze a complete CRB geometry incorporating the grooved cage pocket features. The analytical results demonstrated that the friction reduction from the grooved designs observed in the test setup was consistent for full bearings under various operating conditions. Additionally, the new designs achieved this reduction while improving lubricant delivery to the roller-raceway contacts.

9:00 - 9:20 am
4183678: Modelling Bearing Thermal Performance Using Computational Fluid Dynamics (CFD)
Marco Van Zoelen, Jun Wang, Ying Zhang, SKF, Shanghai, China

Modelling the thermal performance of rolling element bearings using Computational Fluid Dynamics (CFD) involves the simultaneous simulation of oil flow and conjugate heat transfer. This process is challenging due to the differing time scales of convective and conductive heat transfer in bearing operations, especially at high speeds, which can slow down or even prohibit simulations. Additionally, effectively simulating the effect of heat generation on the moving contacts of the bearing raceway presents further difficulties. This paper introduces an efficient method to accelerate heat transfer in bearing structures and incorporates a novel approach to simulate rotating heat sources along the bearing raceways. The integrated method is applied to analyze bearing temperature performance under various operating conditions. The simulation results are validated against experimental data, demonstrating the method's effectiveness and accuracy.

9:20 - 9:40 am
4204909: Tribofilms of Lubricants in Rolling Element Bearings
Daniel Merk, Jörg Franke, Janine Fritz, Schaeffler Technologies, Schweinfurt, Bavaria, Germany

At the FE8 test rigs at Schaeffler, there were done extensive tests with oil lubricated axial thrust washer bearings over the years. This was done to investigate premature bearing failure mechanisms, such as wear or White Etching Cracks (WECs).
Based on multiple samples, generated by FE8 test rigs under mixed friction conditions, the interaction of different lubricants and their tribological contact will be described. The resulting tribo-film therefore is the "real" indicator of the physics and chemistry that acts in the tribo-contact, and influences the bearing performance, finally. The presentation shows results of tribo-film characterization, using three easy to use analytical techniques, with the focus on less time-consuming and spatially resolved investigations, and the meaning for future simulation of bearing service life.

9:40 - 10:00 am
4200399: Boundary Lubricated Rolling with Heathcote Slip and Spin - The Influence of Tangential Solid Body Elasticity
Gerhard Poll, Josephine Kelley, Leibniz University Hannover, Garbsen, Germany

Deviations from pure rolling in the form of Heathcote slip and spin slip or combinations thereof frequently occur in rolling element bearing contacts. They lead to additional frictional losses and, under mixed and boundary lubrication conditions, may also cause wear. Usually, elastic deformations in normal conditions are considered, whereas tangential elastic strains and shear deformations are neglected. However, they change the local distribution of slip in the contact area and may significantly influence wear and losses in the case of boundary lubrication with elevated tangential stresses. These effects are studied in this submission by simulations and a comparison with wear experiments. The simulations are performed with FE analyses as well as with an analytical approach based on Kalker's theory.

10:00 - 10:30 am - **Break**

Materials Tribology I

Session Chair: Tomas Grejtak, Oak Ridge National Laboratory, Oak Ridge, TN
Session Vice Chair: Santiago Lazarte, Florida State University, Tallahassee, FL

8:00 - 8:40 am
4204542: The Worldwide Surface-Topography Challenge – An Update
Tevis Jacobs, Arushi Pradhan, University of Pittsburgh, Pittsburgh, PA; Martin Müser, Saarbrücken, Germany; Lars Pastewka, University of Freiburg, Freiburg, Germany

The Surface-Topography Challenge was a two-year collaborative effort, where 150 people from around the world measured the surface topography of near-identical samples. At STLE 2024, we presented preliminary results; this year, we present the published findings: While surface performance depends critically on topography across applications, standard metrics like Ra are insufficient predictors. To raise awareness of this limitation, assess reproducibility of topography measurements, and advance the state of the art in surface metrology, we conducted the Surface-Topography Challenge. Initially, the 2437 measurements revealed wide disagreement in RMS height. However, consensus was established by correcting artifacts, computing scale-dependent parameters, and removing data that deviated from the majority. Our findings suggest best practices for characterizing topography. The public release of all data and analyses enables global reuse, analysis, and benchmarking.

8:40 - 9:00 am
4205527: Topography-Dependent Adhesion of Wear-Resistant Coatings
Arushi Pradhan, Felix Cassin, Amit Prasad, Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA

High-volume semiconductor fabrication equipment requires wear-resistant coatings with excellent tribological properties. While hard-material adhesion is critical, its prediction remains challenging, because rough surfaces create multi-asperity contacts. This study investigates the adhesion behavior of three wear-resistant coatings—polished microcrystalline diamond, chromium nitride, and amorphous diamond-like carbon—in contact with silicon. Adhesion experiments were performed using atomic force microscope probes, where tip geometry was characterized using electron microscopy. The topography of the wear-resistant coatings was characterized across all scales, from 1 cm to 30 nm. Numerical predictions of computed adhesion force were compared with measured results, to reveal insights about the mechanisms of separation as well as the material and topographical parameters controlling adhesion performance. These results advance the understanding of adhesion in wear-resistant coatings.

9:00 - 9:20 am
4205682: Multi-Scale Surface Interactions: Linking Geometry, Environment, and Adhesion through Surfaces Patterned with Greyscale Lithography
Alexander Briese, Felix Cassin, Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA

To truly understand surface performance such as adhesion and friction in industrial settings, characterizing and linking surface parameters from nano to macroscale has proven to be a necessary but difficult process. The interplay of adhesion and its dependent variables is very complex, and known to be correlated with the interfacial geometry, as well as the environment it resides in. We use greyscale electron-beam lithography to etch different mixtures of superimposed wavelengths onto a flat silicon substrate. Each is then tested for its adhesion with microscale colloidal probes of different sizes in both ambient and dry environments. The gathered adhesion

data was analyzed and numerically simulated using different adhesion models to understand how the shape of the surface, shape of the contacting probe, and environment interact to perform over a magnitude of measured adhesion difference.

9:20 - 9:40 am
4194195: Effect of Carbides on Adhesion Force
Natsumi Kikuchi, Nippon Steel Corporation, Futtsu-shi, Chiba, Japan

Clarification of adhesion on the surface of steel at atomic level is necessary to understand the tribology of carbon steel mechanical components. Carbon steel exhibits various mechanical properties by controlling the crystal structure of iron, the state of carbon and carbide formed from iron and carbon through heat treatments. The authors have investigated the relation between the crystal structure and the adhesion force of iron. In this presentation, we focused on the effect of carbides on adhesion force. Using carbon steel SAE1045, carbide types were controlled by various heat treatments. The adhesion force on the surface of these steels were measured by atomic force microscopy. As a result, the type of carbide affects the adhesion force. That suggests the effect of the crystal structure on the force. Therefore, carbide types could be an important factor for understanding the tribology of carbon steel.

9:40 - 10:00 am
4181917: Effect of Contact Stress on the Growth and Adhesive Transfer of Metal Oxide Tribofilms
Parker LaMascus, Anthony Kholoshenko, Daniel Delghandi, Sage Fulco, Nwachukwu Ibekwe, Kevin Turner, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Pranjal Nautiyal, Oklahoma State University, Stillwater, OK; Marjeta Fusha, Andrew Jackson, Robert Wiacek, Pixelligent Technologies LLC, Baltimore, MD

Novel tribofilm-forming additives are needed to protect next-generation machinery from surface failure in increasingly stringent lubrication regimes. Metal oxide nanoparticles such as ZrO_2 or TiO_2, when dispersed in lubricants, can form such tribofilms at points of contact by stress-driven, room-temperature tribosintering. Stress is an important factor in setting the growth kinetics of these films, but stress also drives wear processes that are experimentally convoluted with tribofilm growth. We isolate the removal process to demonstrate that metal oxide tribofilms can adhesively transfer to countersurfaces that were not initially coated. We then quantify the effects of local contact pressure on this phenomenon quasi in situ with a newly-developed approach to resolve growth rates at different spatial positions in a mini-traction machine tribometer. We estimate the critical junction size of TiO_2 and ZrO_2 tribofilms to discuss transitions in adhesive wear mechanism.

10:00 - 10:30 am - **Break**

1I Regency VII

Electric Vehicles I

Session Chair: TBD
Session Vice Chair: TBD

8:00 - 8:40 am
4200643: Novel Insights into the Role of Electric Fields on Lubricant Additive Efficiency in Boundary Lubrication
Imène Lahouij, Zhengyuan Peng, Frédéric Georgi, Pierre Montmitonnet, MINES Paris | PSL Research

University, Sophia Antipolis, France; Adam Nassif, MINES Paris, Sophia-Antipolis, France

The growing electrification of vehicles has increased the risk of premature failure in lubricated interfaces due to uncontrollable stray currents, highlighting the need to quantify the effects of electric fields on lubrication efficiency. In this study, we employed a modified reciprocating ball-on-disc tribometer to investigate the performance of two driveline fluids under electrified conditions at both ambient and elevated temperatures (80/100°C). The impact of current intensity (0-3A) and direction on wear and tribo-layer formation was thoroughly analyzed using profilometry, SEM-EDS, and XPS techniques. For each fluid, a critical threshold was identified where electric current disrupted the lubricant's ability to form protective tribofilms. We also explore strategies to mitigate the effects of stray currents, including the use of metallic composite coatings and lubricants blended with metal oxide nanoparticles.

8:40 - 9:00 am
4189007: Multifield Lubrication Theory and A Generalized Multifield Reynolds Equation
Xiaoman Wang, Shuangbiao Liu, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL; Ning Ren, Valvoline Global Operations, Lexington, KY

Electric and magnetic fields significantly influence the performances of the lubrication systems in electrical vehicles (EVs), wind turbines, and other types of generators; they sometimes may accelerate failures of the tribological interfaces subjected to such lubrication. A multifield lubrication theory is required, as a core, to properly describe the lubrication system behaviors. This presentation introduces a generalized mechanical-electro-magnetic-thermal-field (MEMT-field) Reynolds equation, proposed to express the pressure-film thickness relationship subjected to coupled mechanical, electric, magnetic, and thermal fields. The effects of electric and magnetic fields, including electromagnetic forces and moments, are integrated into this equation. The equation is further explored for solutions using a numerical iteration method, offering a framework for designing advanced EV lubricants and tribo-pairs that operate effectively across multiple fields.

9:00 - 9:20 am
4195485: Influence of Small Electric Potentials on the Performance of Rolling-Sliding Contacts in Mixed Lubrication
Ammad Yousuf, Amir Kadiric, Imperial College London, London, United Kingdom; Liang Guo, SKF BV, Houten, Netherlands

Tribological components in engineering applications that employ electric machines, such as EVs, are frequently subjected to unexpected electric potentials. Under full film lubrication, the damage caused by such potential is relatively well-documented and understood. However, the impact of such voltages on the performance of rolling-sliding contacts under mixed lubrication conditions is complex and poorly understood. This work uses a ball-on-disc tribometer (MTM), suitably modified to apply controlled DC and AC voltages across the contact, to study the effect of small voltages and currents on surface damage and tribofilm formation under mixed lubrication regime. The study employs a selection of custom and commercial oils. The results are shown to illustrate how even the small potentials can significantly alter wear and tribofilm behaviour and are discussed in terms of a complex interdependency between tribofilm, electric response and wear in the contact.

9:20 - 9:40 am
4178390: Effect of Applied Voltages on Wear Behavior of Rolling Sliding Steel Surface under Lubrication with E-axle Fluids
Reon Furukawa, Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Tokyo , Japan; Takuto Kunii, Rtec-Instruments K.K., Kashiwa, Chiba, Japan

In the development of E-axles for electric vehicles (EVs), concerns arise about electric corrosion in bearings and gears due to inverter drives. Therefore, in addition to countermeasures on the motor side structure, improvements in lubricants and sliding materials are required. However, the extent of voltage and current generation at the sliding interface and how these affect friction and wear remain unclear. In this study, a ball-on-disk type friction test was conducted where arbitrary voltage and current could be applied, to investigate the effects of current and voltage on friction, wear, and surface damage under a lubricated environment using EV lubricants. The results showed that, under direct current (DC) voltage, wear conditions varied between the positive and negative electrodes, with voltage, current, and slip rate influencing wear characteristics. Moreover, under alternating current (AC) voltage, friction and wear behaviors differed significantly from those under DC voltage.

9:40 - 10:00 am
4205456: Modeling Various Lubricant Influences on Rolling Element Bearing Electrical Discharge Damage
Robert Jackson, Sudip Saha, Auburn University, Auburn, AL; Jack Janik, Southwest Research Institute, San Antonio, TX

Stray or leakage currents can cause damage to the mechanical components of a variety of applications, such as electric vehicles, wind turbines, aerospace vehicles, power generators, and in manufacturing. It is difficult to predict what combination of operating conditions and lubricant types facilitate electrical damage. However, if the damage does occur it can cause a component, such as a bearing, to fail or operate poorly (such as having high friction or being noisy). This work uses a semi-analytical model to evaluate theoretically the influence of different lubricants and additives, along with the operating conditions to predict the occurrence of damage. The model considers elasto-hydrodynamic lubrication, rough surface effects, electrical discharge, and transient conditions. Therefore, it depends on many material and electrical properties that can be used to mimic specific lubricant behavior. The results are then compared to experimental results.

10:00 - 10:30 am - **Break**

1J The Learning Center

Non-Ferrous Metals I

Session Chair: Annie King, TotalEnergies Lubricants, Linden, NJ
Session Vice Chair: Andrea Knopp, Constellium, Ravenswood, WV

8:00 - 8:40 am
4199806: Development and Implementation of Soap Free Aluminum Hot Mill Lubricant with Excellent Fines Dispersion
Thomas Oleksiak, Rene Liedtke, Pablo Bakermans, Yao Lu, Quaker Houghton, Conshohocken, PA

Today, both soap-based and soap-free formulations are widely used in the aluminum hot rolling industry. Soap-based products are recognized for having the best lubricity on a wide variety of alloys but struggle with metallic soap build up. Current soap free technologies have good lubricity and dramatically low usage rates but can struggle with poor fines dispersion. This can cause problems not only in the emulsion tank but also on mill surfaces. A unique soap-free formulation has been developed, incorporating newly developed test methods. Subsequently, refined pilot mill protocols were used to better mimic production mill performance. Initial promising field results will be documented. This formulation reached a new level of performance with improved lubricity and

fines dispersion.

8:40 - 9:00 am - **Open Slot**

9:00 - 9:20 am
4174541: How Surfactants Contribute to Rolling Performance in Emulsions for Aluminum Hot Rolling
Ariane Viat, Constellium Technology Center, Voreppe Cedex, France

Aluminum flat products are obtained by hot rolling, in using oil-in-water emulsions as a metalworking fluid. The oil is usually 1-10% concentrated and is composed of mineral base oils, fatty additives, and surfactants for proper emulsification. Emulsion stability is a key feature for such metalworking fluid. The emulsion must be loose enough to allow contaminants rejection but also needs some tightness to remain homogeneous at the roll bite entry. The emulsion performance is driven by its behavior in the roll bite. Different rolling performances are found despite identical mean oil droplet size. This paper investigates further surfactants features to explain rolling performance: particle size distribution, mechanisms of destabilization (coalescence, migration) as for the stability properties. It is also proposed to use the HLD method to characterize the emulsions and to study the oil-water split conditions in relation to the rolling process parameters.

9:20 - 9:40 am
4206475: Filtration of Rolling Fluids
Craig Thomas, Penn State University, Benicia, CA

The manufacturing of Aluminum foil and sheet requires the metal to be rolled to a precise gauge (thickness) for the particular application. This process requires the use of specific rolling oils to help form, cool, lubricate and remove debris from the process. The used and dirtied oil is then filtered to remove the particulate which is a waste formed from the rolling process. This used oil requires precise filtration to remove the particulate and clean the oil for reuse in the rolling process. JR Schneider with its end users have been using a specific filter aid for use in this process. This filter aid provides for significant filtration and long cycle times for the end user's filter. This discussion will provide background on this type of oil/coolant filtration, the chemistry and mechanics of the filtration and the results from using this type of filtration method.

9:40 - 10:00 am
4206193: A Paradigm Shift in Aluminum Cold Rolling Oil Filtration Methods
William Lawrence, CRS Reprocessing, Jeffersonville, IN

Filtration of aluminum cold rolling oil has been done with stack or candle filters using DE and other precoats. While these traditional filtration methods provide clean fluids for aluminum rolling, they generate large amounts of waste containing oil-soaked paper and precoat. These filters contribute debris to the filtered oil after indexing until the precoat cake is stable. These filter processes are expensive to maintain and have not been upgraded for decades. Additionally, they are oversized for the rolling mill requirements sending large amounts of clean filtered oil back to the dirty tank. This paper will explore recent developments with filtration technologies employing a mass balance concept which can replace stack filters eliminating large amounts of waste, the associated harm to the environment, high maintenance costs, and excessive flow rates. These process upgrades come with a paradigm shift in oil quality considerations for particle distribution, debris, and turbidity.

10:00 - 10:30 am - **Break**

Centennial Ballroom

Keynote Presentation – 10:30 am – 12:00 pm

Deep Timken Expertise Enables Deep Space Exploration
John Renaud
Principal Application Engineer
The Timken Company

2A Hanover AB

AI and Machine Learning II

Session Chair: Tianshi Fang, Shell Global Solutions, Houston, TX
Session Vice Chair: Max Marian, Leibniz University Hannover, Hannover, Germany

1:40 - 2:20 pm
4203656: Monitoring of Bearings Using Machine Learning-Based Surrogate Models
Florian König, Georg Jacobs, Florian Wirsing, RWTH Aachen University, Aachen, Germany

The availability of machines and systems is particularly dependent on monitoring the safe operating condition of bearings using condition monitoring systems (CMS). With the emerging trend of machine learning (ML) and Artificial Intelligence (AI), fully automated CM becomes more and more attractive. ML and AI can find correlations in sensor signals beyond human capabilities. However, the interpretation of CMS signals often requires a physical understanding of the technical systems to not only correlate but also understand and thereby improve machine components. The objective of this presentation is to provide an understanding of the targeted application of sensor technology, physics-based, machine learning and statistical models for condition monitoring of bearings. The application in rolling element and journal bearings in the field of wind energy and automotive systems and the potential for industrial implementation will be discussed.

2:20 - 2:40 pm
4204304: Use of Machine Learning to Predict End of Life in a Bent-Axis Pump
Paul Michael, Pawan Panwar, Icaro dos Santos, Estevao Guimaraes, Milwaukee School of Engineering, Milwaukee, WI

One of the first indicators that a positive displacement pump is approaching the end of its useful life is a decrease in hydraulic system performance. If the impending failure remains undetected, a catastrophic pump failure can occur, interrupting production, and dispersing wear particles throughout the system with devastating effects. In this investigation, a high pressure bent-axis pump was systematically degraded and performance data was collected. Synthetic data was produced by Conditional Generative Adversarial Network and used to train, validate and test a Convolutional Neural Network. The CNN demonstrated 100% accuracy in predicting pump failure before it occurred and over 92% accuracy in prediction within a 300-hour window. Accelerometers were used to expand the applicability of the CNN to a broader range of speed and pressure conditions.

2:40 - 3:00 pm
4200615: Beyond Oil Sampling: A Data-Driven Approach To Predictive Maintenance
Harshit Agrawal, Maintonia Technologies Pvt Ltd, Pune, Maharashtra, India

Traditional oil analysis relies on manual sampling and lab tests, hindering proactive maintenance strategies. This paper presents an innovative approach using IIoT-enabled Laser Particle Analyzers for continuous, real-time oil condition monitoring. These systems analyze key parameters like viscosity index, moisture content, Total Acid Numbers (TAN), particle counts, etc. Secure data transmission via industrial protocols allows for real-time processing with oil analysis and predictive maintenance algorithms. This enables actionable insights for proactive maintenance decisions, directly addressing equipment failure risks associated with contamination. This paper explores the transformative potential of IIoT in empowering advanced particle analysis technology. We demonstrate how this approach can significantly increase operational efficiency and visibility for connected devices within the lubrication space.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4207676: Transforming Fluid Analysis with AI-Driven Innovations
Dave Tingey, POLARIS Laboratories®, Indianapolis, IN

The future of maintenance analytics utilizing machine learning and artificial intelligence to further analyze and improve fluid analysis data is here. Through the use of millions of fluid data points, flagging limits and continued machine learning as new lubrication data becomes available, we are now able to precisely analyze laboratory test results to provide more reliable comments and recommendations for maintenance action. In this session, learn about how machine learning and AI technology is advancing the world of fluid analysis, increasing accuracy of flagging limits and where the future lies in the industry using this technology.

4:20 - 4:40 pm
4205006: Predicting Tribological Behavior of Lubricant Additives Using Machine Learning: A Data-Driven Approach to Lubricant Optimization
Wahyu Wijanarko, Bharat Premkumar, Nuria Espallargas, Norwegian University of Science and Technology, Trondheim, Norway

Machine learning (ML) applications in tribology are gaining popularity for their ability to predict complex material behaviors, optimize formulations, and assess performance more efficiently than traditional methods. These advancements reduce physical testing and speed up the development of high-performance materials and lubrication systems. However, the need for large, consistent datasets poses challenges. This study employed boosting and tree-based ML models to predict the behavior of lubricant additives. A list of potential additives was curated from a dataset of 12,982 chemicals, based on their chemical composition and physical properties from the EPA Ecotox database. Our in-house database, built from years of tribological testing, served as the training set, while the Ecotox chemicals were used for testing. Promising additives were identified and experimentally validated. The coefficient of friction and wear data showed a strong correlation between predicted and actual results.

4:40 - 5:00 pm
4205394: Emergence of Coefficient of Restitution as a Key AI-suggested Parameter in Wear Resistance Optimization of High-Speed Engineering Polymer Composites
Tanil Ozkan, Steve Pouliot, Jonathan Penaranda, Burak Bekisli, Dover Innovation Laboratory, Houston, TX

The longevity of high-performance engineering polymer composites in demanding tribological settings and its mechanical underpinnings are of great interest to polymer tribologists. This study explores the application of AI-based semantic clustering search in conjunction with existing polymer composite damage mechanics models to evaluate the parameters that can contribute to longevity. Our findings highlight a more critical role than generally thought for the coefficient of restitution (CoR) in determining the wear resistance and durability of these composites. To support these findings, an experimental investigation conducted with a PEEK-based composite system revealed that the inclusion of nanoscale elastomeric constituents significantly change the CoR and alter the wear resistance especially at high speeds. These experimental results suggest that incorporation of nanoscale elastomeric materials in polymeric matrices can be a viable approach.

2B Hanover C

Commercial Marketing Forum II

Session Chair: TBD

1:40 - 2:00 pm
4297593: Advancion: A New-to-World Multifunctional Additive for High-performance Metalworking Fluids
Min Chen, Advancion Corporation, Buffalo Grove, IL

Evolving trends in the metalworking fluids market increasingly drive formulators toward additives that enhance performance while meeting rigorous regulatory requirements. Building on a more than 80-year commitment to developing unique additives for essential end markets, Advancion (formerly ANGUS Chemical Company) recently launched a next-generation portfolio of multifunctional additives. CORRGUARD™ SELECT is a new-to-world, readily biodegradable multifunctional additive specifically designed to provide superior fluid performance with an excellent safety profile. CORRGUARD SELECT excels in multi-metal compatibility, provides high-efficiency neutralization and enhanced foam control to deliver exceptional performance in the most demanding metalworking fluids applications. Learn how Advancion's purposeful development across market segments enables innovation that brings new additives and value to support the complex metalworking formulation challenges in today's dynamic market.

2:00 - 2:20 pm
4301596: Evonik: Deployment of Efficient Lubricants at Evonik
Ellington JoRuetta, Frank-Olaf Maehling, Evonik, Darmstadt, Germany

Modern lubricants enhance the reliability and efficiency of industrial plants. Plants often use standard lubricants, limiting their potential due to perceived lower costs and acceptance of frequent maintenance. Understanding the advantages and benefits of alternatives can facilitate lubricant upgrades, leading to reduced maintenance, energy consumption, and greenhouse gas emissions.
Evonik has demonstrated the impact of high-performance lubricants on equipment longevity and efficiency through extensive research. High tier fluids based on DYNAVIS® and NUFLUX® technology ensure efficient and reliable operation with extended maintenance intervals.
Evonik's approach at their production sites has shown upgrading lubricants reduces total cost of ownership, offering a quick return on investment. This method also supports sustainability goals by reducing energy use and emissions. Adopting advanced lubricants is a straightforward way to achieve significant cost savings and environmental benefits.

2:20 - 2:40 pm
Functional Products, Inc. Presentation

2:40 - 3:00 pm
4306588: Optimol Instruments: Functional Screening Methods for Performance Assessment of Transmission Components
Gregor Patzer, Optimol Instruments, Munich, Germany

This paper introduces advanced tribological screening techniques designed to assess critical functional properties, such as load-carrying capacity, friction reduction, wear resistance, and material compatibility. These properties are essential to optimizing gear performance under varying operational and environmental conditions. The proposed methods leverage model tests to evaluate the performance of materials, coatings, lubricants, and individual components with high statistical reliability. By correlating laboratory findings with real-world performance, this study provides a robust framework for improving transmission efficiency, durability, and sustainability. Key innovations include the development of a refined testing protocol for low-viscosity fluids and new approaches to assess micro-pitting and pitting resistance using non-circular test disks.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4301324: VBASE® OIL Company: Secondary Polyol Ester™ Technology – Versatility Across the Lubricants Market to Deliver Commercial Value
Stephen Eck, VBASE Oil Company, Pendleton, SC

VBASE® Oil company has commercialized a novel family of Secondary Polyol Ester™ (SPE®) base oils that are high performance, sustainable, API Group V synthetic base oils in the range ISOVG 32-460. SPE® base oils have been 'Designed for Sustainability' by linking building blocks that have high levels of biodegradability to create novel base oils that can help formulators meet the highest technical performance and environmental accreditation requirements.
The presentation will highlight the unique properties and applications of SPE® base oils. This oxygen-rich family of base oils, with built in detergency, offers attributes such as unique thermophysical properties, excellent deposit control, hydrolytic stability, friction control and low heats of combustion making them a versatile tool for formulators of industrial, marine, and automotive lubricants. We will expand upon these features and benefits and show how we see them translating into commercial value for the industry.

4:20 - 4:40 pm
4301660: Zschimmer & Schwarz: Introducing EsterTec: The Future of Synthetic Ester Technology
Douglas Placek, Zschimmer & Schwarz, Gordon, GA

Z&S introduces a breakthrough in synthetic ester technology that delivers superior performance, sustainability, and cost efficiency.
Novel EsterTec VSP esters offer exceptional performance based on their innovative molecular structure achieved via a unique production process. This portfolio of new products can deliver all the features expected from a standard synthetic polyol ester (wide operating temperature range, deposit control, and eco-friendly performance) while also providing best-in-class hydrolytic stability, low volatility, and natural energy efficiency. Enhanced thermal, oxidative and hydrolytic stability make EsterTec VSP base stocks and additives the optimum choice for formulating both standard and next generation lubricants.
Zschimmer & Schwarz continues to offer the world's broadest line of synthetic esters, now further enhanced with EsterTec VSP technology to meet your future formulation needs.

4:40 - 5:00 pm
4307967: LANXESS' DMTD Derivatives - more than yellow metal inhibitors!
Sandra Horstmann, Lanxess Deutschland GmbH, Mannheim, Germany

Corrosion or staining of non-ferrous metals needs to be avoided in many applications. To address this, LANXESS offers not only products based on triazoles (e.g., Additin® RC 8239), but also non-ferrous metal deactivators derived from DMTD (dimercapto thiadiazole), such as Additin® RC 8210 and Additin® RC 8213. The main benefits of DMTD-based products is their ability to offer excellent corrosion protection, extreme pressure (EP) and sulfur scavenging properties. These non-ferrous metal deactivators are ideal for use in formulations for metalworking, greases, EV driveline, and industrial fluids. Additionally, Lanxess offers the specialized non-ferrous metal deactivator Additin® M 82.001, which features enhanced EP-boosting capabilities. We recommend this product for use in greases at a treat rate of 1% - 3%, and in metalworking fluids at a dosage of 0.05% - 0.5%.

2C — Hanover D

Wear II

Session Chair: Wenbo Wang, Oak Ridge National Laboratory, Knoxville, TN
Session Vice Chair: Xue Han, Cummins, Inc., Columbus, IN

1:40 - 2:20 pm
4205420: Investigation on Abrasive Performance of Engineering Plastic Materials Used in Harsh Environmental Conditions
Dorina Mihut, Arash Afshar, Stephen Hill, Mercer University, Macon, GA

Wear effects are recurrent and expensive in many industrial related applications therefore it becomes important to select appropriate resistant materials. There is an increased demand for polymers for applications where abrasive wear is predominant due to their lightweight and cost effectiveness; however, their acceptability depends on performance. The research investigates the abrasive wear of engineering plastics used in harsh environmental conditions. The oscillating sand abrasion tester (ASTM F735) and reciprocating linear abrasion tester (ISO 1518) are used to assess the abrasive wear resistance. The harsh environmental conditions are simulated with an accelerated weathering equipment that is performing tests in conformity with ASTM G154 (UV radiation, high temperatures and moisture cycles). Measurements are taken before and after the testing to evaluate the mass loss of the specimens (electronic balance), surface roughness and volume loss (high accuracy optical microscopy).

2:20 - 2:40 pm
4214496: Explore the Wear Resistance of FeCoNiMo and CrCoNiMo and the Mutual Effects of Mo and Cr on the Formation of Self-Lubricating Oxides up to 1000 °C
Wandong Wang, University of Toronto, Toronto, Ontario, Canada

This study investigates the phase, microstructure, high-temperature hardness, and high-temperature wear behaviours of FeCoNiMo and CrCoNiMo high-entropy alloys. The Mo content and the formation of intermetallics contribute to a distinct hardness until 800 °C, especially for CrCoNiMo with a higher fraction of intermetallics, is much harder than FeCoNiMo. However, the FeCoNiMo still exhibits a comparable, even better resistance to sliding compared to CrCoNiMo with the formation of lubricating spinel Mo oxides at room temperature. Its resistance becomes better at moderate temperatures with quick growth of the glaze layer. However, the Cr-free FeCoNiMo shows a decreasing wear resistance at 1000 °C. In contrast, the Cr-containing

CrCoNiMo exhibits superior resistance and stability up to 1000 °C. These findings suggest that the formation of stable oxide layers and the lubricated effects of Mo oxides contribute to the enhanced high-temperature performance of CrCoNiMo.

2:40 - 3:00 pm
4205637: Sliding Wear Behavior of Superalloys Based on Nickel and Cobalt
Ramanathan Krishnamurthy, Paul Crook, Haynes International, Kokomo, IN

The sliding wear behavior of several Ni-based and Co-based superalloys, nominally strengthened via solid solution strengthening (alloys HAYNES 230, 625, HAYNES 25) or via precipitation of a 2nd phase (alloys HAYNES 282, 718 and Waspaloy) was examined via self-mated pin-on-disk (POD) tests, wherein process parameters such as load, speed and sliding distance were systematically. Comparison of wear volume losses following these tests show that the Co-based 25 alloy had superior wear resistance compared to Ni-based alloys while Ni-based precipitation strengthened superalloys suffer less wear compared to Ni-based solid solutions strengthened alloys. A change in the wear mechanism to one localized to large asperities was also observed at high speeds across all the alloys. SEM and optical microscopy of the wear samples were used to correlate the deformed near-surface microstructures and the dominant alloy strengthening mechanism of the worn samples to the measured wear volume losses.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4203639: Experimental Investigations on the Failure Mechanisms of Synchronous Belts
Philipp Häderle, University of Stuttgart, Stuttgart, Germany

The dimensioning of synchronous belt drives is not standardized, but based on manufacturer information and empirical values. This is partly due to a lack of fundamental knowledge about the system of a synchronous belt drive. To counteract this problem, the different failure mechanisms, that can occur during the operation of a synchronous belt are investigated. Therefore, a test bench for synchronous belt drives is developed. Failure mechanisms known from the literature, such as wear, cord breakage and fabric detachment are replicated on the test bench under certain operating conditions. Especially the parameter settings of the operating conditions, where different failure mechanisms occur are further investigated. The result of this work will be a deeper understanding of the operating conditions that cause certain failure mechanisms. This deeper understanding on the failure mechanisms lays the foundation for further investigations on the service life of synchronous belt drives.

4:20 - 4:40 pm
4205557: Wear Mechanisms of Several Elastomers for Hydrogen Facility
Hiroyoshi Tanaka, Kyushu University, Fukuoka, Japan

To build up a safe and reliable hydrogen energy system, safe operation of high-pressure hydrogen gas is crucial. O-rings are the most common sealing element in hydrogen application, and they must have sufficient reliability and durability to minimize downtime. However, wear on the O-ring surface sometime accelerates during operation, leading to deterioration of the sealing performance. In this study, reciprocating sliding tests were carried out using several elastomers, including three types of base polymers with three different hardnesses. In order to understand friction and especially wear in hydrogen, surface analyses on elastomers and the counter surfaces were performed after sliding tests in both hydrogen and air atmosphere. The analysis revealed different static friction in hydrogen vs air which influences wear processes for short-distance reciprocating motions.

4:40 - 5:00 pm - **Wear Business Meeting**

2D Hanover E

Metalworking Fluids I

Session Chair: Stefanie Velez, Munzing Chemie GmbH, Bloomfield, NJ
Session Vice Chair: Stephanie Cole, Munzing North America, LP, Bloomfield, NJ

1:40 - 2:20 pm
4186162: Sustainable Lubricants: Formulating High-Performance Ester-Based Metalworking Fluids
Lea Tekath, Kao Chemicals GmbH, Emmerich am Rhein, Germany

In response to growing concerns about environmental and health impacts of industrial activities, a novel approach to formulation is required. Beyond reducing carbon footprints and increasing the use of renewable resources, formulators are now tasked with developing more sustainable metalworking fluids that support the circular economy. Biodegradable esters have emerged as an eco-friendly alternative to traditional petrochemical-based fluids. The key to meet future regulatory and performance requirements in addition to overcome formulation challenges lies in the selection of a well-balanced additive package. This study presents a collaborative development effort, incorporating the expertise of an ester supplier, additive specialists, and a specialty lubricants manufacturer, resulting in a low foaming, hard water stable, excellent lubricating metalworking fluid guideline formulation.

2:20 - 2:40 pm
4194933: The Effect of Limited Lubrication by Misting in a Pin & Vee Block Simulation of Cutting and Forming Fluids.
Dirk Drees, Lais Lopes, Pedro Baião, Michel De Bilde, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Erin Kerr, Falex Corporation, Sugar Grove, IL

In previous work, the use of the standard Pin & Vee block method was expanded by adapting lubrication methods, alloys, and data interpretation, to obtain a correlation between tapping torque experiments and the new Pin & Vee Block method. Testing was always done with excess lubrication, so the question has arisen what happens with misting conditions, which are common in certain metalworking processes. To answer this question, the research is expanded to misting conditions, to determine differences between a fully submerged and misted tribocontact. In addition to the change of the lubrication application, also the influence of different alloys, characteristic for some industrial cutting or forming conditions, is studied. Aluminum and copper alloys, as well as stainless steels are being compared in this test method.

2:40 - 3:00 pm
4199482: Metal-Working Fluid Performance Metrics for Sustainability
Shannon McGee, Bob Evans, Philip Zhao, Abigail Meyer, Karl Zhong, Ed Platt, Quaker Houghton, Conshohocken, PA

In the metalworking fluid industry, accelerated sustainability adoption is being driven by stricter regulations, customer demand and the drive for innovative technologies. Much of the focus has been on current or upcoming regulated environmental factors such as GHG emissions and carbon footprint through formulating with bio-based raw materials. However, the performance of metalworking fluids can also be looked at as a sustainability metric. Performance-based

sustainability metrics for companies to focus on can include energy efficiency, fluid productivity, and longevity for example. By focusing on improving potential application capabilities in sustainability, in addition to potential formulation capabilities, there can be innovative sustainable solutions. In this presentation, comparisons are made between an older generation and newer generation metalworking fluid in different applications to highlight technological improvements in performance related to sustainability metrics.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4202857: Introducing a New Amino Alcohol for Metalworking Fluids
Richard Butler, Kathleen Havelka, Advancion, Buffalo Grove, IL

The benefits of using novel amino alcohols in today's high-performing metalworking fluid compositions are discussed. Their primary functions are neutralization of acid-functional ingredients, imparting alkaline pH development and buffering. Additional benefits of amino alcohols are becoming equally important. Examples in a metalworking fluid of novel amino alcohols enhancing lubricating, cleaning, and/or handling properties by providing multi-metal corrosion inhibition, reducing cobalt leaching, and/or stabilizing the metalworking fluid emulsions are presented. This presentation will introduce a new- amino alcohol and its ability to uniquely deliver the range of benefits sought by contemporary MWF formulators.

4:20 - 4:40 pm
4200602: Development of the World's First Sulfurized Algae Oil-Based Extreme Pressure Agent
Hironobu Matsueda, DIC Corporation, Kamisu, Japan; Ted McClure, SLC Testing Services Inc., Westlake, OH

Sustainability is becoming a part of everyday life. Currently, most of the discussion is focused on CO2 emissions, but it is important to consider sustainable supply systems from a broader perspective.
Additionally, the demand of existing natural oils and fats are increasing from the application of SAF (sustainable aviation fuel) for the aviation industry. It is important to prepare in advance and have additional source to build more sustainable supply chain. Moreover, the presented sulfurized algae oil is not only an alternative but is based on algae oil produced more efficiently than the traditional oils. Also, it has excellent performance as an extreme pressure agent. Sulfurized vegetable and sulfurized animal oils each have strong performance characteristics. The presented sulfurized algae oil combines the benefits of both. Data will be presented comparing the performance of sulfurized algae oil with conventional sulfurized natural oils.

2E — Hanover F

Rolling Element Bearings II

Session Chair: Ujjawal Arya, Purdue University, West Lafayette, IN
Session Vice Chair: Travis Shive, SKF USA Inc, Lansdale, PA

1:40 - 2:20 pm
4182459: Advanced Stress-based Life Model for Hybrid Bearings Considering Surface and Subsurface Fatigue Risks
Nikhil Londhe, Timken Company, North Royalton, OH

Rolling element bearing components experience nonproportional, triaxial compressive cyclic stresses in subsurface region of Hertzian contacts and the near surface region of asperity contacts. Subsurface stresses dominate when elastohydrodynamic lubrication film is thick. Stresses within the asperities dominate under thin film conditions. This work proposes a fatigue model for hybrid (steel on Si3N4) contacts. The model studies subsurface and surface stresses and their influence on fatigue. The model incorporates the bearing load distribution and EHL film thickness effects. 3D contact problems are numerically solved using a discrete formulation of contacts of real rough surfaces. Computational efficiency is achieved using fast Fourier transform (FFT) and multi-level multi summation (MLMS) techniques. Fatigue model parameters were optimized using advanced artificial intelligence algorithms. Life predictions with this approach correlate with experimental hybrid bearings fatigue life data

2:20 - 2:40 pm
4199303: A Semi-Analytical Method to Study Fretting Mechanisms in Oscillating Ball Bearings
Rémy Duquesne, Daniel Nelias, Sébastien Morterolle, Contact and Structural Mechanics Laboratory, Lyon, France

Oscillating bearings face tribological challenges due to their small reciprocating motions and fluctuating loads. These operating conditions often lead to false brinelling, a fretting wear process caused by the inability of the bearing to maintain a sufficient lubricant film thickness. This study introduces a novel semi-analytical approach to examine the fretting mechanisms in those bearings, focusing on both rotational fretting due to small oscillations and radial fretting caused by fluctuating normal loads on the rolling elements. By describing micro-slips that arise from the bearing internal kinematics and utilizing advanced semi-analytical methods like DC-FFT (Discrete Convolution – Fast Fourier Transform) for contact resolution, this work provides insights into shear force distribution and stick-slip regions inside the contact zone. Additionally, experimental fretting tests are conducted on a sphere-on-flat tribometer to evaluate the friction coefficient of the lubricated surfaces.

2:40 - 3:00 pm
4202482: Growth Mechanisms of White Etching Cracks and Butterflies
Daniel Merk, Schaeffler Technologies, Schweinfurt, Bavaria, Germany; Joerg Loos, Wolfram Kruhoeffer, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany

We have examined growth mechanisms of White Etching Cracks (WEC) types such as oriented WECs, step-like cracks, WEC networks, and brittle fracture. WECs can occur regardless of the material cleanliness, while butterflies initiate from defects. We have investigated the differences between WECs and butterflies in more detail. To substantiate the growth mechanism of step-like cracks we have performed crack growth simulations. As an outcome we present the typical number of contact load cycles till bearing failure for the discussed WEC types for comparable contact pressures. Finally, we propose basic formation mechanisms for White Etching Areas (WEAs) in the context of WECs and butterflies.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4203062: Very High Cycle Fatigue of High Strength Steels Applied to Aeronautic Rolling Bearings
Hugo Behlal, Daniel Nelias, INSA Lyon, Villeurbanne, France; Geoffray Deterre, Safran Aircraft Engines, Villaroche, France; Jean-Baptiste Coudert, Arnaud Ruellan, SKF Aerospace, Chateauneuf-sur-Isere, France

Our study uses ultrasonic testing devices to approach the rolling contact fatigue (RCF) stress state experienced during rolling on an indented surface, in order to understand the primary cause of failures of rolling element bearings in aeronautics. It relies on testing specimens made of M50-VIM/VAR and M50Nil steels while inducing compressive preload. This leads to a localized multi-axial and non-proportional stress field, induced by an artificial surface defect created via electro-discharge machining (EDM).

4:20 pm - 4:40 pm
4232370: Lubricant Effects on Rolling Contact Fatigue Life
John Fernandez, Curtis Rice, Matthew Wagner, Innovative Scientific Solutions, Dayton, OH; Jeremy Nickell, Daulton Isaac, Robert Sadinski, AFRL Turbine Engine Division, Wright Patterson Air Force Base, OH; Jeffrey Ewin, NAVAIR, Patuxent River, OH

Mechanical systems lubrication selection involves the consideration of many factors such as load carrying capacity, material compatibility, and corrosion resistance. Coupon testing affords a rapid screening tool to understand the performance of developing fluids regarding these and other considerations. A 3 ball-on-rod fatigue tester was used to assess the effects different lubricants have on rolling contact fatigue (RCF) life and wear. M50 steel rods were evaluated with both silicon nitride ceramic and M50 steel balls. Efforts were made to achieve uniformity in the surface roughness of the ball and rod samples. Post test sample wear was quantified through profilometric traces on the rods, fatigue life compared by plots of the Weibull distribution of 10 tests for each oil, and the role of chemical interactions explored through SEM/EDS of rod wear tracks. Preliminary analysis of the test results show a clear difference in the fatigue life offered by each lubricant.

2F Courtland

Sustainability in Motion I

Session Chair: Shubhamita Basu, Perstorp Polyols, Inc., Toledo, OH

1:40 - 2:00 pm
4300268: Why Tribology and Sustainability Mix?
Neil Canter, Chemical Solutions, Willow Grove, PA

STLE is pleased to provide membership with nearly 2 days of talks that will assist our field with gaining information on how to use the tools of tribology to assist in reducing emissions, saving energy, and reducing cost. This initial talk will present the rationale for why tribology can contribute to the move towards sustainability. Examples will be given for how tribology has led to benefits in such areas as transportation and manufacturing. The activities of the STLE Sustainability Committee will be discussed to showcase how this group is assisting membership with providing education content and programming to help them gain information on key topics such as Product Carbon Footprint analysis. In presenting an introduction to sustainability, this talk will show how tribology and sustainability do mix and to pave the way for the rest of the “Sustainability in Motion” program.

2:00 - 2:40 pm
4188683: Influence of Various Tribological Technologies on Sustainability
Vasileios Bakolas, Tim Hosenfeldt, Thomas Koenig, Michael Kobes, Schaeffler Technologies AG und Co KG, Herzogenaurach, Germany; Jennipher Allison, Schaeffler Group USA Inc., Fort Mill, SC

Sustainability encompasses more than just reducing CO2 emissions. It includes minimizing the use of raw materials, recycling used materials, and replacing rare materials whenever possible. Furthermore, sustainability aims to mitigate adverse effects on water and soil through proper end-of-life treatment of products. Green technologies present unique tribological challenges, including wear protection and the replacement of precious metals. Advances in tribology, such as improvements in lubricant technology, surface engineering, and coatings, not only make existing product designs more sustainable but also enable the development and application of innovative, climate-friendly technologies. In this presentation, we will provide an overview of various tribological technologies and discuss their impact on current and emerging technologies, so that we can better understand how they contribute to sustainability and the development of environmentally friendly solutions.

2:40 - 3:00 pm
4189037: Component-Driven Solutions for Improved Sustainability in Lubricants
Brian Casey, John Whitney, Vanderbilt Chemicals, LLC, Norwalk, CT

From cradle to grave, every aspect of the lubrication industry is under scrutiny for opportunities towards improving sustainability. Next generation lubricants must have superior tribological performance as well as reduced environmental impact. For lubricant additive manufacturers, the sustainability of individual components can be improved through lowering the carbon footprint of production. However, traditional petroleum-based additives face inherent limitations in terms of sustainability. Developing alternative additives derived from renewable, bio-based raw materials also improves the lubricant industry life cycle. This presentation will focus on the development of various lubricant additives containing biogenic carbon as a way to simultaneously improve lubricant performance and sustainability.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4246573: The Product Carbon Footprint in an International Environment - Challenges, Procedures, and Possible Solutions
Manuel Zuercher, Vasileios Bakolas, Johannes Moeller, Tim Hosenfeldt, Thomas Koenig, Michael Kobes, Kayla Joyce, Schaeffler Technologies AG und Co KG, Herzogenaurach, Germany

The Product Carbon Footprint (PCF) is now used worldwide as one of the most important variables for decarbonization. How this value is determined and how it is passed on within the supply chain is currently being intensely debated throughout the industry. The huge variety of methodologies and products that need to be brought together does not make this task any easier. This is the reason why well-structured data collection, data management, and data evaluation are very important. The presentation aims to give the audience an insight into how the collection, management, and processing of PCF data are carried out within a large bearing manufacturer. International challenges are addressed, and solutions for their resolution are suggested. In addition, a brief insight is given into the interaction with suppliers and customers.

4:20 - 4:40 pm
4205248: The Transformation of Used Motor Oil into High-Quality Base Oil
Sherry Guo, BlueTide Environmental, Katy, TX

This presentation builds on the continuation and updates the 2024 STLE session on "The Most Sustainable Way to Recycle Used Motor Oil. Used motor oil (UMO) poses significant environmental and health risks when it is improperly disposed of, but when re-refined, it can become a valuable resource. We will provide a brief overview of the recycling process, explaining how UMO is transformed into high-quality base oil. This process not only reduces energy consumption but also

contributes circular economic principles into the product supply chain for a sustainable and clean-energy future. The presentation will focus on the quality of base oils produced through re-refining, comparing their physical properties and performance with those of virgin oils made from crude oil. The findings will emphasize the application of these re-refined oils to re-enter the lubricant supply chain, thus promoting circularity in the industry.

4:40 - 5:00 pm
4308142: Avoided Emissions Enabled Through Lubricants
Andreas Glawar, Shell, Katy, TX

Lubricants have an important role to play in the energy transition; advanced tribological technologies have been estimated to have a long-term reduction potential of more than 3 billion tons of CO_2 (Holmberg, 2017). Lubricants are intended to reduce friction and wear and, as a result, improve the efficiency and longevity of many applications. These benefits can be expressed in an equivalent avoidance of Greenhouse Gas (GHG) Emissions, when making a relative comparison between two scenarios. This talk provides practical insight into the estimation of avoided emissions enabled by lubricants. This includes understanding the difference between "avoided emissions" and a "product carbon footprint" and what to consider when defining a reference scenario for the estimation of avoided emissions. Additionally, insights into a white paper will be shared, which provides a lubricants industry perspective on published voluntary guidance on avoided emissions.

2G Regency V

Materials Tribology II

Session Chair: Tomas Babuska, Sandia National Laboratories, Albuquerque, NM
Session Vice Chair: Adam DeLong, Florida State University, Tallahassee, FL

1:40 - 2:20 pm
4205434: Structure, Process & Property Measurements of Pt-Au Alloys via High Throughput Methods
John Curry, Tomas Babuska, Justin Hall, Manish Jain, Sadhvikas Addamane, Joyce Custer, Nate Bianco, Nathan Brown, Kyle Dorman, Brad Boyce, Michael Dugger, David Adams, Sandia National Laboratories, Albuquerque, NM; Camille Edwards, Filippo Mangolini, University of Texas at Austin, Austin, TX; Brandon Krick, Florida State University, Tallahassee, FL

This work outlines test methodologies for rapidly assessing mechanical and catalytic properties of a 448-sample set of nanocrystalline $Pt_{1-x}Au_x$ (x=0-100) binary alloys. For friction coefficients and generation of worn surfaces (or tribofilms) a robotically automated parallelized tribometer was developed with ~10X increase in throughput and over 70X reduction in hands on time over existing serial testing. Automated measurements of tribofilm/wear scar topography, alloy hardness/modulus, resistivity, roughness, composition, and structure/density are shown. DFT and EAM-X calculations of adsorption and segregation energies are also discussed. Results show many compositions exist with low friction, enabled by mechanochemistry. Spread in friction behavior also appears to be influenced by Pt ion energy recorded during deposition. Predicting friction traces of these systems through AI/ML approaches will also be discussed. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

2:20 - 2:40 pm
4176975: An Investigation of Lubricating Wear Behaviour on Ag-Mg Alloys
Vibin Ramaiah Annadurai, Purdue University, West Lafayette, IN

This study investigates the lubricating wear behavior of Ag-Mg alloys, focusing on pin-on-disc wear tests under various lubrication conditions, including gear oil, filtered water, and SAE 80w, with Vickers hardness testing for material characterization. Utilizing SEM and XRD, it examines alloy morphology and composition, linking coefficient of friction (CoF) and wear rate data to understand wear mechanisms. Surface wear characteristics and tribo layers are analyzed to reveal material transformations during wear. The study includes microstructural investigation, tribolayer thickness evaluation, and phase identification, complemented by 3D surface mapping. Comparative analysis with Mg alloys offers insights to enhance Ag-Mg alloy performance in engineering applications.

2:40 - 3:00 pm
4190044: Scuffing Initiation Experimental Investigations of AISI 52100 Steel and WC-Based Coatings
Kelly Jacques, Stephen Berkebile, U.S. DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Andrey Voevodin, Samir Aouadi, University of North Texas, Burleson, TX; Satish Dixit, Plasma Technology Inc., Torrance, CA; Diana Berman, University of North Texas, Denton, TX

Modern fuel injection systems are prone to catastrophic failures such as scuffing. To improve high-pressure fuel injection system operation in low-viscosity fuel environments and expand compatibility to various fuel chemistries, further examination of state-of-the art materials and their resistance to scuffing is needed. In this work, a high-frequency reciprocating tribometer was used to perform pin-on-flat load-progression experiments on hardened 52100 steel, thermal spray, and cold spray tungsten carbide-based coatings in multiple fuel environments. These experiments were followed by characterization of the friction coefficients, wear, and chemical alterations of the material surfaces. It was found that tungsten carbide coatings prevented scuffing which is attributed to their high hardness. The use of tungsten carbide spray coatings reduces friction, reduces wear, and inhibits the onset of scuffing when applied to steel surfaces otherwise prone to tribological failures.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4206060: Wear Performance of Inconel 718 Produced Through Additive Manufacturing Compared to Conventional Methods
Mary Makowiec, Pratt & Whitney, East Hartford, CT

This presentation covers a microstructural and fretting wear study of DED produced Inconel 718 as compared to the cast and wrought versions. The wear behavior is evaluated isothermally at several elevated temperatures. Specimens were then analyzed using advanced surface and material characterization techniques. Results show good agreement in wear performance between cast and additively produced Inconel 718, while wrought Inconel 718 shows slightly lower wear. Details of the testing and characterization will be shown and discussed.

4:20 - 4:40 pm
4215007: Explore the Wear Behaviours of FeCrNi and FeCoCrNi from Room Temperature to 1000 °C and Understand the Role of Co on the Formation of the Lubricating Glaze Layer
Wandong Wang, University of Toronto, Toronto, Ontario, Canada

Reducing friction and wear remains a significant challenge for many machine components in dry sliding, elevated temperatures, and oxidizing environments. While the wear behaviours at room or moderate temperatures on medium-entropy and high-entropy alloys (M/HEAs) have been extensively studied, 800 °C and 1000 °C are rarely reported, with limited discussion on the roles of alloy elements and oxides formed. A series of cost-effective Co-free M/HEAs have now attracted a lot of attention. This study systematically explores the high-temperature hardness, wear behaviours

and mechanisms of Co-free FeCrNi and FeCoCrNi alloys. By characterizing the wear morphologies and the oxidation forms, we build a connection between the mechanisms with alloy elements, oxidation rates, and oxide types and reveal the role of Co in wear behaviors.

4:40 - 5:00 pm
4205611: Nickel-Based Superalloys Subjected to Laser Peening: Surface Integrity, Microstructural Evolution and High Temperature Tribology
Ali Beheshti, George Mason University, Sterling, VA

This presentation covers multiple studies on high temperature tribology and contact behaviors of various nickel-based superalloys including Inconel 617, 625, and 718 up to 900 °C. The experiments include both wrought and additively manufactured alloys that are studied through indentation creep, unidirectional sliding, and fretting wear tests. In addition, samples are subjected to shot peening and laser peening processes to evaluate the extent of microstructural and tribological improvements, especially at elevated temperatures. Advanced microscopy and cross-sectional indentation techniques are utilized to study the detailed mechanical and microstructural changes. A novel thermally-engineered laser peening method is introduced, demonstrating a significant and long-lasting reduction in contact creep, friction, and wear. The key mechanisms behind the observed enhancements are discussed, and suggestions are made to further improve the effectiveness of laser peening at elevated temperatures.

2I Regency VII

Electric Vehicles II

Session Chair: TBD
Session Vice Chair: TBD

1:40 - 2:20 pm
4205219: The Potential of Tribological Knowledge in Selecting the Right Oil Formulation for Electrical Drive Systems
Mirjam Baese, Magna Powertrain GmbH & Co KG, Lannach, Austria

Main core requirements of eDrive Systems, like "efficiency", "lifetime", "NVH" and more were well discussed in the tribology and oil community the last years. It is well known that the oil formulation plays a major role, when it comes to those requirements. But what’s the right oil formulation for gearboxes of electrical drive systems? The presentation discusses challenges from the application point of view when it comes to the definition of the right requirements to the oil. In this context on the one hand, new component tests are shown specifically developed to test the application near wear behavior of oils. On the other hand the potential of data driven methods with a new developed efficiency prediction tool will be shown, which was developed on a basis of thousands of system test data and with which it is possible to predict the efficiency of different gearbox designs in reference to oil properties.

2:20 - 2:40 pm
4200697: Advancing Both Boundary and EHL Lubrication for EV Transmission Fluids with Novel Ester Technology.
Pieter Struelens, Oleon, Evergem, Belgium; Micky Lee, Marion Kerbrat, Oleon, Port Klang Selangor, Malaysia

The formulation of EV transmission fluids often relies on low viscosity base oils to minimize churning and friction losses. On the other hand, doing so increases wear risk under low-speed, high-load conditions, especially during the initial torque surge of electric motors. To address this, novel esters have been developed to balance friction reduction and wear mitigation. This study shows that incorporating this ester significantly reduces the traction coefficient of mineral oil due to its distinctive rheological properties. Improvements in the traction coefficient are observed across a wide range of sliding-rolling ratios and entrainment speeds. Under high load and high shear conditions, critical for gear operation, the ester effectively minimizes scuffing and lowers boundary friction. Thus, this specially designed esters bridges the gap between the need for low viscosity base oils to reduce traction and higher viscosity oils to mitigate wear.

2:40 - 3:00 pm
4201509: Esters for Heavy Duty Electric Vehicles
Alexei Kurchan, Gareth Moody, Chris Clayson, Marco Auerbach, Cargill, Goole, United Kingdom

Technical development and interest in electrified heavy-duty and off-road vehicles is accelerating. This talk will address the specialized requirements of lubricating transmissions of heavy-duty electric vehicles, including higher efficiency, sustainability and material compatibility whilst maintaining a relevant fluid viscosity.
Using ester-based technology, it is possible to create novel fluids that are suited to larger, heavy-duty electric vehicles. The materials tested were a combination of base oils and higher viscosity materials to meet their specific requirements. Testing of these materials showed that these combinations can show low traction properties even under high loads, as well as excellent material compatibility and oxidative stability to help increase fluid lifetime. Where possible, these esters were created using biobased raw materials and have low product carbon footprints when assessed from cradle to gate.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4202323: Current Induced Friction and Pitting on Lithium Lubricated Steels
Mohsen Tajedini, Hong Liang, Texas A & M University, College Station, TX

Drivetrains in electric vehicles sustain damage due to leak current. In this research, we studied the friction and wear behavior of lithium grease lubricated steel ball-on-steel disk under a series of applied electric currents under various tribological conditions. Experimental results showed that the applied current induced 35% increase in friction and 570% in wear. The pitting density was found lower at high sliding speed and vice versa. This presentation discussed the results and principles behind them.

4:20 - 4:40 pm
4200803: Enhanced Tribological Performance of Base Oils by Protic ionic Liquids Under Electrified Conditions
Seungjoo Lee, Ali Erdemir, Texas A&M University, College Station, TX; Leonardo Farfan-Cabrera, Tecnologico de Monterrey, Monterrey, Nuevo Leon, Mexico; Patricia Iglesias, Rochester Institute of Technology, Rochester, NY

As environmental regulations for the automotive industry tighten, e-mobility is rapidly expanding as a green alternative for the future of transportation. However, many challenges, including the tribological ones exist and call for rapid progress for an efficient, reliable, and green e-mobility future. In particular, bearing currents are detrimental to the reliable functionality of EV drivetrains. Ionic liquids have shown significant promise in addressing tribological issues due to their unique properties, including non-flammability, high thermal and electrical conductivity, and inherent

polarity. This study investigates the lubricating behavior of a protic ionic liquid (PIL) added to base oils under unelectrified and electrified sliding conditions. The results indicate that PIL is highly effective in enhancing tribological performance under such scenarios, making it a promising candidate for enhancing the tribological performance of base oils under electrical sliding environments.

4:40 - 5:00 pm
4203434: Distinct Impact of Different Ionic Liquids on Lubricant's Electrical Conductivity
Jun Qu, Seokhoon Jang, Sladjan Lazarevic, Huimin Luo, Oak Ridge National Laboratory, Oak Ridge, TN; Ewa Bardasz, ZUAL Associates of Lubrication, Mentor, OH

Most lubricating oils are electrical insulators and static charges may build up at the bearing interfaces during operation and result in electrical arcing. Repeated arcing could cause fluid degradation and bearing surface damage. This becomes more of a concern for electric vehicles (EVs) that operate at a high potential (400-800 V). ORNL has previously developed oil-soluble ionic liquids (ILs) as lubricant additives with superior wear protection. Here we present the impact of the ILs on the electrical conductivity of automotive lubricants. Interestingly, some ILs at merely 1% concentration dramatically increased the oil conductivity by several orders of magnitude, but others induced rather small change, and one IL even led to a surprisingly reduced conductivity for a fully-formulated EV oil. Results suggest that both the IL's chemistry and interactions with other lubricant additives are critical in controlling the lubricant's electrical conductivity.

2J The Learning Center

Non-Ferrous Metals II

Session Chair: Thomas Oleksiak, Quaker Houghton, Oswego, IL
Session Vice Chair: Josef Leimhofer, AMAG Rolling GmbH, Ranshofen, Austria

1:40 - 2:20 pm
4199824: Tribological Performance of Aluminum Sheet Forming Lubricants
Daniel Sanchez Garrido, Sarmistha Das, Aude Despois, Chuong Nguyen, Sarin Thokala, Novelis, Atlanta, GA

Lubrication is an essential aspect of sheet metal forming. Historically, forming lubricants have been mainly developed for steel applications. To bridge the gap for aluminum (Al) sheet forming, current and new lubricants must be characterized to better understand their performance and compatibility. This work characterizes the tribological performance of various forming lubricants applied on mill finish and textured Al sheets. Various lab scale tests are employed to measure forming loads and friction and then compared with performance in actual sheet deep draw formability. Non-forming lube characteristics which may influence forming performance were also evaluated. Results enable direct comparison between different forming lubricant types and provide information to guide lube selection for Al sheet forming. Lastly, by combining experimental data with stamping friction models, the study helps elucidate the importance of lubricants to control friction in Al sheet forming performance.

2:20 - 2:40 pm
4204445: Investigation of Tribology Properties of Different Lubricity Additives on Different Metals
Yixing Philip Zhao, Houghton International, Norristown, PA

In metalworking fluids of metal removal, metal deformation and metal rolling, many common lubricity additives are used in product formulas. Due to chemical types, structures, molecular weights, and polarity etc., these materials can perform very differently depending on metal types, operation conditions, etc. The tribology properties of various lubricity additives, boundary, and extreme pressure (EP) types, in neat or water-based formulas were investigated by pin/ball-on-plate, microtap and profilometer methods on aluminum 356, aluminum 6061, steel 1018, stainless and titanium, respectively. The results show some large molecular boundary lubricity additives or big oil droplet sizes of MWF emulsions may provide better lubricity on aluminum whereas high polarity and EP additives as well as surface charges of emulsion droplets may play a bigger role in friction changes on ferrous and titanium. Some polymeric compounds may generate smooth metal surfaces after lubricity tests.

2:40 - 3:00 pm - **Open Presentation Slot**

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4203615: Eco-Design Innovations in Non-Ferrous Rolling Fluids: Reducing Carbon Footprint from Cradle to Grav
Gautier Burette, TotalEnergies, Nanterre, France

Innovation in non-ferrous rolling fluids holds significant potential to contribute reducing the carbon footprint of aluminum manufacturing operations. By adopting a Life Cycle Analysis approach, both hot rolling emulsions and cold rolling oils are designed to minimize environmental impacts. A comprehensive carbon footprint analysis must be conducted across the entire value chain, from cradle to grave. This means evaluating the environmental impact of the product from its initial extraction of raw materials (cradle), through its production, distribution, and use, to its final disposal or recycling (grave). The presentation will showcase cases where an eco-design approach has been successfully implemented in the development of non-ferrous rolling fluids, demonstrating how industry practices can align with global sustainability targets, while ensuring performance in the rolling process.

4:20 - 4:40 pm
4175964: Cold-flow Properties of Estolides: The Old (D97 and D2500) Versus the Mini-(D5773 and D5949) Methods
Grigor Bantchev, Helen Ngo, USDA-ARS, Wyndmoor, PA; Yunzhi Chen, University of Utah, Salt Lake City, UT; DeMichael Winfield, Steven Cermak, USDA-ARS, Peoria, IL

In the current study, we compared the results of the old, widely accepted ASTM methods D97 (pour point) and D2500 (cloud point) to the newer methods D5949 and D5773 for biobased base oils (estolides). The new methods require smaller amount of samples and are easier to perform. The cloud point (CP) results were in good agreement for less colored samples, but D5773 gave lower values for some darker (Gardner color >8) samples, especially esters. The D5949 showed a tendency to report higher pour points (PP), especially for the lower values. Viscosities and densities in wide temperature range (15 to 120 °C) were also measured. The surface tensions were estimated by a literature group method. Viscosity and density effects can only partially explain the differences in the PP values from the two methods. In conclusion, the newer mini-methods are acceptable substitution when larger volumes are not accessible, unless the sample is too dark.
4:40 - 5:00 pm - **Nonferrous Metals Business Meeting**

AI and Machine Learning III

Session Chair: Ilia T. Bagov, Karlsruhe Institute Of Technology, Karlsruhe, Germany
Session Vice Chair: Shuangbiao Liu, Northwestern University, Evanston, IL

8:00 - 8:40 am
4210708: Tribo-Informatics: The Systematic Fusion of AI and Tribology
Zhinan Zhang, Nian Yin, Xin Wang, Shanghai Jiao Tong University, Shanghai, China; Shuaihang Pan, University of Utah, Salt Lake City, UT

Advancements in AI have greatly improved our ability to calculate, design, simulate, and test tribo-systems. Tribo-informatics, which integrates tribology with informatics for efficient research, focuses on five key information types in tribo-systems: input data, system properties, output data, tribological data, and derived state information. It employs both traditional data processing and advanced machine learning techniques such as linear regression, Gaussian models, support vector machines, and random forests. This study explores the application of AI in diverse aspects of tribology, spanning from component-level tribological systems to intelligent tribology systems. Case studies will illustrate the practical implementation of tribo-informatics. By using information technology, tribo-system complexity can be reduced, and research timelines can be shortened, promoting tribology innovation.

8:40 - 9:00 am
4199278: AI-Driven Rapid Prediction of Elastohydrodynamically Lubricated Contacts
Max Marian, Josephine Kelley, Leibniz University Hannover, Hannover, Germany

The prediction of lubricated tribo-contacts is crucial for optimizing mechanical system performance, but it remains complex and computationally intensive. Artificial Intelligence (AI) and Machine Learning (ML) techniques offer efficient and accurate solutions. This presentation explores ML algorithms, particularly artificial neural networks, for modeling lubricated tribo-contact behavior. One focus is on elastohydrodynamically lubricated (EHL) contacts, where ML algorithms trained on extensive numerically generated data efficiently capture complex patterns using input parameters like lubricant properties and operating conditions. This allows streamlining detailed information of EHL contact conditions in higher level system simulations of machine elements or entire drive systems. In the presentation, we demonstrate the fundamental modeling aspects as well as the exemplary usage for predicting rolling and sliding friction as well as electrical capacitance in cylindrical roller bearings.

9:00 - 9:20 am
4188903: Symbolic-Regression Based Extended Hertz Theory of Coated Bodies
Brian Delaney, Shuangbiao Liu, Q. Jane Wang, Northwestern University, Evanston, IL

This work presents an application of symbolic regression to extend Hertz theory toward coated bodies through new functions of the ratio of Young's modulus of the coating to that of substrate (E) and non-dimensional coating thickness (H). Hertzian theory can predict two asymptotic contact performance values (maximum contact pressure, contact radius, and contact approach) in situations of uncoated bodies or coated bodies with sufficiently large coating thickness. Contact performance functions of E and H were constructed, and the parameters were obtained via symbolic regression. The learned functions were responsible for mapping the non-linear transition

of the behaviors of contact parameters from that of the pure substrate to that of a sufficiently thick coating. The new explicit model provides a theoretical framework through which accurate predictions of contact performances can be made over a range of coating-substrate modulus ratios and film thickness-contact radius ratios.

9:20 - 9:40 am
4202140: Multi-Modal Prediction of Friction Evolutions
Nathan Brown, John Curry, Frank DelRio, David Adams, Tomas Babuska, Brad Boyce, Sandia National Laboratories, Albuquerque, NM; Kookjin Lee, Arizona State University, Tempe, AZ

Determining surface friction evolution typically involves resource-intensive experiments, particularly for complex materials like platinum-gold (Pt-Au) alloys, where variability arises from intricate properties and surface interactions. This study applies multi-modal machine learning models to predict the cycle-dependent friction evolution of Pt-Au films, using modalities such as modulus and hardness measurements, X-ray fluorescence (XRF) spectra, and SimTra analysis. We compared the performance of a feedforward regression model and an autoencoder, revealing that certain input modalities significantly enhance predictive accuracy. The most effective models achieved errors comparable to the experimental variance in friction trials, demonstrating their ability to reveal relationships between surface characteristics and friction behavior, thus facilitating more efficient material characterization. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

9:40 - 10:00 am
4205290: Structural Semantics and Machine Learning-based Investigation on the Superior Aspects of PTFE as a Tribological Filler in High-Performance Engineering Polymer Composites
Tanil Ozkan, Steve Pouliot, Jonathan Penaranda, Burak Bekisli, Dover Innovation Laboratory, Houston, TX

This study employs a structural semantics-based approach, leveraging co-occurrence frequency based categorization capability of artificial intelligence to identify the most critical attributes of PTFE that make it an ideal tribological filler. The analysis highlights rapid fluorination of metallic countersurfaces and resilient transfer film formation as the two most critical attributes giving rise to wear resistance. To substantiate this finding, an adaptive machine learning approach was utilized to interpret ab initio simulation results with monolayer level FeF2 and FeF3 clusters. Our findings reveal that the formation of FeF2-type localized surface domains is more likely to contribute to intrinsic mechanical resilience. This work underscores the importance of understanding the fundamental interactions at play to optimize the use of PTFE in tribological applications, particularly in light of evolving regulatory standards and ongoing development of alternatives.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4218541: Shifting from Paper to Digital: Bridging the Gap in Knowledge Digitalization
Nick Garabedian, Ilia T. Bagov, Datin Company, Karlsruhe, Germany

Despite advances in computing and AI, effectively integrating digital tools into scientists' workflows remains a challenge. To harness these advancements, digital systems must grasp the conceptual models that tribologists rely on for critical decisions. This presentation explores practical methods for organizing knowledge to make data findable, accessible, interoperable, and reusable (FAIR). It addresses key misconceptions about FAIR data and reveals unexpected benefits of connecting knowledge and data in AI applications, highlighting how R&D knowledge graphs can drive faster, cross-disciplinary discovery and collaboration.

11:00 - 11:20 am
4205412: Predictive Models in Tribology Using Machine Learning
Nuria Espallargas, Nicolai Olsen, NTNU, Trondheim, Norway; Wahyu Wijanarko, Norwegian University of Science and Technology, Trondheim, Norway

Tribology is vital for optimizing engineering materials. Traditionally, empirical methods have been used to analyze tribological performance, but advances in machine learning have transformed the field. This work utilizes molecular descriptors from AlvaDesc to predict key tribological metrics like the coefficient of friction (COF) and wear rate. These descriptors are derived from the Simplified Molecular Input Line Entry System (SMILES), which encodes chemical structures. By correlating these descriptors with in-house experimental data, we developed machine learning models to forecast lubricant behavior. We tested various algorithms, including Linear Regression, Decision Trees, Random Forest, SVR, AdaBoost, XGBoost, MLP, RNN, and CNN. Boosting algorithms like AdaBoost and XGBoost excelled in managing data imbalances and outliers. This predictive capability based on molecular structure streamlines the development of high-performance lubricants and reduces the need for extensive testing.

11:20 - 11:40 am
4204871: Machine-Learning Models for Predicting Friction from Roughness
Lars Pastewka, Johannes Hörmann, Paul Strauch, University of Freiburg, Freiburg, Germany; Antoine Sanner, ETH Zürich, Zürich, Switzerland; Kurt Beschorner, Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA

Surface roughness plays a critical role in determining properties like adhesion and friction, but achieving quantitative predictions from topographic measurements has remained challenging. Here, we demonstrate how statistical machine learning can establish strong correlations between roughness measurements and surface properties, enabling predictive data-driven models. Our approach is based on a novel class of statistical descriptors, called scale-dependent roughness parameters (SDRPs), which capture surface roughness across multiple scales and allow combining multiple measurements on the same specimen into single statistical descriptor. These SDRPs are used as features in Gaussian process classifiers and regressors to predict surface properties. We apply this to predict friction coefficients in shoe-floor interactions, modeling the complex tribosystem of viscoelastic rubber soles sliding on rough surfaces, enhancing our understanding of friction behavior in practical applications.

11:40 am - 12:00 pm
4270715: A Computer Vision Tool for Automatic Recognition of Bearings Failure Modes
Marco Van Zoelen, Christine Matta, Stephan Baggerohr, Sebastian Echeverri Restreppo, Mourad Chennaoui, Cees Taal, SKF B.V., Houten, Netherlands

Industrial users increasingly rely on advanced digital technologies to monitor the health of their equipment. Modern condition monitoring systems apply advanced analytical techniques to detect the early signs of wear or damage in bearings and other critical parts. Once an issue has been identified an experienced application engineer is called on-site. Accessing a skilled bearing analyst isn’t always easy. To address this issue, we developed a computer vision model that can evaluate bearing damage using digital photographs. The model is based on CNN and can classify and detect failure modes on images of roller bearings components. In this study, we will present the model, the approach taken to identify different failure modes from actual bearing applications. The model is a valuable tool for detecting and classifying bearing failures, helping to improve equipment maintenance, prolonging the life of critical machinery, and contributing to improving their global carbon footprint.

Commercial Marketing Forum III

Session Chair: TBD

8:00 - 8:20 am
4309901: SI Group : Developing an Additive to Address Impending Regulatory Challenges of Substituted Diphenylamine-Based Antioxidants
Timothy Chipuk, SI Group, The Woodlands, TX

The development of alkylated aromatic amine antioxidants began in 1930s. Substituted diphenylamine antioxidants (SDPAs) continue to be regarded amongst the most important single purpose, ashless antioxidants in many lubricant applications with annual usage volume exceeding 100 kT globally. The latest challenge facing SDPA technology comes in the form of regulatory scrutiny, primarily chemical reprotoxicity. Two CLH dossiers have been submitted to the ECHA regarding the widely used C4/C8 and C9 alkylated DPA materials. Reclassification of the materials to Repro 1B CLH triggers restriction on professional uses and potentially industrial uses. SI Group will present the results of a multi-year research project detailing the development of a new diphenylamine reaction mass that looks to mitigate the risk of current regulatory scrutiny whilst maintaining the usability and performance expected from the SDPA chemistry.

8:20 - 8:40 am
4301789: Nouryon: Advanced Solutions for Friction Mitigation
Alina Filin, Ezio Amerio, John Dixon, Nouryon, Deventer, Netherlands

Mitigating friction and wear in automotive and industrial oils is crucial for enhancing performance and extending equipment lifespan. With a rich history of providing organic friction modifiers and phosphorus-based anti-wear additives, Nouryon leads in innovative lubrication solutions. Nouryon's progressive polymeric friction modifiers feature multiple functional groups within a single molecule, achieving remarkable friction reduction at low treat rates. Additionally, Nouryon has developed a new generation of friction modifiers with advanced solubility in low polar base stocks, expanding their applicability in modern lubricants used in automotive and industrial applications. Overall, Nouryon's anti-wear additives and friction modifiers represent a significant advancement in lubrication technology, offering effective friction reduction, compatibility with other additives, and improved solubility, contributing to optimal lubricant performance.

8:40 - 9:00 am
4301579: Evonik: Three Step Approach to Improve Fuel Economy in Engine Oils
Mark Petit, Sabrina Strube, Rhishikesh Gokhale, Seemann Michael, Evonik, Rochester Hills, MI

Improving fuel efficiency is a major goal of the automotive industry to reduce the consumption of fossil fuels and CO2 emissions. Lubricants, in contrast to personal driving style, can deliver a constant contribution to vehicle efficiency. One way to achieve efficiency with lubricants is by adopting an engine oil with a flat viscosity profile.
This approach maximizes engine oil efficiency within the same SAE grade. Evonik has identified three steps to improve efficiency in this fashion. They can be applied as single steps or combined together to maximize the effect.
The three-step approach provides maximized fuel economy within the same SAE grade by over 1% based on an optimization of the viscometric properties. Such a lubricant delivers highest efficiency for new engine technologies, such as hybrid and hydrogen technologies, as well as for existing engine designs.

9:00 - 9:20 am
4301538: Lubrizol Hybrid Grease System - A Lithium Alternative
Timothy Saari, Lubrizol, Rochester Hills, MI

As demand for lithium expands with the growing global EV market, the cost of lithium has been dynamic over the last several years. In addition, lithium is under regulatory pressure in Europe and elsewhere. In an effort to mitigate the ever-changing cost landscape of lithium and simultaneously address expected product hazard changes, Lubrizol has developed a lithium free thickener system which is cost competitive with current lithium complex and standard lithium greases. This development together with a novel manufacturing process yields hybrid greases which achieve comparable performance to lithium based grease systems.

9:20 - 9:40 am
4299914: NYCO: Expanding Synthetic Lubricants through NYCO's High-Performance Specialty Esters
Kyle Elgert, NYCO America, Newnan, GA

NYCO, a global leader in the design and production of high-performance synthetic esters, is a renowned partner known for expertise in aviation, defense, industrial, and automotive lubricants. With over 70 years of innovation, NYCO excels in creating high-performance ester chemicals structures and finished specialty lubricants. Users will benefit by reducing carbon emissions, improving wear, and extending the lifespan of lubricants and equipment through superior thermal oxidative stability, excellent low-temperature properties, and enhanced frictional benefits. Whether considering eco-friendly or food grade approvals, NYCO's customized solutions deliver. These enticing features substantiate the industry growth for synthetics and esters in the marketplace. Recently, NYCO completed a greenfield project in Newnan, GA to make it easier to supply high-quality products locally. Thereby reinforcing its position as a trusted technical advisor and reliable partner in the lubricants industry.

9:40 - 10:00 am
4319164: Biosynthetic Technologies: Estolides - High-Performance Sustainable Base Oils for Lubricant and Metalworking Formulations
Matt Kriech, Biosynthetic Technologies, Indianapolis, IN

Biosynthetic Technologies delivers high-performing and innovations for a sustainable future. As such, we offer products that are bio-based and readily biodegradable yet also deliver superior performance characteristics. In this session, we will discuss our expanding product line of sustainable base oils which are made from derivatized organic fatty acids. These oils provide excellent hydrolytic stability, oxidative stability, seal compatibility as well as other superior performance characteristics. This 30-minute session will be a must for anyone looking to develop a high-performance EAL product line.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4269606: ChainCraft: Upcycling Waste into Fatty Acids: A Sustainable Path to Advanced Synthetic Esters
Dilek Ersu, ChainCraft, Amsterdam, Netherlands

The fatty acids used in polyol esters (POEs) come from petroleum or vegetable oils as castor, coconut, palm kernel oil, etc. Although vegetable oils are considered a greener alternative, they often have an equal or higher carbon footprint than petroleum and present environmental challenges. Caproic acid (C6) has not been commonly used for POE synthesis due to its historic

scarcity. However, the unique chain length of C6 could bring many functional benefits. ChainCraft is ready to provide a large and stable supply of C6 produced by proprietary fermentation of organic residues from the food industry. This novel technology leads to production of lower carbon footprint, circular fatty acids, does not compete with food production and EUDR exempt. In this presentation, after briefly explaining ChainCraft's technology for fatty acids manufacturing, we will focus on the role and potential of C6 in POE production and discuss how it compares to commonly used C5- and/or C7-based POEs.

11:00 - 11:20 am
4299878: MÜNZING's New FOAM BAN® 439: MOSH/MOAH Free, Organo-Modified Siloxane Antifoam for Non-Aqueous Lubricants
Safia Peerzada, MUNZING CHEMIE GmbH, Bloomfield, NJ; Stefanie Velez, Munzing North America, Bloomfield, NJ

There is a shift in the non-aqueous lubricants market towards sustainable and synthetic fluids. Two big issues regarding sustainability of these fluids are PFAS and MOSH-MOAH chemistries. FOAM BAN® 439 is a PFAS free, MOSH-MOAH free antifoam designed for synthetic Group III+, PAO, PAG and Ester base fluids that provides improved performance. The MOSH-MOAH free carrier in FOAM BAN® 439 allows for improved stability and compatibility in these lubricants while maintaining good foam control and low impact on air release. The performance of FOAM BAN® 439 in multiple applications and fluid types, including gear oil, hydraulic fluid and EV Fluid, will be discussed.

11:20 - 11:40 am
4301631: BASF Corporation: Discover BASF's Expanding Line of Industrial Additive Packages Designed to Meet the Highest-Level OEM Requirements
Daniel Niedzwiecki, Eugene Scanlon, BASF Corporation, Florham Park, NJ

BASF's Fuel and Lubricant Solutions is committed to developing products that meet the emerging needs of our customers. This session will highlight our industrial additive packages portfolio, which includes Hydraulic (IRGAPAC® H) , Turbine (IRGAPAC® T) and Gear (IRGAPAC® G) packages, with a special focus on our latest innovations. Designed to meet the highest-level OEM approvals, our new premium ashless hydraulic package delivers on performance. It offers superior wear and extreme pressure protection across FZG, Conestoga, and Bosch Rexroth pump tests. Formulated with our customers' environmental, health, and safety objectives in mind, our new hydraulic package will not impart any hazard labels on the finished fluid at the recommended treat rate. This is one of our latest innovations covered in this presentation. As a leading global supplier of lubricant base stocks and additives, BASF is proud to offer additive package solutions to help you tackle the challenges of today and tomorrow.

11:40 am - 12:00 pm
4301645: Coast Southwest: Integrated Technology, Innovation, and Solutions
Anthony Cimo, Coast Southwest, Inc., Paso Robles, CA

Coast Southwest is a leading full-service chemical manufacturer, distributor, and ingredient technology company. Starting from humble origins as a distributor in southern California, Coast Southwest has expanded its capabilities in manufacturing, R&D, and innovation. This vertical integration has allowed us to offer a wide variety of products and services to formulators of lubricants and metalworking fluids, from product sourcing and logistics, custom manufacturing, and technical expertise. Our team of highly experienced formulators will assist with solutions from start to finish on any lubricant application. In October 2023, Coast Southwest acquired the Paso Robles manufacturing plant from the Lubrizol Corporation. where we produce a variety of surfactants for metalworking applications, and our partnership with MFG Chemical allows us to provide a near-universal line of additives, including corrosion inhibitors, anti-wear additives,

extreme pressure agents, and detergents.

3C Hanover D

Condition Monitoring I

Session Chair: Alfredo Garcia, Luval SA, Santiago, Region Metropolitana, Chile
Session Vice Chair: Misty Bickerdyke, Empire Fluid Analysis, Dayton, NV

8:00 - 8:40 am
4200450: Asset Reliability Through Integration: Setting the Standard for Success
Dave Tingey, POLARIS Laboratories®, Indianapolis, IN

In today's landscape of asset reliability, the term "integration" is frequently associated with data-driven approaches. However, reliability extends beyond mere data; it is a comprehensive process that encompasses insights from various sources, including vibration analysis, thermography, fluid monitoring, telematics, and operational observations. Currently, these technologies often function in isolation, limiting their ability to share critical data and diminishing overall reliability effectiveness. This presentation will explore the common advantages and disadvantages of each technology and demonstrate how their integration can enhance reliability outcomes by fostering collaboration and maximizing data utility.

8:40 - 9:00 am
4200314: Filtration and Characterization of Sub-Micron Contaminants in Used Lubricants.
Myrna Cortes Morales, Aldara Naveira Suarez, SKF RecondOil, Stockholm, Sweden; Vicente Benavides, Laboratorio GMAS SAS, Bogotá, Colombia; Roland Larsson, Par Marklund, Luleå University of Technology, Luleå, Sweden

Correct lubricant operation in industry highly depends on the control of contamination levels. Particle contamination will increase wear in mechanical systems and accelerate the degradation of lubricants. Most filtration systems and techniques focus on removing particles larger than 4 µm, overlooking the potential risks posed by sub-micron contaminants. This work focuses on the qualitative analysis of recovered contaminant particles from used commercial lubricants, after being treated with different depth filtration methods. Results suggest that conventional depth-filtration systems are not enough to remove sub-micron contaminant particles and should be combined with other technologies to enhance their removal. Findings indicate that the composition of contaminant particles consists of a mixture of wear metals from the operation and common additive elements, which highlights the importance of their removal to extend the lubricants' service life.

9:00 - 9:20 am
4205405: Monitoring Lubricant Quality by Applying Machine Learning to Acoustic Emission Signals from Rubbing Contacts
Tom Reddyhoff, Robert Gutierrez, Mein Yeak Siow, Imperial College London, London, United Kingdom

Acoustic Emission (AE) – i.e., high frequency stress waves caused by micro deformations of component surfaces that propagate through material – is a rich source of tribological information. AE monitoring is non-invasive, relatively low cost, and therefore well suited to condition monitoring of sliding contacts. However, this has yet to be used extensively in practice, since the relationship between friction behavior and sound is highly complex. The approach taken in this work is to

conduct sliding tests, while measuring both friction and AE. Machine learning algorithms are then applied to process the high frequency sound emitted and correlate this with the measured friction and also lubricant properties. Results show that machine learning can accurately predict friction and also provide information on lubricant quality and composition based acoustic emission data, provided the correct algorithms and preprocessing methods are applied.

9:20 - 9:40 am
4202012: Ultrasonic Reflection Measured Oil Film Thickness on Slipper Bearings of an Axial Piston Pump
Min Yu, Pan Dou, Tonghai Wu, Xi'an Jiaotong University, Xi'an, China; Tom Reddyhoff, Imperial College London, London, United Kingdom

Axial piston pumps are critical power elements in hydraulic systems, the performance in energy efficiency and endurance is reflected by lubrication health of key tribo-pairs in slipper-swashplate, piston-cylinder, and valve plate-cylinder interfaces. Ultrasound reflection is an effective non-destructive method for in-situ oil film thickness measurement, however, the complex geometry of groove-textured slipper surface and the high rotational speed present significant challenges. To address these problems, finite element method is used to simulate wave propagation through a lubricated slipper-swashplate contact, the results of which compensate for the effect of surface textures; high-pulse repetition frequency of ultrasound equipment is established to identify the angular position of a slipper with respect to the sensor. An aviation fuel piston pump is adopted for in-situ ultrasound measurements, where ultrasound measured oil film thickness are consistent with theoretical calculations.

9:40 - 10:00 am
4189335: Comparison of Traditional and Remote Inline Continuous Condition Monitoring Methods for Air Compressor Fluids
Joseph Schultz, David Aaserud, Kris Clark, Kevin Manouchehri, Lubrizol Corporation, Wickliffe, OH; Alex Pelkey, Poseidon Systems, LLC, Victor, NY

Maintaining the integrity of the lubricant is vital to industrial equipment. The standard suite of tests in a typical oil condition monitoring program consists of viscosity, acid number, metals & water content, and particle count. Advanced tests can also be included depending upon the application and desires of the requester. Each result is merely a snapshot of the system, and trends need to be analyzed to fully obtain a benefit. Companies spend a great deal of time, money, and effort to take, send and test samples that ultimately show no deviation from their standard used oil specifications. Delays in shipping samples and getting results, however, can be detrimental to equipment in peril. This work describes two methods for inline, continuous monitoring of different chemistries of air compressor lubricants. Sensor responses and trends from the continuous monitoring data are compared to both traditional wet chemistry testing and more advanced formula component analysis.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4302466: Prediction of Physical Properties and Composition of Used Lubricants Using Near-infrared Absorption Spectra
Kyoko Kojima, Hitachi, Ltd., Kokubunnji, Tokyo, Japan

From the near-infrared absorption spectra of lubricants, information on the type of lubricants, physical properties and composition of lubricants can be easily obtained using regression and classification machine learning. Spectroscopy has the advantage of being able to measure without contact with lubricants. Near-infrared spectroscopy has the advantage of cheaper sensors

compared to mid-infrared spectroscopy. So far, the results of evaluation using model oils in which additives and water are added to the base oil have been presented. In this presentation, examples of predicting the water content, acid number, and viscosity of the used oils using a small sensor will be presented.

11:00 - 11:20 am
4177421: Innovative Tools for a Better Prevention of Organic Fluids Oxidation and Varnish Build up
Marie Roucan, Jérémy Pallas, ANTARA GROUPE, Chateaudun, France, France

Degradations pathway, mainly caused by oxidation, have been seen in lubricants application to often result in systems failure. Oxidation induces the formation of soluble and insoluble contaminants leading in varnish build up. Tracking species responsible for systems failure is of interest although appears to be difficult, and direct method to detect these chemical species has not yet been found. The main issue lies in the numerous and different species formed. We design nanocomponents to separate the various unstable entities, such as radicals or oxygen containing molecules, generated by oil oxidation. Coupled with EPR technics, it allows for the identification of the diverse species. Along with the spin trapping method, we were able to identify several degradations residues which can be utilized as quality indicators in the monitoring of oil oxidation. Moreover, the fine tune of nanocomponents chemical structures is opening a new lead to develop specific adsorbents for oil treatment.

11:20 - 11:40 am
4205265: Vibration-Based Detection and Classification of Compound Gear and Bearing Faults Using Ensemble Learning
Vishwadeep Handikherkar, Vikas Phalle, Veermata Jijabai Technological Institute (VJTI), Mumbai, Maharashtra, India; Ramesh Bhandare, K.K Wagh Institute Of Engineering Education and Research, Nashik, Maharashtra, India

Compound faults, arising from simultaneous damage to both gears and bearings, pose a significant challenge in vibration-based fault diagnosis due to the complex interaction of multiple fault sources. This paper presents a novel approach for detecting and classifying compound gear and bearing faults through vibration signal analysis enhanced by ensemble machine learning techniques. Time and Frequency Domain features were extracted from collected vibration signals. An ensemble model, incorporating Random Forest, Gradient Boosting, and Support Vector Machine classifiers, is proposed to improve classification accuracy. The model is evaluated on experimental datasets, showing superior performance in distinguishing between normal and faulty conditions. Results demonstrate that the ensemble approach achieves higher classification accuracy and robustness compared to individual classifiers, highlighting its potential for reliable fault diagnosis in complex industrial machinery.

11:40 am - 12:00 pm
4204902: Laboratory and Field Trials of a Railway Wheel Mounted Ultrasonic Sensor for Contact and Lubrication Detection
Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom; Henry Brunskill, Hary Shackleton, Peak to Peak Ltd, Sheffield, United Kingdom; Andrew Little, LB Foster Rail Technologies Corp, Surrey, British Columbia, Canada

Railway wheels move laterally on track during vehicle curving; to avoid damage caused by sliding particularly sharp curves are greased. The location of the wheel on rail and presence of grease are important parameters. In this work we have built and field-tested ultrasonic sensors to detect both. Ultrasound is partially reflected at a rough surface contact. The proportion of wave amplitude reflected depends on the stiffness of the interface. Addition of grease into asperity gaps makes the

contact slightly stiffer and a resulting change in reflection can be detected. Using this approach, we assess the size of the wheel rail contact and if it is lubricated. Arrays of small ultrasonic sensors were bonded onto both a lab-based wheel-rail simulator and a train wheelset on a heritage line. Tests on the former assessed contact and lubrication under controlled conditions of load and lubricant application. Tests on the latter showed the practical capability of the method as a train-based sensor.

3D — Hanover E

Metalworking Fluids II

Session Chair: Stephanie Cole, Munzing North America, LP, Bloomfield, NJ
Session Vice Chair: Stefanie Velez, MUNZING CHEMIE GmbH, Bloomfield, NJ

8:00 - 8:40 am
4203455: A Seminal Tribological Study of Chlorinated Paraffins and Alternative Chemistries for Extreme Pressure and Anti-Wear.
Robert Stepan, Univar Solutions, Strongsville, OH

A seminal tribological study of chlorinated paraffins and alternative chemistries for Extreme Pressure and Anti-Wear. Regulation of Chlorinated Paraffins (ECHA and future limitations MCCP). Scope of Work: A comparative tribological study of 3 commercially chlorinated paraffins and a wide spectrum of alternative additives. Project Overview: The purpose of this project is to evaluate the performance characteristics of specific mid-chain chlorinated paraffins against a selection of industrial additives. The testing is conducted using established tribological testing methods: the 4-Ball Extreme Pressure (EP) & Wear, the Falex Pin & Vee Block, the Mini-Traction Machine (MTM), SRV with 3D polarimetry, Micro Tapping-Torque, and Timken OK Load. Finally, Report outcomes in a comparative matrices between the large sample population of alternative chemistries v. chlorinated paraffin

8:40 - 9:00 am
4201733: Effect Cooling-Lubrication Condition and Abrasive Grit Size and on Tribological Behavior of SAE 52100 Hardened Steel after Grinding
Rosemar Batista da Silva, Bruno Souza Abrão, Mayara Fernanda Pereira, Federal University of Uberlandia, Uberlândia, Minas Gerais, Brazil; Raphael Lima de Paiva, Federal University of Piaui, Teresina, Piaui, Brazil; Alisson Rocha Machado, Pontifícia Universidade Católica do Paraná, Curitiba, Parana, Brazil; Mark James Jackson, Kansas State University, Salina, KS; Rogerio Valentim Gelamo, Federal University of Triângulo Mineiro, Uberaba, Minas Gerais, Brazil

Coolant in grinding is delivered generally at high flow rates that can reach up to 300 L/min (18000000 mL/h). However, due to environmental, social, and economic issues, research has been carried out to reduce fluid volumes, without compromising functionality of ground components. The addition of solid particles to the coolant combined with the minimum quantity of lubricant technique (< 500 mL/h) has shown promising results in grinding processes, improving the tribological conditions. This work evaluated the effect of adding multilayer graphene particles to the cutting fluid on the surface integrity of the SAE 52100 hardened steel. Combination of 2 aluminum oxide grinding wheels (46 and 60 meshes) with coolant delivered under the conventional, MQL and MQL+Graphene cooling-lubrication conditions were tested. Roughness and surface texture of workpiece were investigated. Presence of graphene particles lead to improved tribological behavior providing low roughness and better texture.

9:00 - 9:20 am
4201177: The Challenge to Determine Anti-Wear and Extreme Pressure Properties of Dry Lubricants in Industrial Lubrication Applications.
Dirk Drees, Lais Lopes, Pedro Baião, Michel De Bilde, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium

Dry lubricants are in industrial forming processes, notably wire drawing. Consisting of flakes, pellets, or powders, they stick to the workpiece and pass through a die or forming tool, where localized high pressure melts them. Characterizing their EP and Anti-wear properties in a lab test is challenging: a constant supply of particles into a standard tribological geometry needs to be achieved. Four ball wear/ep tests fall short.
Further, the aspect of cooling needs to be addressed, in the industrial setting the cooling is done by workpiece mass transport, but this cannot be simulated in a lab test. In this presentation, the method to apply a consistent and systematic amount of dry lubricants into the tribological contact of a Pin&Vee block setup is shown, as well as how test conditions can be modified to obtain a repeatable and useful test method that correlates with expectations of the products under test. This opens an avenue to a standardized QC test for solid particle lubrication.

9:20 - 9:40 am
4200903: Boundary Lubricant Additive Multimetal Boundary Lubrication Optimization Using Twist Compression Tests (TCT) and Combination DOE
Ted McClure, Alexes Morgan, Joseph Chiarelli, Sea-Land Chemical Co., Cleveland, OH

Materials and manufacturing processes continue to evolve in response to changing requirements. Electric current and thermal management are important considerations for EVs, contributing to increasing use of copper and aluminum. Metalworking fluid end users also require fluids performing with multiple metals, for improved efficiency and inventory control. The Twist Compression Test (TCT) is used to evaluate the boundary lubrication performance and galling resistance of material couples. High performing additives with AISI 1018 steel, 5182-0 aluminum, and Copper 110-H02 were identified and TCT results presented earlier. A combination mixture DOE, with the metal type as a three level categoric factor, along with three selected additives, was designed. The resulting matrix was tested using TCT. The test results and DOE analysis will be presented. The aim is to provide useful data, and one possible process, for formulation of lubricants in applications involving multiple metals.

9:40 - 10:00 am
4202870: Advancing Sustainability in MWFs with High Renewable Content Amino Alcohol Derivatives
Richard Butler, Kathleen Havelka, Advancion, Buffalo Grove, IL

A novel fatty acid AMP alkanolamide emulsifier with high renewable content has been developed through the covalent coupling of a renewable fatty acid with an amino alcohol. This innovative amide broadens the formulation possibilities for water-dispersible fluids containing carboxylic acids and amino alcohols. Formulations incorporating both ionic and covalent coupling of these components exhibit exceptional heat removal and lubrication properties.
This presentation will systematically explore the use of a fatty acid AMP alkanolamide alongside conventional emulsifiers and other fatty acid alkanolamides. Structure-property relationships that highlight the advantages of an AMP alkanolamide and amino alcohols for creating high-performance, sustainable metalworking fluids are discussed. The unique multifunctionality of AMP alkanolamide, combined with amino alcohols creates new opportunities for optimizing next-generation metalworking fluids.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4205066: Development and Performance Testing of Dicarboxylic Acid Replacements
Marlon Lutz, Biosynthetic Technologies, Indianapolis, IN

MWF formulations need to be specifically designed for a given metalworking operation such as cutting, grinding, drawing, stamping, sawing, tapping, milling, drilling, and cleaning. Metalworking fluids formulations regularly requires the addition of a dicarboxylic acid additive that functions as a coupler, emulsifier, anti-corrosion inhibitor, and provides lubricity. Most importantly, this multi-functional additive must allow formulations to be ultimately stable for long durations and deliver suitable performance during the machining of metal specimens. Within this talk, a new series of a dicarboxylic acid replacement additives for the metalworking fluid industry has been evaluated and details around the analytical and performance testing results will be discussed.

11:00 - 11:20 am
4200245: EP Additives with Enhanced Sustainability for Water-miscible Metalworking Fluids
Salvatore Rea, Kevin DiNicola, John Williams, LANXESS Corporation, Naugatuck, CT; Wilhelm Rehbein, Isabell Lange, LANXESS Deutschland GmbH, Mannheim, Germany

Extreme pressure additives are an essential component for many water-borne metalworking fluids. They generate protective layers on metal surfaces in heavy duty cutting and forming processes. Compared to other types of EP additives, sulfur carriers can be used in a broad range of metalworking processes to reduce friction and prevent adhesive wear. They can be easily emulsified and are suitable components for soluble oils and semisynthetic metalworking fluids. Some sulfur carriers are even water-soluble and work as excellent EP additives for synthetic cutting and forming fluids.
Sulfur carriers are very low in toxicity, hydrolytically stable and non-corrosive to ferrous metals. Many sulfur carriers are based on renewable raw materials and can be used as components in eco-friendly formulations.
Based on tribological tests, the presentation demonstrates the possibility to increase the performance and sustainability of water-borne metalworking fluids by adding sulfur carriers as EP additives.

11:20 - 11:40 am
4199298: Innovative Mineral Oil Free Water Based Synthetic Cutting Fluid With Improved Performance
Simmi Datta, Ramababu Bolligarla, N Sivasurian, Kavita Rai, Subinoy Paul, A Arora, Mukul Maheshwari, Indian Oil Corporation Ltd., Delhi, India; M Dubey, IOCL R&D Center, Faridabad, Haryana, India

Water based synthetic cutting fluid is free of mineral oil, emulsifier, conventional EP & AW additives which provide excellent biostability but less lubricating property as compared to mineral oil containing emulsifiable oils. This paper describes the development of an innovative mineral oil free water based synthetic cutting fluid having improved tribological properties than conventional water based synthetic cutting oil. The product exhibits excellent biostability, corrosion inhibition and at par lubricity characteristics as compared to emulsifiable cutting fluids. The paper also describes the field performance of developed products in auto ancillary industries for ferrous machining ranging from mild steel, cast iron, hardened alloy steel, stainless steel.

Rolling Element Bearings III

Session Chair: Daulton Isaac, AFRI Turbine Engine Division, Wright Patterson Air Force Base, OH
Session Vice Chair: Ujjawal Arya, Purdue University, West Lafayette, IN

8:00 - 8:40 am
4205539: Micropitting Damage in Lubricated Contacts
Amir Kadiric, Pawel Rycerz, Mao Ueda, Benjamin Wainwright, Imperial College London, London, United Kingdom

Micropitting is a type of surface fatigue damage that occurs due to asperity stress fluctuations in lubricated contacts operating under thin film conditions. Despite its growing significance, the physical mechanisms behind micropitting are poorly understood. This paper presents results of several experimental and numerical studies into micropitting conducted over the past decade at Imperial College. A triple-disc contact fatigue rig is used to investigate the effects of roughness, slide-roll ratio, specific film thickness and contact pressure on micropitting. The effect of lubricant formulation is studied using a separate ball-on-disc set-up which allows for simultaneous observations of micropitting damage and tribofilm growth. Finally, an in-house numerical model for rough surface contacts is used to predict the onset and progression of microptting by analysing the asperity stress history. The findings are discussed in relation to physical mechanisms responsible for micropitting.

8:40 - 9:00 am
4173730: Identifying Facts from Failure in Forensic Bearing Investigations
Thomas Russell, Exponent, Natick, MA

Although bearing failure modes are generally well-understood, the root cause diagnosis of a failed bearing in a forensic investigation is not always straightforward. Secondary damage caused after initial bearing failure, i.e., damage occurring from surrounding machinery or post-accident rescue/containment events, can and often does, obfuscate the root cause of failure. Incorrectly attributing bearing failure to a secondary damage mechanism can result in the implementation of ineffective solutions to prevent subsequent failures. This presentation will provide a general overview of best practices for conducting effective forensic bearing investigations in real-world applications and highlight common evidentiary features in failed bearings that are similar in appearance but different in cause.

9:00 - 9:20 am
4185168: Metastudy of Deep Groove Ball Bearing and Cylindrical Roller Bearing Fatigue Testing Relative to Various Fatigue Life Models
Jason Brady, Jonathan Adler, Mike Venier, SKF, Plymouth, MI; Jack Gayney, General Motors, Warren, MI

In automotive powertrain applications, fatigue testing is often specified during the design verification phase. This testing is often run under constant operating conditions unrepresentative of the actual application and consumes considerable resources and time. This study surveys historical fatigue testing and presents a statistical analysis of deep groove ball bearing (DGBB) and cylindrical roller bearing (CRB) performance against various predictive bearing fatigue life models to understand design margins and the value of continued fatigue testing in retiring risk to the application.

9:20 - 9:40 am
4200695: Influence of Initial Kinematic Conditions on Bearings Subject to Shock Loads.
Scott Hart, Rex Swindoll, Ryan Schaeffler, Schaeffler Group USA, Inc., Fort Mill, SC

This study summarizes the influence of a bearing's initial kinematic operating conditions on the likelihood that either surface damage or damaging cage stresses will occur when transient speed and load conditions of interest are applied. The rolling element bearing multibody simulation tool CABA 3D was used to model 4 different bearing types in various applications where the initial kinematic conditions resulted in high slippage. In each different bearing application, when traction forces in the contacts increased and the expected kinematic conditions were achieved, both surface-initiated damage and excessive cage stresses were predicted as observed in tested components. Actions to prevent both types of damage were assessed and compared with the original cases.

9:40 - 10:00 am
4205695: Enhancing the Fatigue Life of Rolling Element Bearings by Using Layered Cylindrical Hollow Rollers
Mitul Solanki, Dr. Vishwanath Karad MIT World Peace University, Pune, Maharashtra, India; Dipak Vakharia, S. V. National Institute of Technology, Surat, Gujarat, India

Fatigue life is a crucial factor in the selection of rolling element bearings. Hollow rollers were introduced to enhance fatigue life, but their thin cylindrical walls often led to catastrophic failures under moderate loads. To address this, the layered cylindrical hollow roller (LCHR) was developed. This paper presents a numerical investigation of the LCHR, which shows increased contact width, reduced Hertzian contact stress, and greater resistance to failure, promising higher fatigue life compared to solid and hollow rollers. Using the Ioannides-Harris (IH) theory, the fatigue life of LCHR was predicted, and finite element analysis in ANSYS revealed its superior performance under varying loads.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4205098: Electromechanical Dimension Value Against Fluting
Simon Graf, Oliver Koch, RPTU Kaiserslautern Landau, Kaiserslautern, Germany

Combined electrical and mechanical loads on highly loaded tribological contacts can cause characteristic damage. These include grey frosting, possible lubricant changes, and electrically induced fluting on the metallic contact bodies. This damage can occur in various machine elements such as roller bearings and gears. In this context, the article focusses on experimental investigations into factors influencing the formation of fluting. Furthermore, a hypothesis for the dimensioning of tribological contacts against the occurrence of fluting under electromechanical load is derived and presented.
This dimension value combines the electrical load applied to the contact with the lubricant film height. By applying this parameter over the time axis, curves can be derived for the analyzed influencing factors, which allow an approximation of the time of fluting formation.

11:00 - 11:20 am
4205699: Rolling Contact Tribological Study of ATSP Vitrimer Coated Surfaces Under Varying Slide, Load, and Abrasive Conditions.
Jack Sorrell, Andreas Polycarpou, The University of Tulsa, Tulsa, OK; Vasilis Tsigkis, ATSP Innovations, Inc., Houston, TX

Vitrimer tribopolymers in the ATSP family have shown low friction and wear under sliding and abrasive conditions. Yet, there is little information on the rolling performance of these materials. The goal of this work is to better understand the performance regime of ATSP vitrimer coatings in mixed rolling and sliding contact. Potential applications of these coatings include lunar conditions; thus, we aim to determine the coatings abrasive tolerance with respect to the standard performance regime. Our results show no measurable wear for lower loading conditions regardless of slide ratio, and minimal wear at higher loads when in favorable sliding conditions. The addition of lunar dust simulant increases wear and friction for all testing conditions but does not significantly disturb the surface at lower loads. This study shows the use and viability of roller bearings using dry vitrimer lubricants and their ability to extend the lifespan of bearings in harsh environments.

11:20 - 11:40 am
4203089: Improved Tribological Performance of Ball Bearings with 3D Printed Cage Designs
Rahul Dahiwal, Christoph Bayer, Thomas Kreis, Gebr. Reinfurt GmbH & Co. KG, Rimpar, Bavaria, Germany

The cage not only separates the rolling elements but also acts as a lubricant reservoir and guides the elements through no-load zones, playing a critical role in the overall bearing dynamics. An optimized cage design can significantly reduce friction, wear, and heat generation, thereby improving tribological performance.
This study investigates and proposes an optimized geometric cage design specifically for miniature ball bearings to improve tribological characteristics and ensure better running stability to minimize vibrations. Traditional manufacturing methods struggle to produce complex cage geometries, so additive manufacturing (3D printing) was employed.
A series of performance tests, including start-up and dynamic friction torque and noise tests, were performed on various cage designs. Based on the dynamic simulations, the influence of geometric, material and dimensional parameters on the overall bearing performance was investigated.

11:40 - 12:00 pm
4283043: Influence of Steel on RCF Life of Bearings under Current Flow
Monica Ratoi, Grigore Cernalevschi, Brian Mellor, University of Southampton, Southampton, United Kingdom; Yuxue Cai, ESSO Deutschland GmbH, Hamburg, Germany

Steel particularities such as elemental composition, inclusions, hardness etc. along with lubricant formulation have been universally acknowledged as being the most influential factors controlling the RCF life and wear mechanisms of bearings. Bearings employed in applications subjected to current flow undergo a complex array of wear mechanisms and the steel makeup can play an important role. This study ran MPR tests with rollers made of AISI52100 bearing steel from two suppliers. The rollers were lubricated with a gear oil in the boundary regime and were neutral (absence of electrical fields) or positively (anodic) / negatively (cathode) polarized using an electrical setup. The relationship between the roller polarization, steel makeup and lubricant tribofilm formation provide critical insights into the wear mechanisms and RCF life of bearings

3F Courtland

Sustainability in Motion II

Session Chair: Shubhamita Basu, Perstorp Polyols, Inc., Toledo, OH

8:00 - 8:40 am -
4246564: Sustainability Regulations: A New Operational Framework
Vasileios Bakolas, Schaeffler Technologies AG und Co KG, Herzogenaurach, Germany

A significant number of new regulations regarding sustainability in general have been introduced during the last years. These regulations affect the way companies and organizations operate, the data that they are reporting and also the way they are communicating among themselves and with their customers. These regulations pose a variety of new challenges but also provide the opportunity of innovation. In this talk, an overview of the major sustainability-related regulations will be presented along and the implications that they have on everyday operations will be discussed.

8:40 - 9:20 am - **Invited Talk 2**

9:20 - 10:00 am - **Invited Talk 3**

10:00 - 10:40 am - **Break**

10:40 am - 12:00 pm - **Moderated Panel Discussion**

3G Regency V

Materials Tribology III

Session Chair: Kylie Van Meter, Sandia National Laboratories, Albuquerque, NM
Session Vice Chair: Craig Barbour, Florida Agricultural and Mechanical University, FL

8:00 - 8:40 am
4201954: Toward Sustainable and Hydrogen Compatible Sealing Materials
Geraldine Theiler, Natalia Cano Murillo, BAM, Berlin, Germany; Yoshinori Sawae, Hironori Shinmori, Kyushu University, Fukuoka, Japan; Hikaru Hashimoto, Ayako Aoyagi, NOK Corporation, Fujisawa, Japan; Emiel Dobbelaar, Freudenberg Technology Innovation SE & Co. KG, Material Technologies, Weinheim, Germany

As sealing components, polymeric materials are used in a wide range of applications e.g., as O-rings and piston rings in high-pressure and/or cryogenic hydrogen. For these extremely demanding application, PTFE or PPS based materials are often used as high-performance polymer matrix. This project aims to provide a safe and sustainable sealing solutions for hydrogen applications. New materials with improved sustainability were investigated and compared with conventional grades. Tests were performed in hydrogen over a wide range of temperature and pressure (0.1 MPa to 40 MPa, and 100°C down to -150°C) at Kyushu University and BAM using a pin-on-disk apparatus in a continuous sliding motion. Polymer samples ran against 316L disk at 0.5 m/s and 3 MPa contact pressure. Based on the tribological results and surface analyses, promising candidates are

suggested along with friction mechanisms in both high-pressure and low temperature hydrogen.

8:40 - 9:00 am
4199846: Impact of Temperature on the Tribological Behavior of DLC Coatings in Hydrogen-Containing Atmosphere
David Zeradjanin, Tina Hirte, Robert Bosch GmbH, Stuttgart, Germany; Thorsten Staedler, Xin Jiang, University of Siegen, Siegen, Germany

Hydrogen-containing atmospheres have a positive influence on friction and wear during tribological load on hydrogen-containing, amorphous carbon coating (a-C:H). A specially converted oscillating wear test rig is operated with a gas mixture consisting of 5% hydrogen and 95% nitrogen, to use a gas that is not classified as flammable. During the tribological tests, the coated body is tempered to temperatures between 300 K and 420 K, while the gas is passed over the contact at 300 K. The cof decreases with increasing temperature while neither the distance that the upper body covers until a stable low cof is reached nor the wear volume is changed by the temperature variation. However, an influence on covered distance till run-in and wear is shown by changing the sliding frequency, whereas the cof after run-in remains unchanged regardless of the frequency. In addition, it is observed that the wear mainly occurs during run-in-phase.

9:00 - 9:20 am
4203937: Hydrogen Embrittlement on Microstructural, Tribological, and Mechanical Behavior of Refractory Alloys
Catherine Fidd, Craig Barbour, Sam Mao, William Oates, Fumitake Kametani, Brandon Krick, Florida State University, Tallahassee, FL; Yan Xin, National High Magnetic Field Laboratory, Tallahassee, FL; Kari Johnson, Florida International University, Miami, FL; Prashant Singh, Duane Johnson, Gaoyuan Ouyang, Hailong Huang, Rameshwari Naorem, Nicolas Argibay, AMES Lab, Ames, IA

As hydrogen becomes an increasingly viable clean energy source, questions arise on the longevity of the mechanical components required to produce and use it. Hydrogen diffusing into a material microstructure can detrimentally affect mechanical properties such as reduction in ductility, increased susceptibility to cracking, and increases in friction and wear. Refractory alloys have been investigated as structural alloys in applications with hydrogen exposure due to their ability to absorb hydrogen with minimal loss in mechanical properties. This project examines hydride formation, in refractory metal alloys using XRD corroborating with diffraction patterns to analyze changes in the crystal structure after hydrogen aging. TEM is also used to visualize the effects of hydride penetration in the alloy microstructure on the nanoscale. Paired with mechanical testing, such as scratch testing, we examine the mechanism of hydrogen aging on the micro and nanostructure of refractory metal alloys.

9:20 - 9:40 am
4204518: Tribo-Film Formation at Polymer/metal Sliding Interface in Hydrogen - Effects of Gas Pressure and Temperature –
Yoshinori Sawae, Hironori Shinmori, Qian Chen, Wenxiao Li, Kyushu University, Fukuoka, Japan; Geraldine Theiler, Natalia Cano Murillo, BAM, Berlin, Germany; Hikaru Hashimoto, Ayako Aoyagi, NOK Corporation, Fujisawa, Kanagawa, Japan; Emiel Dobbelaar, Freudenberg Technology Innovation SE & Co. KG, Weinheim, Germany

The energy density of gaseous hydrogen is so small that it should be compressed or cooled to increase the volumetric density in case it can be used as a fuel in the transportation sector. Therefore, tribological elements comprising the hydrogen supply network should be able to operate properly over a wide range of gas pressure and gas temperature. Polymer composites are used as piston rings and rod packings in the oil-free reciprocating hydrogen gas compressor and sliding against the metal cylinder in hydrogen gas environment during the compressor operation. In this

study, sliding tests of polymer composites/316L stainless steel were performed in hydrogen over a wide range of temperature (-150 °C to 100 °C) and pressure (0.1 MPa to 40 MPa) at Kyushu University and BAM. Dedicated surface analyses were conducted to explore the effects of high-pressure and low temperature hydrogen on the tribo-film formation at the sliding interface and the subsequent wear mechanism of polymer composites.

9:40 - 10:00 am
4204745: Friction and Wear of High-Temperature Hydrogen-Aged DLC
Santiago Lazarte, Thomas Lockhart, Brandon Krick, Florida State University, Tallahassee, FL; Tomas Babuska, Kylie Van Meter, John Curry, Steven Larson, Alexander Mings, Sandia National Laboratories, Albuquerque, NM; Matthew Besser, Trevor Riedemann, Nicolas Argibay, AMES National Laboratory, Ames, IA

Diamond-like carbon (DLC) coatings are often used for their low-friction and low-wear properties for automotive engine components or high-pressure mechanical seals. With the current interest in hydrogen as a cleaner energy source, the need for structural materials and coatings that can perform in extreme environments is rapidly increasing, including high hydrogen concentrations at high (>1000°C) and low (cryogenic) temperatures. This work explores the effect of variable temperature hydrogen aging on the properties of DLC coatings. Tribological properties and microstructures were characterized before and after 1 atm H_2 aging at 300°C, 500°C, and 700°C. This resulted in a significant difference in the early-stage (run-in) friction behavior and wear rate. Samples aged at 500°C showed a decrease in cycles needed to reach steady-state behavior and a wear rate of $8x10^{-8}$ $mm^3/(N-m)$. Additional aging conditions were used to explore microstructure and properties evolution in DLC coatings.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4205403: Promising Prospect of MBene as a Solid Lubricant Showcasing Superlubricity
Sai Varun Sunkara, Subramanian Sankaranarayanan, University of Illinois Chicago, Chicago, IL; Shiba Adhikari, Zachary David Hood, Anirudha Sumant, Argonne National Laboratory, Lemont, IL

Transition metal carbides and nitrides, called MXenes, have been widely studied due to their 2D structures and exceptional physical and chemical properties. In this work, we explored MBene (Mo_2B_2) as a solid lubricant spray-coated onto a stainless-steel substrate and studied its tribological properties using ball on disk experimental setup in ambient air and dry nitrogen environment with different counterface balls such as stainless steel and diamond-like-carbon (DLC) coated stainless steel. The lubricant has shown excellent lubricious behavior with DLC coated steel tribo-pair in nitrogen with coefficients of friction reaching superlubricity in some cases and wear rates as low as in the magnitude of 10^{-9} $mm^3/(N-m)$. This is an interesting behavior unlike other MXene (such as $Ti_3C_2T_x$) where they degrade even in dry nitrogen environment unless coupled with other 2D materials. More studies are in progress to understand the exact mechanism of lower friction and wear.

11:00 - 11:20 am
4216116: Water-Induced Entropy Reduction and Its Impact on Friction and Hardness of Alumina Borate Solid Lubricant
Sung-Yup Kim, Eunja Kim, University of Texas at El Paso, El Paso, TX

This study investigates the intricate interplay of chemical reactions, mechanical dynamics, and material properties in friction simulations, focusing on Alumina borate as a solid lubricant. Contrary to conventional expectations, our findings reveal that specific combinations of temperature and velocity lead to unexpected increases in the coefficient of friction (COF),

influenced by the elemental distribution in the lubricant's surface layer. While Alumina borate generally maintains its structure across various conditions, certain thermal and mechanical environments cause deviations that negatively affect COF and hardness. Notably, the introduction of water molecules to the lubricant surface improves both COF and hardness, a result linked to the reduction of system entropy through water-lubricant interactions. This mechanism, which counters the typical trade-off between friction and hardness, introduces two saturation points where optimal performance for each property is observed.

11:20 - 11:40 am
4201938: Enhancing the Efficiency of Biomass Preprocessing of Shredders by Utilizing Wear-Resistant Tool Materials
Tomas Grejtak, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN; Miranda Kuns, Jeffrey Lacey, Idaho National Laboratory, Idaho Falls, ID; Oyelayo Ajayi, George Fenske, Argonne National Laboratory, Lemont, IL; Peter Blau, Blau Tribology Consulting, Enka, NC

Shredders are commonly used to process biomass and municipal solid waste into the desired particle sizes. The size reduction is achieved through the tearing action between the cutter teeth, which can be prone to wear and damage due to contaminants in the feedstock. This study investigates the performance of a small-scale shredder by utilizing more wear-resistant cutter materials. A series of shredder tests were conducted for size reduction of a high-ash corn stover feedstock using cutters fabricated from D2 tool steel (baseline), M42 tool steel, and iron-borided-D2 steel. The cutter performance was evaluated based on the measured wear rate, feedstock throughput and power consumption. Worn surface characterization of the cutters was conducted to identify the dominant wear mode(s) for each tool material. The experimental results were used as input for a techno-economic analysis to estimate the economic benefits of the shredder operation with using the more wear-resistant materials.

11:40 am - 12:00 pm
4171792: On the Friction and Wear Aspects of Fabric Pilling
Kenneth Budinski, Bud Labs, Rochester, NY

Pilling is the formation of macroscopic protuberances composed of tangled fibers of varying size and density on the surface of fabrics. Pilling is caused by the fabric rubbing against itself or a foreign surface and friction and wear are important factors in different stages of pilling, fuzz entanglement, pills that the pilling tendency of fabrics.
The purpose of this study was to understand the correlation between the static friction and wear behavior of fabrics with their pilling tendencies. ASTM G219 inclined plane friction tests were conducted, under selfmated conditions as well as against various counterfaces to determine if the static coefficient of fabrics correlates with their pilling tendencies. Oscillating wear tests after ASTM D4157 were performed on test fabrics with a silicon rubber counterface. It was concluded that breakaway friction is not a good predictor of pilling tendencies but an oscillating wear test was successful in identifying pilling tendencies in fabrics.

3H — Regency VI

Aerospace I

Session Chair: Wai Mak, University of California, Los Angeles (UCLA), Inglewood, CA
Session Vice Chair: Pial Das, Iowa State University, Ames, IA

8:00 - 8:40 am
4200763: Thin Film Coatings for Aerospace Applications
Peter Schmidt, United Protective Technologies, Locust, NC

Thin film coatings have evolved significantly since their introduction. Modern nanocomposite coatings can significantly reduce surface wear when employed with low-viscosity lubricants. Some thin films can be formulated to achieve coefficients of friction as low as 0.05. This work provides an overview of current capabilities and recent developments targeted at aerospace applications, such as gears, bearings, and valve mechanisms. Tribological test results are presented, along with case studies of potential interest to designers.

8:40 - 9:00 am
4205496: Investigation of MoS_2-Coated NITINOL60 In Low-Temperature Dry Environments
Adam DeLong, FAMU-FSU College of Engineering, Tallahassee, FL; Tomas Babuska, John Curry, Steven Larson, Sandia National Laboratories, Albuquerque, NM; Christopher DellaCorte, University of Akron, Akron, OH; William Scott, Marshal Space Flight Center, Huntsville, AL; Catherine Fidd, Thomas Lockhart, Brandon Krick, Florida State University, Tallahassee, FL

60NiTi is a pseudo-shape memory alloy with excellent corrosion resistance, high strain to failure, and a hardness of 60HRC (~8GPa). These properties give 60NiTi the potential to be used in triboelements for space environments. MoS_2 has low vapor pressure, low operating temperatures, and long life making it an ideal space lubricant. MoS_2-coated 60NiTi has shown comparable tribological properties to MoS_2-coated 440C in a dry nitrogen environment at room temperature but has not been investigated at temperatures below 0°C. The tribological performance of MoS_2-coated 60NiTi at temperatures below 0°C is investigated to continue previous efforts to characterize lubrication methods for 60NiTi. In the same deposition run, 60NiTi and 440C stainless steel substrates were coated in pure MoS_2 on top of Ti adhesion layers with magnetron-sputtering to produce comparable coatings. Friction and wear experiments were conducted in a temperature-controlled tribometer, and measured results are reported.

9:00 - 9:20 am
4203680: Novel Application Method of Burnished MoS_2 Coatings for Springs in Solar Arrays Release Mechanisms and Testing Campaign.
David Kostal, Ivan Krupka, Martin Hartl, Brno University of Technology, Brno, Czechia

Application of burnished films on the frictional surfaces is usually done by hand work. This work consists of mechanical shearing of the MoS2 powder against the surface of the part thus creating rather thick film. However, this method has low productivity and repeatability. Novel highly productive approach with high energy vibration deposition was used and tested on coil springs used in deployment mechanisms for solar panel arrays. Newly created coatings were thoroughly tested on the vacuum pin-on-plate tribometer in wide range of temperatures to ensure its performance and inspected with SEM to check MoS2 flakes distribution. Also entire coated component was tested to ensure safety of the procedure for its reliability.

9:20 - 9:40 am
4202813: Low-Temperature Mechanism of MoS_2 Dry Film Lubricants
Abrar Faiyad, Daniel Miliate, Samuel Leventini, Ashlie Martini, University of California, Merced, Merced, CA; Duval Johnson, Jet Propulsion Laboratory, Pasadena, CA

MoS_2 is the most widely used dry film lubricant in space applications due to its resilience in extreme environments. However, its performance is highly temperature-dependent, with significant degradation in cold temperatures. In this study, we integrate tribometer experiments, surface characterization techniques, and reactive molecular dynamics simulations to explore the

mechanisms driving MoS_2 performance deterioration at low temperatures. Our results confirm the lubricant's degraded performance in cold temperatures. Utilizing microscopy techniques reinforced by simulations we provide key insights into the mechanisms responsible for the DFL's degraded tribo-properties in cold.

9:40 - 10:00 am
4205099: Effect of Substrate and Environment on Solid Lubricant Performance
Andrew Clough, Wai Mak, The Aerospace Corporation, El Segundo, CA

The space environment poses unique challenges to the effective lubrication of mechanical systems. Extreme temperatures can render liquid lubricants ineffective, dramatically shortening the operational lifetime of mechanisms. In this work we explore the impacts of temperature and material selection on lubricant performance. Novel lubrication strategies were evaluated using pin-on-disk vacuum tribometer testing. The results inform considerations for the robust lubrication of moving mechanical assemblies in space.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4205508: Development of a High-Vacuum Pin-on-Disk Test Instrument for Aerospace Applications
Juan Bosch Giner, Hannah Liggett, Leon Burky, Christopher DellaCorte, University of Akron, Akron, OH

We present an in-house developed vacuum pin-on-disk test instrument for aerospace applications, adaptable to multiple configurations such as pin-on-disk and ball bearings. The chamber offers easy access via a removable top plate, with a high-capacity pumping system achieving rapid pump-down in ~1 hour. The design targets operations up to 600°C, vacuum levels in the mid-10-8 torr range, and sliding speeds of 3450 rpm (up to 54 m/s with 12-inch disks). Future upgrades include a cryogenic stage and a low-speed, high-torque, unidirectional/oscillatory drive. The instrument measures coefficient of friction and temperature under varied conditions (e.g., load, speed, temperature, purge gases). To date, it has achieved 10-7 torr, 5 m/s speed, and ambient operation. Initial tests with space-compatible greases and solid lubricants like MoS2 and Ag show stable, repeatable results, demonstrating the system's potential to enhance lubricated contacts in space applications.

11:00 am - 11:20 am
4205306: Friction and Wear Life of Aerospace Dry Film Lubricants in Point and Line Contacts
Samuel Leventini, Michelle Padilla, Abrar Faiyad, Daniel Miliate, Ashlie Martini, University of California Merced, Merced, CA

Dry film lubricants (DFLs) are frequently selected for aerospace tribological applications where conventional lubricants, such as grease and oil, aren't ideal to use under extreme conditions. To quantify and understand friction coefficient and wear behaviors, researchers have made numerous comparisons between DFLs through ball-on-disc benchmark testing. However, those tests may not reflect every contact that occurs during the operation of machinery in aerospace. In this study, we complemented ball-on-disc testing with block-on-ring configuration to test the tribological properties of DFLs that are being considered for aerospace use. After testing, results were analyzed in the context of various theories that have been proposed in the literature.

11:20 - 11:40 am
4205346: Impact of Substrate Adhesion on MoS_2 Lubrication
Wai Mak, Andrew Clough, The Aerospace Corporation, El Segundo, CA

In the lubrication of moving mechanical assemblies for space, dry film lubricants and coatings act as alternatives to liquid lubricants when temperature extremes preclude effective lubrication by oils. Although solid lubricants have been used in space systems since the 1950s, there has been limited research on how solid lubricants' adhesive properties affect tribological performance of the contacting surfaces for relevant space mechanisms. In this study, we examine the interfacial properties that affect solid lubricant performance by examining solid lubricants that have applicability to space applications. Friction and mechanical properties of materials were tested in vacuum at varying temperatures utilizing pin-on-disk and scratch testing methodology. The results will inform future materials selection and designs of moving mechanical assemblies for space applications.

11:40 am - 12:00 pm
4205326: Wear Liner Composites for Aerospace Wear and Friction Applications
Hau-Nan Lee, Lucas Amspacher, Justine Paul, Natalie Kadlubowski, Timothy Harper, Richard Fiedler, DuPont, Wilmington, DE

Wear liners are self-lubricating materials used in a wide range of aerospace applications. These liners reduce friction in components like fan blades and thrust reversers, effectively eliminating metal-to-metal contact wear and increasing component lifespan. To lower the friction, traditional wear liners often utilize PTFE which is continually coming under regulatory pressure. This presentation introduces a new safe-and-sustainable-by-design wear liner developed by DuPont™ Vespel®, which does not use PTFE as an ingredient. A proprietary solid lubricant added to a polymer matrix provides the critical wear and friction performance. Our tribological evaluations, conducted under pin-on-plate configuration, demonstrate that the new material achieves equivalent or improved performance compared to existing PTFE-containing options. By advancing wear liner technology, we are addressing regulatory challenges while promoting component longevity and safety in critical aerospace applications.

3I Regency VII

Electric Vehicles III

Session Chair: TBD
Session Vice Chair: TBD

8:00 am - 8:40 am
4205093: All-In-One e-Fluid Technology to Cool Inverter, e-Motor and Provide EV Gear Lubrication
Michael Gahagan, Lubrizol, Derby, Derbyshire, United Kingdom

An e-fluid technology is described as handling high-power density electrical drivetrains that effectively protects and cools inverters, e-motor, and gearbox system. This means a combination of advanced hardware cooling approaches and an advanced fluid to prevent overheating. The benefit in this approach compared with the use of multiple coolants requiring different cooling & lubrication circuits with associated equipment is that it is more conducive towards high power densities. This summarizes consortium work by FlandersMake, Dana, Diabatix and Lubrizol and we present a thermal-hydraulic model and assembly of an electrical drivetrain which is cooled by a

single oil cooling & lubrication circuit using modelling environments and physical testing in actual hardware. These models were verified and the thermal response of the electrical drivetrains under varying load conditions and using different cooling approaches was investigated with the e-fluid.

8:40 - 9:00 am
4200888: Dedicated e-Fluids for Improving Energy Efficiency
Hitesh Thaker, Anusha Srinivas, Infineum USA L.P., Linden, NJ; Shaochi Ma, Infineum International Ltd., Shanghai, China

As part of their commitment to reducing CO2 emissions, many OEMs are increasingly incorporating higher levels of electrification in vehicle designs, focusing on more compact and higher voltage systems. Additionally, they are transitioning to lower viscosity fluids to enhance electrified powertrain efficiency while ensuring hardware protection. This shift has driven the development of a new generation of e-fluids that deliver both efficiency gains and durability, along with material compatibility. Comprehensive electric drive unit efficiency testing, which combines drive cycle analysis with full operation range mapping (steady state testing), provides deeper insights into the impact of lubricants compared to standardized test procedures like WLTP. This paper discusses the highlights and the significant roles that both base oils and additives play in achieving optimal performance.

9:00 - 9:20 am
4203235: Creating EV Fluids for Extending Driving Range.
Jason Carter, SK Enmove, Clarkston, MI; Eunjin Jeong, SK Innovation, Daejeon, Republic of Korea

Every electric vehicle system on the market has its own unique set of demands. Driving range is a key performance indicator for any EV vehicle. We will demonstrate how custom EV additives and baseoil combinations can lead to overall vehicle performance and improve driving range. Data and example fluids from in-house blending and testing of mock finished EV fluids will be provided.

9:20 - 9:40 am
4188548: Efficiency Measurements of Fluids for E Axle Application
Torsten Murr, Shell Global Solutions Deutschland, Hamburg, Hamburg, Germany

With the automotive world looking now already into the 2nd & 3rd generation of E Fluids, lubricant manufacturers are designing fluids that can best protect highly integrated electric powertrains with a clear target to further help to improve the efficiency to support extended ranges of BEV s. Low viscosity solutions are not always been the only solutions. The new fluid solutions need to provide lower CO_2 intensive products to decarbonize the lubricant formulation. In order to balance the technical properties and requirements with available and more sustainable components and base oils, Shell has generated studies to assess key aspects of those next generation formulations for transmission fluids. The study aims to generate and assess data for understanding performance aspects like efficiency and the potential to formulate low viscous fluid solutions, oxidation stability, material compatibility and CO_2 footprint.

9:40 - 10:00 am
4204268: Eco-Design and Validation of EV fluids
Flavio Sarti, TotalEnergies, Solaize, France

In alignment with the European Union’s Fit for 55 initiatives and the transition to electric mobility, the eco-friendly design of lubricants can significantly reduce emissions. This work addresses CO2 reduction across multiple levels: from the careful selection of additives and base oil components to the energy mix of manufacturing plants, the control of friction and mechanical losses in electric vehicles (EVs), and the potential downsizing of battery packs. This research demonstrates a

practical case where a completely eco-designed fluid has been tested and validated through tribological, drive units durability, and EV fleet tests.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am - **Open Slot**

11:00 am - 11:20 am
4190253: High Speed Aeration Test Development and Findings for e-Fluids
Masahiro Ishikawa, Infineum USA, Linden, NJ

In automotive electrification, motors and gear boxes operate at extremely high speeds, as compared to ICE for which the foaming test methods ASTM D892 and D6082 had been previously developed. At higher speeds of >20,000 rpm, aeration increases and a lubricant's ability to release air becomes even more critical for proper lubrication. The need for high-speed aeration performance is compounded further when formulating low viscosity e-fluids for greater efficiency. Infineum have developed the High-Speed Aeration Test (HSAT), using a homogenizing aggregator that generates extremely high speeds under shear (up to 27,000 rpm). A correlation study between the HSAT and ASTM D892 and D6082, standard foaming tests, show no sign of correlation. HSAT has properly differentiated e-fluid viscosity while ASTM tests D892 and D6082 could not. This paper addresses the further findings from HSAT studies such as mineral vs synthetic base oil, additive effects, thermal aging effects, and others.

11:20 - 11:40 am
4203368: Copper Corrosion Inhibition in e-Transmission Fluids – A Mechanistic Insight
Loan Vo, Dairene Uy, Oluwaseyi Ogunsola, Sarah Matthews, Shell Global Solutions (US) Inc., Houston, TX

Copper corrosion is a critical concern for e-transmission fluids, as exposure of the copper windings of e-motor to fluids can compromise vehicle reliability and safety. Laboratory tests frequently show that fluids with sulfur-containing additives tend to exhibit poorer performance with respect to copper corrosion but the mechanism of corrosion has not been well established. It was hypothesized that the corrosive molecules such as hydrogen sulfide, a potential degradation product of sulfur-containing additives, may contribute to this corrosion issue. This paper presents a test method developed to detect degraded gaseous byproducts in lubricants, aimed at better understanding the underlying corrosion mechanisms. The test method has been correlated with other standard copper corrosion test methods. Additionally, solid analysis on corroded deposits provides further evidence and insights into the species that may contribute to copper corrosion in electric vehicles.

11:40 am - 12:00 pm
4200367: Low Aeration/Traction Lubricant Solutions for High-Speed Electric Drivetrain
Philip Ma, Donna Mosher, Chad Steele, BASF, Florham Park, NJ

The advancement of electric drivetrains has intensified the need for specialized lubricants that optimize performance while ensuring efficiency and longevity. This study investigates the formulation of low high-speed-aeration, low traction lubricants tailored for electric drivetrain systems. These innovative fluids are designed to minimize air entrainment while reducing frictional losses, which is critical for maximizing energy efficiency and ensuring smooth operation. Our experimental results reveal that low high-speed-aeration, low traction lubricants significantly improve heat management, and efficiency, leading to enhanced performance of electric drivetrain. This research underscores the potential of low high-speed-aeration, low traction lubricants as a

crucial element in the evolution of electric mobility.

3J The Learning Center

Rheology I

Session Chair: TBD
Session Vice Chair: TBD

8:00 - 8:40 am
4200674: Rheology Can Help Tribology
Laurent Rougeau, Mikaël Petit, INS, Genay, France

Rheology, in the service of tribology, can help understand phenomena or to discriminate lubricants for specific applications. Two examples will be discussed, one for space applications, the other for automotive. The need for new lubricants for space assemblies led two years ago to the synthesis of 2 new lubricants (gelled oils) with very similar behavior in ball bearings. The use of rheological analysis made it possible to choose the most suitable solution in terms of cold (until -150°C) and hot (150°C) conditions and long-term behavior. For automotive, cold start conditions can be strongly linked to the quality of the engine oil, particularly when soot begins to accumulate (before changing the oil). Rheology helped to understand the low shear thickening effect (related to engine start-up) and to evaluate dispersants efficiency (reduction of this thickening effect) leading to a more effective engine oil. Various test assemblies (including rheo-tribology) and protocols will be discussed.

8:40 am - 9:00 am
4205745: Rheological Test Methods for Driveline and EV Fluids
Carlos Sanchez, Southwest Regional Research Institute, San Antonio, TX

Lubricants in electric vehicles tend to behave differently in the presence of an electric field. There are many rheological test methods used for engine and drivetrain applications that are relevant to EV systems. Rheology can be used to evaluate all lubricants for visco-elastic behavior, loss modulus, and viscosity, and to name a few. Previous studies at SwRI have demonstrated that an electric field affects the viscosity of new and used driveline fluids in different ways. Using a similar approach, other lubricant properties were investigated while subjected to an electric field. This work will discuss different rheological test methods used for evaluating greases and driveline fluids.

9:00 - 9:20 am
4206132: Extracting Temporary Shear Thinning Curve of Lubricant from MTM Traction Test Data
Pinzhi Liu, Silabrata Pahari, Jie Lu, Weixue Tian, ExxonMobil Technology and Engineering Company, Annandale, NJ

Fluid temporary shear thinning at the contact zone of non-conformal contact contributes to the measured traction coefficient. Traction coefficient can be calculated with computational EHL knowing the high-pressure viscosity relationship and the shear thinning characterization of the lubricant. However, direct measurement of high-pressure shear-dependent viscosity is challenging, especially for pressures higher than 1GPa, which are highly relevant in actual applications. In this paper, we'll use PAO4 as an example to back-calculate the shear thinning curve from MTM traction test data. We'll assess and compare the applicability of Carreau and Eyring stress shear thinning models, which are two commonly used models for temporary shear thinning. The acquired high-

pressure shear curve can then be used as input for modeling of other non-conformal contact applications and geometries.

9:20 - 9:40 am
4203405: Automated Measurement of Mid-Shear Viscosity in Full Shear Curve Mapping Using the Tapered Bearing Simulator (TBS)
Loan Vo, Tianshi Fang, Oluwaseyi Ogunsola, Shell Global Solutions, Houston, TX

Understanding rheological characteristics of a fluid is essential for fluid development, especially for optimizing lubrication performance and fuel efficiency. The impact of temperature and shear rate on fluid viscosities requires multiple viscometers to capture the complete shear profile, ranging from 10 to 10^7 s^{-1}. Mapping of viscosity across this broad range of shear rates is essential to characterize the viscosity changes across multiple operating conditions and explore how the resulting profile can influence energy efficiency. The mid-shear rate range of 10^4 to 10^6 s^{-1} is particularly important, as it is where fluids often exhibit the most significant viscosity changes. In this study, a method using TBS was developed to measure viscosities of fluids over this critical mid-shear rate range. The data collected was incorporated into a full shear viscosity curve, providing valuable insights on the influence of temperature, shear rate, and chemical compositions on fluid viscosity.

9:40 - 10:00 am
4192489: Tribological and Rheological Insights into the Lubrication Potential of Eco-Friendly Thixotropic Silica Gels
Arun Kumar, Vivek Kumar, Yogesh Joshi, Manjesh Singh, Indian Institute of Technology, Kanpur, India,

Toxicity from conventional oil and grease lubricants can be mitigated by introducing water-based lubricants with improved rheological properties. We present a thixotropic colloidal gel of silica nanoparticles formed in the presence of NaCl. Our experiments demonstrate that the tribological performance of the formulated gel can be optimized by tuning its rheological properties. We achieved an optimal combination of super-low friction and negligible wear using a thixotropic and chemically robust gel formed through van der Waals interaction between the flocs which provides self-repairing properties and continuous tribo-film formation. These attributes enable the gel to maintain and regain its structure during periods of inactivity, while also forming a thin film with sufficiently low viscosity to slip into the interfacial contact zone and continuously replenish it with lubricant.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4177179: Low Temperature Mechanical Properties of Lubricating Greases Using Rheology and Comparison to Current Industrial Techniques
Jacob Bonta, Valvoline Global Operations, Lexington, KY

In this study the low temperature mechanical properties of greases is evaluated using a parallel plate rheometer with an environmental testing chamber (ETC) and compared to current industrial techniques. Lubricating greases (LGs) are found in nearly all mechanical devices and are employed in diverse environmental conditions. Understanding the mechanical properties of these materials under low temperature usage is vital to their design and current techniques suffer poor repeatability. Here LGs of varied thickener and base oil chemistries are considered. First, small amplitude oscillatory (SAOS) testing under low strain is used to monitor the evolution of the viscoelastic moduli during a temperature sweep from 25°C to -40°C. Next, the apparent viscosity and yield behavior is determined in a 1-minute flow test at varied temperature. Finally, each LG is

examined using the traditional ASTM D1748 and DIN 51805 methods to compare measured behaviors.

11:00 - 11:20 am
4205648: Rheology as a Tool for In-Service Grease Analysis and Compatibility Testing
Richard Janosky, Dylan Kletzing, Richard Wurzbach, MRG Labs, York, PA

Rheology has broad applicability to the field of grease analysis. Though it has seen notable historical use and research, growth of the technology within the grease analysis field has been hampered by the lack of a standardized methodology. Currently, a published ASTM method, utilizing a stress rheometer, is imminent. The potential impact of this method is vast, with specific applicability in areas such as new grease quality control testing and grease compatibility testing. While publication of this method serves as a significant milestone for grease analysis, it is imperative that concerns for in-service grease analysis also be addressed. This research will aim to evaluate the applicability of the imminent ASTM method for compatibility testing, and for in-service grease analysis, and compare with those that have been historically used for this testing, laying out specific concerns for in-service samples.

11:20 - 11:40 am
4205659: Establishing Grease Rheology Testing Triggers From Screened In-Service Grease Analysis
Dylan Kletzing, Richard Janosky, Richard Wurzbach, MRG Labs, York, PA

Screening In-service grease analysis is an often overlooked and underutilized tool to maintain an important asset, the grease. Grease screening is performed by a lab to identify outlier samples for full analysis and onsite as a QC check. Currently grease consistency could use a way to correlate in-service evaluation with advanced testing. Die extrusion testing will be evaluated for correlation with rheology testing to develop the method to identify samples that should be tested via rheology if possible.

11:40 am - 12:00 pm
4283048: The Story of Asphalt – From Rheology to Tribology
Kartik Pondicherry, Paul Staudinger, Julius Heinrich, Anton Paar GmbH, Graz, Austria; Runhua Zhang, University of Wisconsin, Madison, WI

Asphalt is a mixture of bitumen and aggregate materials such as gravel or crushed stone, and more than 90% of the roads in the world are paved using asphalt mixtures. While rheological characteristics of bitumen play an important role in the performance and lifetime of the roads, the tribological interaction between the aggregate and the bitumen can influence the laying process (mixing and compaction) itself. This process is very energy-intensive and the high process temperatures lead to generation of undesirable fumes and also cause thermal ageing of the asphalt. To counter this, certain additives are added to the asphalt which could potentially reduce the mixing and compaction temperature. The current work offers a short overview of bitumen rheology along with case studies showing the performance enhancing effect of additives on the tribology of the asphalt mixture.

STLE JAST Early Tribology Symposium I

Session Chair: Kyle Schulze, Auburn University, Auburn, AL

8:00 - 8:40 am – Open Slot

8:40 - 9:00 am
4241586: The Effect of Graphite Domain Direction on the Friction Coefficient of Ta-CNx Coating Measured by Polarized Raman and SERS Analysis
Takayuki Tokoroyama, Noritsugu Umehara, Nagoya University, Nagoya, Aichi, Japan

Polarized surface-enhanced Raman scattering was applied to low- and high- friction surfaces of tetrahedral amorphous carbon nitride (ta-CNx) to reveal the presence of the graphite structure and investigate the angular dependence of the graphite domains that formed on the topmost surface. The measured D peak intensity differed along the incident electric field toward the sliding direction, from parallel to perpendicular and armchair edges may be present. The results for the low- friction surface indicated that graphite domains exist on the ta-CNx disk and transfer layer on the counter material (Si_3N_4) ball in directions different from the sliding friction, which suggests an incommensurate configuration.

9:00 - 9:20 am
4303617: Accelerating the Discovery of Tribological Materials using High-Throughput Workflows
Tomas Babuska, Justin Hall, Thomas Diebold, Michael Dugger, John Curry, Sandia National Laboratories, Albuquerque, NM

The requirements, performance, & reliability of tribological materials are difficult to characterize & predict due to system properties being highly stochastic. Many contacts have time dependent properties due to external influences, requiring extensive testing time. This limits the development of process-structure-property-performance relationships without high-throughput techniques. We explore the benefits/limitations of high throughput & automated testing methods & discuss the need to enhance all aspects of the tribological research process from sample preparation to testing & analysis. The pros & cons of serialized vs. parallelized testing, contributions of test duration, & required human interaction are all explored for large material systems. An exemplar binary nanocrystalline metal coating system (Pt-Au), showing ~2688 tests performed in multiple environments across 448 unique compositions is highlighted. SNL is managed & operated by NTESS under DOE NNSA contract DE-NA0003525.

9:20 - 9:40 am
4242215: Nanorheology and Nanostructure of Lubricious Soft-Boundary Films
Shintaro Itoh, Nagoya University, Nagoya, Aichi, Japan

Polymer films formed on solid surfaces have been reported to exhibit high lubricity in boundary lubrication. For lubrication design using polymer films, it is essential to clarify the mechanical properties and molecular conformations of the films. In our previous research, we successfully quantified the mechanical properties (shear viscoelasticity) of nanometer-thick polymer films by applying the fiber wobbling method (FWM), a nanorheology measurement method we developed. Furthermore, we are working to elucidate the lubrication mechanism by analyzing the interface nanostructure of the polymer films using neutron reflectometry. In this presentation, we report representative and recent results.

9:40 - 10:00 am
4303200: From Haptics to Lubricant Additives: the fundamental questions that drive innovation in Tribology
Sitangshu Chatterjee, Afton Chemical Corporation, Richmond, VA

Haptics (derived from the Greek word 'haptikos') pertains to the sense of touch, and the use of haptic devices is ubiquitous in consumer electronics - phones, laptops, cars, gaming consoles etc. Lubricant additives enhance the performance of base oils and are critical for prolonging the working life of automobiles and industrial equipment. What does innovation in these seemingly unrelated domains have in common?
In this talk, I will shed some light on the things that helped me transition from studying haptic devices as a graduate researcher, to supporting an organization's lubricant additive R&D efforts as an industry professional. Taking examples from my early career, I will talk about the role of taking a first-principles approach and the importance of asking fundamental questions in solving complex problems.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4241783: Rubber Friction Control Focusing on Local Stick-Slip Induced by Stiffness Inhomogeneity
Satoru Maegawa, Fumihiro Itoigawa, Nagoya Institute of Technology, Aichi Nagoya City, Japan

Hysteresis friction arises when a viscoelastic material like rubber slides on a rough hard surface, due to deformation resistance from surface asperities. This friction is correlated with tanδ, the ratio of storage modulus to loss modulus, indicating whether elastic or viscous properties dominate. Typically, increasing tanδ enhances hysteresis friction, making tanδ control key for friction design. This study proposes a novel approach focusing on structural design of viscoelastic materials. Rubber specimens with nonuniform stiffness in the sliding direction are examined. When a asperity slides on rubber with alternating soft and hard regions, lateral deformation increases as asperities engage the hard regions, generating local stick-slip. This local stick-slip enhances friction via hysteresis loss. Experimental and simulation results are presented, along with a friction prediction model incorporating lateral deformation behavior.

11:00 - 11:20 am
4272074: Cavitation Dynamics at the GEL-Water Interface
Alexander McGhee, University of Arizona, Tucson, AZ; Jin Yang, Zixiang Tong, University of Texas, Austin, TX; Christian Franck, University of Wisconsin, Madison, WI

Cavitation at liquid-solid interfaces critically influences engineering and medical applications, yet subsurface effects remain poorly understood. Here, we employ laser-induced inertial cavitation (LIC) along with Spatiotemporally Adaptive Quadtree mesh Digital Image Correlation (STAQ-DIC) and Embedded Speckle Pattern (ESP) techniques for high-fidelity, full-field measurements of deformation, velocity, and strain within soft materials. By varying LIC nucleation standoff distances, gel stiffnesses, and cavitation energy, we develop a predictive model for maximum damage. Our findings reveal how nucleation distance profoundly affects spatiotemporal deformation, wave propagation, and mechanical strain within gels. These insights advance our understanding of soft tissue responses to cavitation, guiding improved therapeutic strategies and engineering designs that harness cavitation’s benefits while reducing harmful effects.

11:20 am - 12:00 pm
4231698: Achieving Superlubricity Through the Synergistic Effects of DLC Coatings and Organic Acids
Motoyuki Murashima, Tohoku University, Sendai, Miyagi, Japan

This study explores the achievement of superlubricity through the combination of diamond-like carbon (DLC) coatings and organic acid lubricants. Friction tests revealed that specific solutions, such as lactic acid and serine at optimal concentrations, can reduce the friction coefficient to below 0.01. Molecular dynamics simulations using the ReaxFF potential demonstrated the strong adsorption of lactic acid molecules on DLC surfaces, highlighting their role in forming stable, low-friction interfaces. Additionally, dielectric barrier discharge (DBD) treatment was utilized to modify the DLC surface, generating carboxyl- and hydroxyl-rich layers crucial for maintaining superlubricity. The development of intermittent DBD application further enhanced the durability of the low-friction state. These findings underscore the synergistic effects of DLC coatings and organic acid lubricants in achieving and sustaining superlubricity under atmospheric conditions.

4A Hanover AB

AI and Machine Learning IV

Session Chair: Max Marian, Leibniz University Hannover, Hannover, Germany
Session Vice Chair: Shuangbiao Liu, Northwestern University, Evanston, IL

2:00 - 2:40 pm
4279249: How Industry and Academia Collaborate in the Digitalization of Materials in Germany and the EU
Peter Gumbsch, Karlsruher Institut für Technologie KIT, Karlsruhe, Baden-Württemberg, Germany

The digital transformation will expedite materials development, component assessment, and lifetime predictions. A cornerstone is the collaborative creation of a materials knowledge base grounded in aligned knowledge graphs, coupled with a distributed FAIR data research platform. This talk aims to sketch out how an ontology-based federated materials data infrastructure can capture the hierarchical dependencies between processes, microstructure, properties, and behavior of advanced materials, and how this is prototypically implemented with academia and industry in Germany. Lessons learned will be reported, outlining strategies for participation at various levels. This includes a sample framework for scalable generation of FAIR data. It also gives a showcase FAIR data package for a pin-on-disk tribological experiment, which demonstrates a collection of scalable techniques that extend the reliability and reusability of experimental tribological data beyond typical publication practices.

2:40 - 3:00 pm
4188321: A Contemporary Review and Data-Driven Evaluation of Archard-Type Wear Laws
Brian Delaney, Q. Jane Wang, Wei Chen, Yip-Wah Chung, Northwestern University, Evanston, IL; Ryan Evans, The Timken Company, Canton, OH

This review evaluates recent sliding wear experiments to determine whether Archard's Wear Law and its variants still hold theoretical value. In this analysis, modified Archard models (incorporating variable exponents for load, sliding speed, and material hardness) were optimized for 39 independent studies out of 74 reviewed papers. A Gaussian mixture model clustered the optimized exponents into two groups: one centered around the original Archard model, and the other reflecting alternative optimized exponents. The review found that 79% of the papers referencing a

wear model employed an Archard variant. Analysis showed that models using material hardness as the primary factor influencing wear volume struggled to make accurate predictions. Although the Archard-type model maintains its theoretical relevance in relating wear volume to applied load and sliding speed, its dependence on a constant wear coefficient and material hardness falls short in describing wear phenomena comprehensively.

3:00 - 4:00 pm – Exhibitor Appreciation Break

4:00 - 4:20 pm
4192490: Estimation of Friction Force from In-Situ and Top-View SEM Images of Polyacetal Friction Interfaces and Generation of Low-Friction SEM Images Using Deep Learning
Hiroshi Kinoshita, Serina Tanaka, Naohiro Matsumoto, University of Hyogo, Himeji, Japan; Yoshiyuki Sugai, University of Hyogo & Daicel Corporation, Himeji, Japan

We have pioneered the development of a device that enables direct in-situ, top-view observations of friction interfaces using scanning electron microscopy (SEM) with a microtribometer and electron-transmitting membranes. This device allows the acquisition of SEM images capturing the formation of transfer films, wear debris, rolled debris, and free layers on polyacetal (POM) resin friction interfaces. However, the relationship between these phenomena and friction forces remains unclear. Friction forces were estimated from the SEM images using deep learning, and the key feature points influencing the deep learning decisions were identified through class activation mapping (CAM). Furthermore, low-friction SEM images of POM friction interfaces, corresponding to friction forces below the minimum values observed in friction tests, were generated using generative AI.

4:20 - 5:00 pm - AI and Machine Learning Business Meeting

4B Hanover C

Commercial Marketing Forum IV

Session Chair: TBD

2:00 - 2:20 pm
4301599: Lubrizol: A Versatile Rust Preventive for Long-Term Outdoor Corrosion Protection
Amelia Hadler, Maria Shepherd, Robet Dura, Lubrizol Corporation, Wickliffe, OH

Heavy-duty rust preventives are vital for long-term corrosion protection in applications such as automotive underbody coatings and outdoor metal frameworks. Existing products tend to use aging technology limiting formulating options, obscuring metal surfaces, and exhibiting poor UV stability. This talk introduces Lubrizol's Alox® MT9335, a novel polymer-based coating that forms a clear, dry film with excellent corrosion protection and UV stability. Designed for versatility, its clear color broadens application scope, while its concentrated composition offers expanded formulating flexibility.

2:20 - 2:40 pm
4301470: Cargill: Priolube™ bio-based synthetic ester thickeners
Scott Davis, Nick Weldon, Cargill, York, North Yorkshire, United Kingdom

There is an increasing demand for lubricants to be more efficient, last longer while reducing oil sump capacity in both the industrial and automotive sectors. Synthetic base oils and additives are

utilized to meet these demands. There is also a desire to increase the bio-based content of lubricants. Competing aims of performance and higher bio-based content can conflict, as commonly used synthetic base oils are predominately petroleum-based polyalphaolefins (PAOs). One way to address these competing demands is to formulate with ester-based shear-stable thickeners. Such lubricants can provide outstanding friction reduction, improved formulation efficiency and the biobased content of formulations can be increased. This can be achieved over a wide viscosity range.
Here we will present new Priolube™ bio-based synthetic ester thickeners which allow the formulator to create high viscosity but also high efficiency formulations with low wear while increasing the bio-based content.

2:40 - 3:00 pm
4301761: Lubrizol: Zinc Free Hydraulic - Enabling the Future of Hydraulic Fluids
Jared Cornett, The Lubrizol Corporation, Wickliffe, OH

The need for environmentally conscious, zinc-free hydraulic fluids are gaining momentum in marine/offshore, construction, forestry, and mining industries. High-performing, OEM approved, zinc-free hydraulic fluids not only ensure a more sustainable solution but also pave the way for the future of hydraulic fluids by setting new standards in oil drain intervals, equipment durability, and sludge control. In this talk, we will discuss how Lubrizol enables the hydraulic fluids of tomorrow with our new, top tier, zinc-free hydraulic additive: Lubrizol® AH933ZF.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:40 pm
4301897: BASF Corporation: Emgard® Transportation Lubricants - Lubricant Solutions for a Sustainable Future
Michael Barry, Arjun Goyal, Donna Mosher, Philip Ma, BASF Corp., Florham Park, NJ

BASF's Fuel and Lubricant Solutions is a leader for sustainable high-performance drivetrain lubricants in selected transportation markets.
With our leading progressive technologies for EMGARD® transmission and axle lubricants, we establish industry standards for high performance and sustainable lubricants through joint customer developments providing maximum value to all.
This session will highlight those advancements in our BASF portfolio while highlighting areas of efficiency, carbon reduction, e-mobility and enabling a sustainable future.

4:40 - 5:00 pm
4304002: ExxonMobil: Advanced PAO Technology Enabling High-performance Passenger Vehicle (PV) Fluid Solutions
Raymond McDonald, ExxonMobil, Emmaus, PA

Evolving regulations and consumer trends will continue to drive the automotive industry to reduce CO_2 emissions. This in turn will drive new ICE designs and operation, as well as adoption of alternate powertrain vehicles such as BEVs, HEVs and PHEVs. Next-generation PV hardware designs are likely to require high performance, low viscosity fluids. New engine oil specifications and EV hardware designs for integrated electric drive units will challenge formulators to deliver low viscosity fluids that balance traditional lubrication with volatility and efficiency. Therefore, base oil selection will be a critical consideration when developing these fluids. This presentation summarizes recent evaluations documenting benefits in efficiency, and other performance areas, made possible via an advanced low-viscosity/low-volatility PAO technology platform. The results demonstrate that this novel technology can enable development of next-generation fluids and

greases with improved performance.

4C Hanover D

Condition Monitoring II

Session Chair: Jacob Bonta, Valvoline Global Operations, Lexington, KY
Session Vice Chair: Matthew Hobbs, EPT, Calgary, Alberta, Canada

2:00 - 2:40 pm
4200473: Reliability Starts Here: Best Practices for Fluid Analysis
Josh Gaschler, POLARIS Laboratories®, Indianapolis, IN

A world-class lubrication program involves several key elements, including proper sampling techniques, appropriate frequencies, safe storage and handling, and effective contamination control. Oil contamination is a leading cause of component wear and equipment failure, making it essential to use only clean lubricants in operations. Cleanliness-control centers play a vital role in ensuring that lubricants are stored and transferred in a contamination-free environment. Participating in routine sampling with an oil analysis program is a critical step when it comes to increasing equipment reliability. Furthermore, extracting clean, accurate oil samples is key to receiving accurate data and maintenance recommendations back from the lab; simply put, it's a case of "garbage in, garbage out." In this presentation, we will discuss best practices for fluid analysis and the foundational principles necessary for a successful lubrication program.

2:40 - 3:00 pm
4205664: Achieving ISO 17025 Accreditation for Inservice Grease Analysis Programs
Jonathan Wright, Dylan Kletzing, Richard Wurzbach, MRG Labs, York, PA

In the field of tribology, grease analysis has historically represented a small fraction of samples tested, with the majority being oil samples. More recently numerous industries have realized the benefits of in-service grease analysis, resulting in significant cost-savings, decreased downtime, optimized lubrication intervals, and a greater focus on proactive maintenance. With such large industry decisions riding on the results of grease analysis, it is important for laboratories to maintain rigorous quality programs to ensure the reliability of data. Achieving ISO 17025 accreditation for the Quality Program of a grease analysis lab provides such documentation. This paper will reveal a proven approach for laboratories to achieve ISO 17025 for in-service grease analysis per ASTM D7918, and demonstrate how end users of grease analysis services can rely on this accreditation to for confidence in the value of analysis on samples that they submit.

3:00 - 4:00 pm – Exhibitor Appreciation Break

4:00 - 4:20 pm
4204935: Condition Monitoring Method for Oxidation of Biodegradable Hydraulic Oils
Tomomi Honda, University of Fukui, Fukui, Japan

Recently, it is required to use biodegradable oil from the viewpoint of global environmental problems. On construction machines, online sensing systems have been developed, and some construction machines are beginning to use fluid property sensors. However, there are few reports on the degradation diagnosis of biodegradable hydraulic fluid using fluid property sensors. In this study, we aimed to improve the diagnostic accuracy by investigating their relationships with the parameters of the color analysis sensor and the fluid property sensor. We made oxidized

biodegradable oils using the RPVOT without water and catalyst and measured color parameters, physical properties, and TAN using these sensors. As a result, it was suggested that using a combination of color analysis and fluid property sensor, we can detect the early stage of oxidation and indirectly know the value of TAN from the dielectric constant.

4:20 - 4:40 pm
4205126: Electrical Impedance Spectroscopy for Lubricant Condition Monitoring
Tom Reddyhoff, Thomas Kirkby, Imperial College London, London, United Kingdom

Monitoring the condition of lubricants is crucial in maintaining the efficiency and longevity of mechanical transmissions across various sectors such as transportation, power generation, and industrial equipment. Electrical impedance spectroscopy (EIS), a powerful tool to determine electrochemical properties, is underutilized in lubricant monitoring. This study uses both in situ and ex situ approaches to examine lubricants. Ex situ bulk properties were analyzed using a novel EIS probe, while in situ properties were investigated using a lubricated ball-on-disc contact in a mini-traction machine (MTM) tribometer. Lubricants were tested to investigate the effect on resistance, capacitance, and tribological behavior, correlating with friction and wear data. Anti-wear film thickness was also investigated by comparing in-situ EIS data with MTM-SLIM data with results showing a good correlation. This paves the way for EIS to be utilized in both lab-based and online testing of engine oils.

4:40 - 5:00 pm
4302474: Identification of Lubricant Types Using Near-infrared Spectroscopy and Machine Learning
Kyoko Kojima, Hitachi, Ltd., Tokyo, Japan

Near-infrared spectroscopy is difficult to interpret spectral data and applying machine learning, but the equipment is inexpensive, suitable for transmittance measurement, and easy to use. Until now, the physical properties of lubricants and the moisture content in lubricants have been predicted from the near-infrared absorption spectra with data preprocessing and applying regression algorithms. In this presentation, a new technology that processes near-infrared absorption spectral data with a classification algorithm to identify commercially available lubricant products will be introduced. Also, it was demonstrated that it is possible to distinguish the oil type even if the oil is used for the same product. The technology is expected to be used for fuel quality assessment and counterfeit oil detection.

5:00 - 5:30 pm - **Condition Monitoring Business Meeting**

4D — Hanover E

Metalworking Fluids III

Session Chair: Stefanie Velez, MUNZING CHEMIE GmbH, Bloomfield, NJ
Session Vice Chair: Stephanie Cole, Munzing North America, LP, Bloomfield, NJ

2:00 - 2:40 pm
4186275: A Statistical Approach to Studying Additive Interplay for Chlorinated Paraffin Replacement in Cutting Oils
Andrew Yoder, Taylor Lagler, Johnnie Thomlison, The Lubrizol Corp, Wickliffe, OH

Through a controlled statistical approach across three experimental phases, an extensive study utilizing a Tap and Torque instrument was conducted to understand the additive effects of various esters, sulfur carriers, and over based calcium sulfonate. A chlorinated paraffin and a commercially available chlorine alternative were used as controls. An optimal type and balance of these components were identified as crucial for good performance in the first two phases. In the third phase, we explored the effect of additive package concentrations on performance and some surprising results emerged. In all phases, we observed that the tool life had a significant impact on torque even after extensive testing. Variability was also attributable to the bar and/or tap itself. Overall, our findings highlight the complex interplay of additive components and tool conditions in determining performance, underscoring the need for careful consideration of formulation and experimental variables.

2:40 - 3:00 pm
4194864: Study of Tribology Properties and MWF Chemistries in Titanium Drilling
Yixing Philip Zhao, Quaker Houghton Company, Conshohocken, PA; Reza Riahi, University of Windsor, Windsor, Ontario, Canada

Titanium is used in aerospace, biomedical devices, defense, etc. due to its light weight, high strength, and good corrosion resistance. However, it is difficult to machine titanium alloys, due to difficulty machinability and low thermal conductivity. Water based metalworking fluids can reduce friction, low tool wear, provide good surface finish.
The effects of three different types of MWFs on some key tribological properties were investigated in CNC drilling on titanium in different load and feed rate conditions. The torque, tool wears, surface morphologies, and drilling force profiles were analyzed. The results showed the coolants with different chemistries can provide lubrications more specifically for EP, boundary, and mixed regimes due to different lubricity additives, emulsion technologies and cooling properties. These results may give us good tools to formulate and engineer advanced water base MWF for machining not only titanium but also steels and aluminums.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 5:00 pm - **Metalworking Committee Meeting**

4E — Hanover F

Rolling Element Bearings IV

Session Chair: Thomas Russell, Exponent, Natick, MA
Session Vice Chair: Daulton Isaac, AFRI Turbine Engine Division, Wright Patterson Air Force Base, OH

2:00 - 2:40 pm
4202633: Measurement of Bearing Frictional Torque with a New High-Speed Test Rig
Joseph Shore, Amir Kadiric, Imperial College London, London, United Kingdom; Pawel Rycerz, Guillermo Morales-Espejel, SKF Research and Technology Development, Houten, Netherlands

Rolling bearings employed in aerospace, machine tool spindles and electric vehicles applications are subjected to ever increasing speeds, reaching NDm values exceeding 2 mln. There is therefore growing interest in understanding bearing frictional performance under such conditions. However, common bearing friction models have not been tested at these high speeds and there is a lack of relevant experimental friction data. To address this, a new custom bearing test setup, the High-

Speed Bearing Rig (HSBR), has been developed to measure friction torque at speeds up to 45000rpm (>2 mln Ndm). The novel arrangement implemented in the HSBR allows for measurement of friction torque in a single bearing, in contrast to previous similar attempts employing two pre-loaded test bearings. This paper will describe the HSBR and its use to investigate the frictional performance of a super-precision hybrid ACBB under oil mist lubrication, focusing on the influences of axial load, speed, and oil supply.

2:40 - 3:00 pm
4203594: Effect of Nanoparticles on the Rolling Bearing Life in oil lubrication
Yoji Sunagawa, Idemitsu Kosan Co., Ltd., Ichihara, Japan

Rolling contact fatigue test of bearings were conducted with ZrO_2 nanoparticles dispersed lubricant. The ZrO_2 nanoparticles dispersed lubricant showed an extension of fatigue life compared to the lubricant without ZrO_2 nanoparticles. The surface analysis of the ball after the fatigue test showed that a ZrO_2 layer formed. Residual stress measurement on the disc surface after the fatigue test resulted in increased compressive residual stress. It was concluded that the ZrO_2 layer formed under rolling conditions suppressed surface damage and crack propagation.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 5:00 pm - **REB Business Meeting**

4F Courtland

Sustainability in Motion III

Session Chair: Shubhamita Basu, Perstorp Polyols, Inc., Toledo, OH

2:00 - 2:20 pm
4175352: Carbon Emission Reductions Utilizing Renewable Energy for Chemical Production of Estolide Base Oils
Matt Kriech, Biosynthetic Technologies, Indianapolis, IN

With concepts like sustainability and environmental performance gaining momentum in the lubricant industry, many companies are finally seeking ways to incorporate such characteristics into their product lines. While such terms seem simple at first glance, their subjective nature can make them difficult to understand and implement. One tool for navigating such concepts in a more objective way is the Life Cycle Assessment (LCA). In 2022 a cradle-to-gate LCA was conducted on the production of Estolide Base Oils. The findings suggested that the largest source of emission were (1) driven by fertilizer production for the growing of Castor crops used in the production of Estolides, and (2) the electricity used in the facility that was produced from coal. Utilizing this data 2.3 MW of renewable wind turbines and a 2.0 MW solar array were installed at the facility. The results and lessons learned from updating the 2022 LCA utilizing these new sources of renewable energy will be presented.

2:20 - 2:40 pm
4201951: Novel and Innovative Process Technology to Reduce the Carbon Footprint of Lubricant Esters.
Jef Van de Poel, Oleon NV, Ertvelde, Belgium

Sustainability has shifted from being a market differentiator to an expectation from customers. The lubricants industry is in need of a comprehensive portfolio of safe and sustainable solutions, contributing to the global transition towards a net-zero carbon economy. Enzymatic esterification is an innovative technology that utilizes enzymes, nature's own catalysts, in the production process. These enzymes offer numerous advantages, including natural origins, high specificity, and lower temperature and pressure requirements, ensuring safer production conditions. Additionally, they act as non-hazardous biocatalysts, minimize processing waste, and significantly reduce CO2 emissions. A detailed LCA comparison will be discussed, comparing classical esterification methods with this innovative process technology.

2:40 - 3:00 pm
4294844: Tribology & Sustainability: Integrating in Plant Production to Achieve ROI and Lowering Carbon Footprint
Douglas Sackett, Dilmar Oil Co., Monticello, FL

Lubrication and Reliability have taken on a whole new meaning with new corporate responsibility to achieve "net zero" or "carbon neutrality" by 2035-50 and how as Tribologist or Reliability/Lubrication Engineers do we look at all the avenues that we can utilize to achieve and document this goal. Working with the companies in the field to teach, train and asses this process to integrate the leading Tribology research and development and how to use it properly in the field. The UN explains the difference between sustainable development and sustainability as follows: "Sustainability is often thought of as a long-term goal while sustainable development refers to the many processes and pathways to achieve it".
We will look at new and old lubrication formulation, technology and how to implement Tribology knowledge into plant reliability strategy to lower your GHG or carbon footprint while assessing and calculating how to achieve the highest ROI.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4G — Regency V

Materials Tribology IV - Tribute to Yip Wah Chung Special Session

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

2:00 - 2:20 pm
4296553: Tribochemical Activation of Diels-Alder Cycloaddition Reactions
Ashlie Martini, Sourabh Kumar, Donglin Yang, University of California Merced, Merced, CA; William Oprisu, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Adam Braunschweig, CUNY, New York, NY

Shear and normal stress in a tribological interface can activate chemical reactions, a phenomenon that can be leveraged for mechanochemical synthesis. Here, we focus on the use of tribological conditions to activate [4+2] Diels Alder cycloaddition reactions. Experiments are performed using a mini traction machine as a liquid anvil cell to generate high stress within a polyalphaolefin base oil that is transmitted to the reactants to activate the reaction. Rates of the Diels-Alder reactions are quantified with proton NMR. Classical molecular dynamics simulations, modified to capture the cycloaddition reactions of interest under conditions matched to the experiments as closely as possible. The simulations enable the effects of heat, normal stress, and shear stress to be differentiated and show how force is transmitted from the base fluid to the reactants, thus providing new insights into tribochemical activation mechanisms more broadly.

2:20 - 2:40 pm
4297023: Sliding At the Nexus of Surface Science and Tribology
Seong Kim, Pennsylvania State University, University Park, PA

Many principles of surface science are deeply rooted in tribological phenomena. One such process is the adsorption and reaction of molecular species from the environment (either from the gas phase or a liquid lubricant), which influence friction and wear between two solid surfaces moving at different relative speeds. The adsorption of water molecules in humid air can alter the tribological response of solid materials, while the adsorption of organic molecules from a gaseous environment can lead to unexpected yet highly effective lubrication. If these molecules are reactive, they can modify the surface chemistry of solids undergoing frictional shear. Additionally, friction itself can induce chemical reactions of adsorbed molecules that would not otherwise occur. This talk will highlight several examples where surface science plays a critical role in advancing tribological understanding.

2:40 - 3:00 pm
4297010: The Promise of Carbon-based Materials in Friction and Wear Control
Ali Erdemir, Texas A&M University, College Station, TX

Carbon-based materials have been at the forefront of intense scientific research due to their diverse chemical and structural forms, some providing exceptional friction and wear properties. Natural graphite and diamond have existed for many millennia, but myriad others have been synthesized in laboratories. In particular, using advanced physical and chemical vapor deposition methods, researchers have developed synthetic diamond and diamond-like carbon films exhibiting superlubricity and extreme resistance to wear. In this talk, I will elaborate on the tribology of these and other forms of carbon, including the ones resulting from tribocatalysis and contact electrification. I will also discuss the potential of such carbon forms in a range of industrial applications. Overall, new discoveries in carbons are leading the way for further reducing friction and wear in real mechanical systems and, hence, potentially contributing to a green and sustainable future.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4291547: Stress-Dependent Activation Volumes and Viscosity: From Shear Thinning to Glass Formation
Wilfred Tysoe, Nicholas Hopper, University of Wisconsin-Milwaukee, Milwaukee, WI; Rosa Espinosa-Marzal, University of Illinois at Urbana-Champaign, Urbana, IL

While theories for both sliding friction and metal deformation by dislocation motion rely on atomic-scale models, there are no molecular-scale models for fluid viscosity. We thus propose a molecular ensemble that enables the transport of molecules in a fluid by allowing a central molecule to exchange with one of its nearest neighbors. The model is analyzed using strategies developed for tribochemical reactions. The results depend on an activation volume for the exchange process, which itself decreases with increasing normal and shear stresses. The decrease in volume of the reacting ensemble with increasing pressure causes it to reach a point at which there is no longer space for molecules to exchange without the size of the molecular ensemble increasing. This size increase finally causes the formation of a glassy material. Finally, this change in activation volume with shear stress or strain rate leads to a formula for shear thinning that is in excellent agreement with experiment.

4:20 - 4:40 pm
4298990: Wear of Diamond
Hong Liang, Texas A & M University, College Station, TX

In engineering applications, diamond materials are far from lasting forever. This presentation will discuss the wear and wear mechanisms of diamond in general and the tribochemical interaction and phase transformation in detail. Under various contact conditions, we will investigate the effects of temperature and environments on diamonds in terms of microstructure, phase transformation, oxidation, and others that might affect their stability.

4:40 - 5:00 pm
4272762: Material Tribology and Tribochemistry for Steels
Zaid Al Hassan, Xinqi Chen, Shuangbiao Liu, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL; Nikhil Murthy, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Wear presents a significant challenge in high-performance engineering, where steel components are subjected to extreme pressure, elevated temperatures, and continuous sliding contact. While traditional coatings synthesized with Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) offer wear resistance, they can be costly, difficult to scale, and hard to regenerate. This research investigates in-situ formation of self-replenishing carbon-based tribofilms from lubricant additives. Cyclopropanecarboxylic acid (CPCa) undergoes tribopolymerization under stress and heat, forming durable wear-resistant films on steel. Raman spectroscopy confirms their stability, showing graphitic or diamond-like carbon features. The catalytic properties of steel, particularly chromium and nickel, promote tribopolymerization. These findings suggest a scalable and sustainable approach to enhancing wear resistance in steel, offering a promising alternative to traditional coatings.

4H — Regency VI

Aerospace II

Session Chair: Daniel Miliate, University of California - Merced, Merced, CA
Session Vice Chair: Adam DeLong, Florida State University, Tallahassee, FL

2:00 - 2:40 pm
4185032: Development of L-PBF Fabricated Bi-Metallic IN718 and L605 Superalloys for Mitigating High-Temperature Fretting Wear in Aerospace Components
Sathisha CH, GE Aerospace Research, Bengaluru, KA, India; Kesavan D, Arivu Y, Indian Institute Of Technology Palakkad, Palakkad, KL, India

The aerospace industry needs components that improve jet engine performance and durability against fretting wear. Multi-material components are increasingly popular, as they combine advantageous properties. Laser Powder Bed Fusion (L-PBF) effectively produces these advanced components, enabling intricate geometries and the integration of multiple alloys in a single process. This study explores the application of L-PBF to produce bi-metallic superalloys, specifically combining IN718 (nickel-based) and L605 (cobalt-based) alloys. By controlling the volumetric energy density (97 J/mm^3 to 100 J/mm^3), researchers achieved an optimized alloy with a stable interlayer, forming strong metallurgical bonds essential for mechanical integrity. Fretting wear tests (1645 N load, 650°C) revealed that the L605 bi-material system exhibited superior wear

resistance due to a protective cobalt-chromium glaze layer, while IN718 experienced greater wear due to the absence of such protection.

2:40 - 3:00 pm
4203343: Indentation Deformation Behavior of Cold-Sprayed Nanocrystalline High-Entropy Alloys
Philip Egberts, Kasimuthumaniyan Subramanian, Moses Adaan Nyiak, Ahmed Tiamiyu, University of Calgary, Calgary, Alberta, Canada

Metallic surfaces of structural components operating in harsh environments degrade prematurely. Hence, coatings are applied to preserve the underlying substrate. Herein, we investigate the nanomechanical elasto-plastic response of light weight, stable nanocrystalline high-entropy alloy (HEA) coatings deposited via cold-spray technique on a A36 steel substrate using nanoindentation technique and atomic force microscopy (AFM). Specifically, two types of these coatings were examined: undoped $Al_{25}Co_{25}Cr_{25}Fe_{25}$ and doped $Al_{24.6}Co_{24.6}Cr_{24.6}Fe_{24.6}Zr_{1.5}$, each approximately 8 μm thick. Despite being 25% lighter, the hardness of the coatings are almost 4 times higher than the steel substrate. Interestingly, HEA coatings subjected to heat treatment also showed notable improvement in hardness and elastic moduli. Altogether, we report the thermal stability of the HEA coatings developed and the role of elasto-plastic behavior on governing the hardness and moduli of the coatings and substrate.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4179855: Additive Manufacturing of Bearings for Aerospace Applications - Integration of Cooling Channels
Andreas Rottmann, Adrian Popp, Schaeffler Aerospace Germany GmbH & Co. KG, Schweinfurt, Germany

Additive manufacturing (AM) of M50NiL with selective laser melting has been successfully tested to compare the material properties (e.g., tensile strength, rolling contact fatigue behavior) with conventional M50NiL. The next step was to test the printed material under more specific conditions with small angular contact ball bearings, which resulted in comparable endurance capabilities. A mainshaft bearing with ceramic balls and integrated cooling channels was designed to use the advantages of AM under real application conditions. The integrated colling channels could be placed closer to the raceway which results in an improved heat removal up to factor of two compared to mainshaft bearings with cooling channels that are made in a conventional way.
To further improve the use of powder-based materials and metal 3D-printing the cooling channels of the full-scale bearing have been successfully improved via electrolytic polishing. This generates a smoother and more flow-optimized channel.

4:20 - 4:40 pm
4199832: Exploring Tribological Behavior of Aluminum Alloy for Space Application Fabricated via Multimodal Metal Additive Manufacturing Processes
Sougata Roy, Pial Das, Iowa State University, Ames, IA; Annette Gray, Matthew Mazurkivich, William Scott, Marshall Space Flight Center NASA, Huntsville, AL

Friction-induced energy dissipation poses a significant obstacle in space applications, especially during extended missions where energy losses accumulate and become substantial due to the limitations of lubrication in space. The Al6061 aluminum alloy stands out as a promising material for spacecraft component manufacturing due to its corrosion resistance, impressive strength-to-weight ratio, and its inherent insensitivity to the harsh conditions of the extraterrestrial environment. In this effort, we conducted a detailed investigation on the additive manufacturability

and tribological behavior of Al6061 alloy in ambient and vacuum atmospheric conditions at 20C temperature. We specifically examined two distinct additive manufacturing techniques: large scale Wire Arc Additive Manufacturing and meso-scale Laser-Powder blown Direct Energy Deposition. Additionally, in-depth characterization of worn our regions was conducted to explore the primary wear mechanisms in different conditions.

4:40 - 5:00 pm
4194351: Tribological Performance of a Ni Based 3D Metal Printed Aeronautical Alloy
Dirk Drees, Lais Lopes, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Katerina Papanikolaou, Angelos Koutsomichalis, Emmanouil Georgiou, Hellenic Air-Force Academy, Athens, Greece; Athanasios Tzanis, Electronics Depot-R&T Centre, Athens, Greece; Panagiotis Skarvelis, Hellenic Aerospace Industry S.A., Schimatari, Greece

3D metal printing has significantly advanced, becoming a revolutionary technology in aerospace by enabling the layer-by-layer creation of complex structures. This allows for customized parts from advanced alloys with superior mechanical and electrochemical properties, which were previously expensive or difficult to manufacture using traditional methods. However, additive manufacturing still has high setup costs and complexity. This study explores the potential of using conventional welding methods, such as Tungsten Inert Gas (TIG) welding, to produce simplified components from 718 Inconel alloy. A comparison of friction and wear performance with other commonly used aerospace materials will be made to assess this alternative method's applicability in the aeronautical field.

4I — Regency VII

Electric Vehicles IV

Session Chair: TBD
Session Vice Chair: TBD

2:00 - 2:40 pm
4203979: Estimating Power Losses in Electric Vehicle Drive Units: A Combined 1D Analytical and 3D CFD Approach
Abdul Motin, Rivian Automotive, Plymouth, MI

This study presents a sophisticated methodology for accurately estimating the power losses in electric vehicle drive units (e-DU). By integrating one-dimensional (1D) analytical models with three-dimensional (3D) computational fluid dynamics (CFD), we focus on quantifying power losses primarily related to mechanical contact friction and oil drag in key components, including gears, bearings, and seals. Given the growing demand for electric vehicles (EVs), understanding power losses is indispensable for enhancing the overall efficiency and range of these vehicles. Our research examines various analytical models, validates them against experimental data, and analyzes the influence of drive torque and oil properties on power losses. The findings reveal a strong correlation between gear contact losses and experimental results, underlining the effectiveness of our combined methodological approach.

2:40 - 3:00 pm
4201425: Enhancing Efficiency in Electric Drive Units (EDUs) through Lubricant Optimization
Matthew Hauschild, Dmitriy Shakhvorostov, Evonik Oil Additives, Horsham, PA

In this study, we explore the impact of lubricant composition and physical properties on the overall efficiency of wet coil Electric Drive Units (EDUs) under both Worldwide Harmonized Light Vehicles Test Procedure (WLTP) and stationary conditions. Our study focuses on variations in kinematic viscosity (ranging from 3 to 6 cSt), viscosity index (ranging from 130 to 350), and base oil type (mineral and synthetic). Additionally, we explore the impact of viscosity index improvers with linear and comb structures.
Our results demonstrate that by increasing the lubricant viscosity index similar efficiency gains can be achieved without compromising durability which is consideration growing in importance for future EDU units.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:20 pm
4199751: Reconstructing the Internal Shape and Interfaces in a Lithium-Ion Battery using Ultrasound
Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

Lithium-ion batteries provide the power source for most EVs. Determining their health non-invasively is challenging. A new method to determine the battery internal structure using ultrasound is presented. As a cell charges electrodes absorb lithium, changing modulus and hence, ultrasonic reflection. However, there are many internal layers, and the reflection is complex.
A reflection model in a layered body is built and compared to data measured from battery samples. A genetic algorithm is used to vary model inputs (number, thickness, and properties of layers) until the prediction matches measurement. In this way, the internal structure of the battery is reconstructed. Predictions are compared with CT scans of the battery.
When no prior-data is given to the model the prediction is close. With prior-data (such as the layer number or properties) an almost exact prediction is made. The method has potential for detecting defects in batteries or as a sensor for battery health.

4:20 - 4:40 pm
4200262: Low Conductivity Electric Vehicles Coolants for Battery Thermal Management System
Simmi Datta, Naresh Gutta, Neelam Agarwal, Subinoy Paul, IOCL R&D Center, Faridabad, Haryana, India; Kavita Rai, A Arora, Mukul Maheshwari, Indian Oil Corporation Ltd., Delhi, India

Battery thermal management system plays vital role in controlling the battery thermal behavior by retaining the operating temperature at optimum range (15 to 35°C). Liquid cooling is more efficient & most promising coolant system which delivers best performance to maintain battery pack in uniform atemperature range due to its high heat capacity & higher heat transfer coefficient. Since the coolant flow in battery pack carrying electric power, the key performance parameter that differentiate the coolants for electric vehicles from coolants for ICE is the low electrical conductivity requirements for electric vehicle coolants. This paper discusses the development of low conductivity EV coolants for EV buses, passenger vehicles & bombardier metro rail engines for indirect liquid cooling system. Developed coolant found to have excellent chemical & thermal stability, corrosion protection and compatibility with material of cooling assemblies of battery pack.

Rheology II

Session Chair: TBD
Session Vice Chair: TBD

2:00 - 2:40 pm
4174786: Quantitative EHL-Eighteen Years In
Scott Bair, Georgia Institute of Technology, Atlanta, GA; Wassim Habchi, Lebanese American University, Byblos, Lebanon

Eighteen years have passed since the first full elastohydrodynamic lubrication simulation employed the real pressure and shear dependence of viscosity measured in viscometers to accurately predict both film thickness and friction. This presentation will enumerate the advances in understanding brought on by the application of high-pressure rheology to the EHL problem. The central film thickness often depends on the shear-thinning at low pressure and time-temperature-pressure superposition demands that the same shear dependence be active at the high pressure where friction is generated. In this article some of the revelations resulting from quantitative EHL are reviewed. For example, it has been discovered that the minimum film thickness in point contacts depends upon the viscosity at the highest pressures of the contact. Quantitative EHL provides quantitative predictions of contact behavior.

2:40 - 3:00 pm
4199299: Evaluating Slippage Characteristics in Nanogaps by Lubricant Flow Measurement Using Fluorescent Particle Tracking
Hidetaka Ozeki, Naoki Azuma, Kenji Fukuzawa, Shintaro Itoh, Hedong Zhang, Yuxi Song, Nagoya University, Nagoya, Japan

In lubrication in a nanometer-sized gap, it has been found that large slippage occurs at the interface between the lubricant and the solid surfaces. The slippage causes the flow profile in the nanogap which is quite different from that in the microgap and changes the lubrication properties such as the vertical and frictional forces. Therefore, the method to evaluate the properties of the slippages in nanogaps is required. In this study, we propose a method to evaluate the properties of the slippages in nanogaps based on the flow velocity measurements of squeeze flow. The flow velocity was measured by particle image velocimetry (PIV) using the fluorescent particles whose sizes were nanometer-order, and the slippage velocities were calculated by analyzing the obtained velocity values. We evaluated the dependency of the properties of slippages on the sizes of nanogaps and found that shear stress was the important factor to determine the slippages.

3:00 - 4:00 pm – Exhibitor Appreciation Break

4:00 - 4:20 pm
4202690: Characterization and Analysis of Polyol Ester Oil of Operating and Failed Scroll Compressors
Hannah Liggett, Juan Bosch Giner, Christopher DellaCorte, University of Akron, Akron, OH

Though the popular R410A refrigerant gas is compatible with Polyol Ester Oil (POE) because of its solubility, the effects of its interaction have not been studied to its failure point. Limited literature has been addressed regarding the long-term effects of their interaction over 10 years of service. This study analyzes two field compressors, revealing that the failed scroll compressor's oil was dirtier compared to the operating compressor. This proposed work aims to characterize the oil's

properties from both scroll compressors. Oil characterization and tribological tests, along with assessing oil contamination will be conducted. The results will be compared to fresh oil samples to observe changes in tribological and rheological properties between the three POE samples. This analysis could provide insights into the projected changes in POE oil properties when paired with new refrigerant gases, as the use of R410A refrigerant gas is expected to decline over the next 15 years.

4:20 - 4:40 pm
4199436: Study on the Effects of Antifoam Additives on Film Drainage and Bubble Dynamics in Oil-Based Systems
Paul-Anael Pogu, Tom Reddyhoff, Imperial College London, London, United Kingdom; Eliane Gendreau, Robert Mainwaring, Hayley Bunce, Shell, London, United Kingdom

Foam stability in oil-based systems is a critical factor influencing performance in lubrication and tribology applications. While antifoaming agents are commonly used to mitigate foam formation, their precise effects on the dynamics of bubbles in oil remain less understood.
This study investigates the impact of antifoam additives on the drainage and thinning behavior of single bubbles rising through oil systems. A mechanical syringe pump was used to reliably produce bubbles in a liquid pool which were then tracked using high speed imaging. Once at the surface, both fluorescence and interferometry techniques were employed to observe the bubble film, measuring drainage rates, film thinning, anti-foam bridge formation, and tracking bubble rupture time. The efficiencies of different rupturing mechanisms were compared across a variety of antifoams and liquid systems, providing a greater insight into the selection of additives and the formulation of lubricants for specialized applications.

4:40 pm - 5:00 pm
4308234: Running in Procedures for Grease-lubricated Bearings: Impact on Grease Ageing
Gabriel Calderon Salmeron, Sergei Glavatskih, KTH Royal Institute of Technology, Stockholm, Sweden; Johan Leckner, Axel Christiernsson Int. AB, Nol, Sweden

Grease ageing impacts the frictional performance and service life of rolling bearings. Most of the grease ageing occurs within the first hours of operation, during the churning phase when the lubricant redistributes within the bearing. The ageing extent in this phase is influenced by the operational conditions, such as rotational speed. This raises the question of whether different running-in procedures (speed profiles) can reduce the level of grease ageing.
This work studies the effects of two distinct running-in procedures on two widely used greases: lithium complex and polyurea. Ageing is assessed through changes in the grease's rheological properties, with samples collected from both the bearing shoulders and raceway regions. The findings indicate that the choice of running-in procedure should be tailored to the thickener type to minimize grease degradation. These insights suggest a way to optimize running-in procedures in industrial applications based on grease formulation.

STLE JAST Early Tribology Symposium II

Session Chair: Kyle Schulze, Auburn University, Auburn, AL

2:00 - 2:20 pm
4236493: Quantification of Strain Distribution in Rubber Bulk During Friction Using Synchrotron
Toshiaki Nishi, Sintaro Kurano, Ryosuke Ueda, Xiaoyu Liang, Wataru Yashiro, Takeshi Yamaguchi, Tohoku University, Sendai, Miyagi, Japan

Slip resistance for vehicle tires and shoes is important for preventing traffic and slip-and-fall accidents. In both cases, rubber treads are mounted to ensure the required slip resistance. Due to the low elastic modulus of rubber, the generation of friction force is accompanied with large strain. Regardless of adhesion, hysteresis, and plowing terms, it would be meaningful to understand and design the strain distribution of rubber bulk during friction. Although the strain distribution in rubber has been eagerly investigated based on numerical simulation, it is difficult to experimentally quantify it. The purpose in this study is to experimentally clarify the strain distribution in rubber bulk during friction against one resin sphere by using X-ray. The experiment was conducted in a synchrotron radiation facility (SPring-8) to ensure high intensity of X-ray. In result, the quantification of strain distribution in rubber bulk was experimentally completed.

2:20 - 2:40 pm
4273153: Insights into the Fundamental Mechanisms of Ultralow Wear PTFE Composites
Kylie Van Meter, Sandia National Laboratories, Albuquerque, NM; Brandon Krick, Florida State University, Tallahassee, FL

Polytetrafluoroethylene (PTFE) is a thermoplastic polymer known for its chemical inertness, vacuum compatibility, high-temperature stability, and low coefficient of friction (<0.1). However, unfilled PTFE suffers from high wear rates (~10^{-4} mm^3/Nm) and is prone to creep, limiting its use in engineered components. Incorporating filler materials into PTFE to create composites can enhance wear resistance by 10 to 100 times, with reductions of up to 10,000 times with the right fillers. These “ultralow wear” composites experience minimal height loss of less than ~30 μm over 50 km of sliding. This talk will explore the fundamental mechanisms behind the significant improvement in wear resistance of PTFE composites, including 1) crack propagation prevention, 2) mechanochemical changes at the sliding interface, and 3) modifications of the sliding interface through filler accumulation and tribofilm reinforcement.

2:40 - 3:00 pm
4233118: Laser Micro Texturing for Enhancing the Friction Between Metal Surfaces
Yosuke Tsukiyama, Niigata University, Niigata, Japan

The laser micro texturing is widely used to enhance the mechanical properties and tribological properties. Although it is well-known that the shallow dimple patterns significantly improve the lubrication properties, the effect of micro protrusions on the friction has not been studied much yet. Our objective is to clarify the effect of micro protrusions formed on the metal surfaces on the high friction. In this study, the micro protrusions are made by nano second and Q-switched laser pulses. The laser is pulsed and scanned over the metals such as steel, Titanium and Aluminum alloy surfaces at specific intervals to form an array of micro protrusions. The friction between the laser processed surface against a counter surface showed more than two times as high as friction of as-polished ones. The effect of the laser irradiation on the apparent hardness of the protrusions

was considered as either heat effect and/or shape effect.

3:00 - 4:00 pm - **Exhibitor Appreciation Break**

4:00 - 4:40 pm
4276243: Active Matter and Tribology: The Conundrum of Establishing Mechanical Models to Complex Systems
Kyle Schulze, Emily Guo, Auburn University, Auburn, AL; Thomas Angelini, Steven Chisolm, University of Florida, Gainesville, FL

The need to understand our biology as a material is clear: health is directly related to the environment and our body's response to external stimuli. However, for engineers living systems add an interesting wrinkle to our analytical tools, namely that they are composed of agents that consume energy and are not in thermal equilibrium. The cells within our bodies behave not unlike schools of fish or flocks of birds, they can all signal each other and move collectively or independently. Understanding how these motions are affected by the degree and rate of compressive loading (the most common condition a cell experiences) and in turn affect the mechanical performance of the tissue as a whole will hopefully lead to new health interventions. Here we explore the effects of rate and degree of pressure applied to cell monolayers in situ and resulting effects on mechanical performance.

Bonus1 Courtland

Bonus Program: Career Pathways Panel Discussion

5:15 – 6:15 pm

Join STLE for a panel discussion that delves into the diverse career paths of professionals who have successfully transitioned between industry and academia. Our distinguished panelists, each with a unique journey, will share their personal experiences, challenges, and achievements as they navigated these significant career shifts. This event aims to provide attendees with a deeper understanding of the motivation behind such transitions, the skills and mindset required, and the impact these changes have had on their professional and personal lives. Whether you're considering a move from industry to academia or vice versa or simply interested in learning more about the dynamic career landscapes, this panel will offer valuable perspectives and practical advice to guide you on your own career path.

Lubrication Fundamentals I

Session Chair: Ashish Jha, Chevron, Richmond, CA
Session Vice Chair: Xin He, Syensqo, Levittown, PA

8:00 - 8:40 am
4201731: Unusual Lubricity and Lubrication Mechanism of CO2 Under Severe Tribological Conditions
Ali Erdemir, Seungjoo Lee, Cagatay Yelkarasi, Texas A&M University, College Station, TX; Hitoshi Washizu, Ryuichi Okamoto, University of Hyogo, Kobe, Hyogo, Japan

Carbon dioxide (CO2) is one of the largest contributors to climate change, nearly accounting for over 75% of the global greenhouse gas emissions. In this work, combining comprehensive tribological tests with surface analytical studies, we confirmed that CO2 can reduce friction and wear by orders of magnitude below those observed in ambient air. Surface and structural studies confirmed the formation of carbon-rich tribolayers on rubbing surfaces when sliding occurs in a CO2 environment. Computational simulations revealed that CO2 can decompose under the influence of high pressure and shear of sliding test and thus turns into a carbon-rich tribofilm. Initial test results under lubricated contacts also look very promising. Overall, our work shows how an environmentally harmful gas like CO2 can be turned into an environmentally friendly lubricant for severe tribological applications.

8:40 - 9:00 am
4201472: Importance of Contamination Control Within Zinc-Containing Hydraulic Fluids
Rachel Drewitt, Afton Chemical Ltd, Bracknell, Berkshire, United Kingdom

Contamination of hydraulic fluids has been an end user concern for a number of years; with water identified as the greatest concern within the majority of applications. Understanding both the direct and indirect technical challenges contamination can cause in the field is key to developing a robust hydraulic fluid which provides reassurance and confidence to end users.
The ISO 13357 filtration tests are one of the key industry accredited methods in assessing hydraulic fluid performance in the presence of water. By further developing these filtration tests it is possible to better define potential failure modes which can then be related to the field. A key learning from this being able to link test data to in field failures and subsequently how formulation style can minimize these indirect challenges caused by water contamination.

9:00 - 9:20 am
4199496: Reactive Molecular Dynamics Simulations of Antioxidants
Shihab Ahmed, Ashlie Martini, University of California Merced, Merced, CA; Stefan Eder, Nicole Dörr, AC2T research GmbH, Wiener Neustadt, Austria

Antioxidants play an important role in inhibiting oxidative degradation of lubricants. However, their mechanisms are not fully understood, which inhibits the development of new, potentially environmentally friendly additive chemistries. To address this, reactive molecular dynamics simulations were used to investigate the mechanisms by which antioxidants inhibit the oxidation of polyalphaolefin base oil through radical scavenging. Key parameters, such as the onset of scavenging activity and scavenging efficiency, were analyzed to evaluate the oxidation inhibition performance of commercially available and potential new antioxidant chemistries. We also

developed a semi-automated approach for identifying reaction pathways from the simulations to clarify how radicals are scavenged by the antioxidants. The findings reveal correlations between molecular features and radical scavenging mechanisms and provide a computational framework for broader investigation of oxidation inhibition processes.

9:20 - 9:40 am
4181729: Achieving Superlubricity in Water-based Lubricants Modified with Potent Corrosion Inhibitors
Xiaoman Wang, Alex Love, Zaid Al Hassan, Q. Jane Wang, Yip-Wah Chung, Northwestern University, Evanston, IL; Xiaoqian Wang, Ning Ren, Valvoline Global Operations, Lexington, KY; Jaylin Trice, Louisiana State University, Baton Rouge, LA

While water-based lubricants can achieve low-friction performance, even reaching the superlubricity regime (friction coefficient ≤ 0.01), they also introduce significant risk of corrosion in metallic systems. In this study, we addressed this issue by using aqueous glycerol solutions as the base fluid, supplemented with three corrosion inhibitors. Tribological tests on a mini-traction machine (MTM) revealed that these additives maintain the same ultralow friction performance under identical loads and rolling speeds as the aqueous glycerol solutions alone. Moreover, corrosion tests followed by modified ASTM D1384 showed that WB-4 with potent corrosion inhibitor provided excellent protection against corrosion in cast iron, steel, copper, and brass, compared to glycerol solutions without additives (WB-1). These results indicate that water-based lubricants, when combined with effective corrosion inhibitors, can provide both ultralow friction and enhanced corrosion protection.

9:40 - 10:00 am
4199290: Asphaltene Solvency of a Marine Trunk Piston Engine Oil – A Solution
Ramanathan Ramaswamy, Sathyam Reddy, Anil Bhardwaj, Indian Oil Corporation R&D Center, Faridabad, Haryana, India

This abstract describes the studies conducted on a marine lubricant formulation with various polar additives and surfactants to assess their effectiveness in dissolving asphaltene contaminated to a marine lubricant in a marine engine. Screening method for assessing the asphlatene solvency is an in-house test method named ‘filterability test.’ The test was conducted by mixing the measured quantity of Heavy Furnace Oil with marine oil formulation at room temperature and thermal ageing at 100 °C for 24 hrs followed by immediate filtration of weighed quantity of aged mixture. A test was conducted against industry reference oil. Candidate blends with special additives were subjected to thermo-oxidation evaluation to assess their effect on oil deterioration. The special additives are observed to be non-detrimental w.r.t thermal & oxidative degradation of the base line formulation. Additives which have aromaticity and polar functional group have yielded excellent results w.r.t asphaltene solvency.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4190006: Atomistic Insights into Friction and Wear Mechanisms of PTFE and its Synergy with PEEK
Thomas Reichenbach, Stefan Peeters, Gianpietro Moras, Michael Moseler, Fraunhofer IWM, Freiburg, Germany

PTFE is a widely used solid lubricant with high chemical stability and temperature resistance. However, its low wear resistance limits its applicability in highly-loaded contacts. A possibility to extend the lifetime of PTFE lubrication is by mixing PTFE with other polymers that are more resistant to wear, such as PEEK.

In this contribution, I will first summarize our current understanding of the friction, wear and transfer mechanisms of PTFE as obtained by molecular dynamics simulations. Afterwards, I will discuss how physically, and chemically mixed PTFE/PEEK composites can exhibit friction values as low as those obtained with PTFE alone, while strongly reducing the lubricant's wear. Our simulations indicate that the former property originates from shear localization within crystalline PTFE layers, while the latter is enabled by anchoring PTFE to PEEK via physical or chemical interactions.

11:00 - 11:20 am
4205713: Insights Into Synergistic Workings of Additives Improving Engine Cleanliness Performance of Lubricant Oils
Devin Wall, Ashish Jha, Felix Kha, Allan Isenberg, Matthieu Decuupere, Sandy Lemesle, Chevron Oronite, Gonfreville l'Orcher, France

As internal combustion engine designs continue to evolve, driven by the pursuit of improved fuel efficiency and enhanced power output, the demands placed on lubricating oils have reached unprecedented levels. These advancements in engine technology necessitate lubricating oils that can maintain engine cleanliness under more stringent operating conditions. This presentation will delve into the mechanistic insights of component synergies, exploring how various components within the formulations interact to meet these elevated performance standards. By understanding these synergies, we can develop lubricating oils that not only meet but exceed the challenges posed by modern internal combustion engines, ensuring optimal performance and longevity.

11:20 - 11:40 am
4201600: On the Effects of Reaction Order When Using the Arrhenius Equation to Estimate Lubricant Life.
Paul Shiller, FirstPower Group, LLC, Twinsburg, OH

Extrapolating lubrication life from one temperature to another using an Arrhenius relationship likely assumes first-order kinetics. The literature does not speak to the significance of this assumption. This paper presents the results of testing model and fully formulated lubricants by differential scanning calorimetry and thermogravimetric analyses. From these results, the reaction orders of hydrocarbon lubrication oxidation are calculated, along with activation energies. The assumption of first-order kinetics versus higher-order reaction kinetics is discussed.

11:40 am - 12:00 pm
4202292: High-Pressure Viscometry of ISO Viscosity Grade Mineral Oils
David Casey, William Hannon, Rachel Wasik, Timken, Munroe Falls, OH

Lubricant properties are required for elastohydrodynamic modeling. These properties are seldom available due to the paucity of high-pressure laboratories, and the labor it takes to generate sufficient data. Prior works addressed Aerospace, Industrial, Automotive lubricants. This work focuses on mineral oils and the transition of properties across seven viscosity grades. High-pressure density and viscosity modeling parameters are tabulated for ISO VG 22, 32, 46, 68, 100, 150 and 220. These single sourced lubricants only include basic rust and oxidation inhibitors. The standard deviation residuals, of density and low-shear viscosity models, are less than 0.25 and 6.65%, respectively. Integration of the low-shear viscosity models yields temperature dependent reciprocal asymptotic iso-viscous pressure-viscosity coefficient models. Conclusionary observations note that although the viscosity grades are ordered by reference viscosities, interpolation of high-pressure parameters can be misleading.

Commercial Marketing Forum V

Session Chair: TBD

8:00 - 8:20 am
4307282: LANXESS Hybrid PU-CSC Innovative Grease Technology. A focus on CV-Joint Grease Development for Electric Vehicles.
Wayne Mackwood, LANXESS Canada Co/Cie, Ajax, Ontario, Canada

LANXESS has patented grease technology, Hybrid Polyurea-Calcium Sulfonate Complex or Hybrid PU-CSC. This technology marries the performance of CSC grease (EP, AW, CI, Stability) with that of PU grease (antioxidation) in a stable, high-performance platform. As the inventor of CSC grease, LANXESS' G-2000 series has shown impressive performance in a range of demanding applications. Building on this expertise, it has created PU-CSC formulations for CV-Joints in electric vehicles. EV CV-Joints, particularly in China, see load and torque beyond that of traditional ICE CV-Js; current grease for ICE is not meeting those needs. This has led to the creation of several formulations using the PU-CSC platform. These products have excellent EP, AW, life, friction, and noise. Two are commercial and the enhanced versions are in road trials. This talk will review the benefits of this novel technology, the challenges in lubricating EV CV-Joints, and the options being developed at LANXESS.

8:20 - 8:40 am
4301805: LANXESS Additin® High Performance Additive Package: Flexible Treat Rate Solution for Top-Tier Ash Hydraulic Fluids
Kevin DiNicola, LANXESS Corporation, Naugatuck, CT; Dana Kupenova, LANXESS Switzerland, Frauenfeld, Switzerland; Carsten Friedrich, LANXESS Deutschland GmbH, Mannheim, Germany

The LANXESS industrial additive package portfolio caters to a wide range of applications, supported by manufacturing facilities on three continents, including one in the US. With extensive expertise in additive technologies and in-house hydraulic pump test rigs (e.g., Bosch and Parker), our versatile formulation solutions enhance efficiency, streamline handling, and reduce system costs. Hydraulic fluid formulators need adaptable and technologically advanced solutions to meet ever-evolving performance benchmarks. Additin® RC 9200 N, a premium hydraulic fluid package, offers a highly flexible treat rate solution designed to meet these stringent demands. Approved by Bosch, Parker, and other leading OEMs, it performs at a treat rate of just 0.6%. At a treat rate of 0.45%, it meets ASTM-level performance requirements, while a treat rate of 0.85% accommodates customers seeking extended TOST and/or high zinc levels.

8:40 - 9:00 am
4280010: ADEKA CORPORATION: Pioneering Lubricants for the Next Generation, ADEKA's Organic Molybdenum Compounds and Other Functional Materials
Kenji Yamamoto, ADEKA Corporation, Tokyo, Japan; Tatsuya Niijima, ADEKA USA Corporation, Hasbrouck Heights, NJ

ADEKA CORPORATION, a key player in the lubricant industry for over 50 years, has been manufacturing organic molybdenum compounds, ADEKA SAKURA-LUBE since the 1970s. Highly efficient lubricants are more necessary than ever, as new vehicles must be more resource-conserving, and enthusiasts of traditional premium vehicles pay close attention to keeping their machines in optimal condition. Our unique organic molybdenum compounds, which enable low friction and high thermal stability, have become an increasingly essential option for meeting the

latest lubricant requirements.
We will introduce the latest application examples of various organic molybdenum compounds. In addition, we will present aromatic phosphate esters, ADEKA ECOROYAL AWP-3000, in which the TPP content has been controlled to less than 1 mass%, in response to tightening regulations in the US and Europe.

9:00 - 9:20 am
4301342: Afton Chemical: How to Address the Diverse and Intense Industrial Gear Needs with Your IGO Lubricant Portfolio
Laurie Hulton, Afton Chemical, Richmond, VA

Since the industrial revolution of the 18th century, a multitude of equipment, tools and machines have been used to improve all aspects of industry around the world. Today, the market demands more: reduce total cost of ownership, address diverging OEM requirements, deliver efficiency beyond incumbent lubricants, and offer base oil flexibility. All of this is at the foundation of addressing the complexity of industrial gear oil needs and helping customers differentiate their product offerings in meaningful ways. It is no surprise that simplification would be sought after in today's environment. Join us to discuss what the industrial market is seeking and how Afton can help with broad coverage and flexibility to efficiently address your customers' needs.

9:20 - 9:40 am
4205415: Advanced Chemical Concepts: Soluble Bases and Water-Based Rust Preventative Technologies for the Metalworking Industry
Christopher Monday, Joe Eldick, Advanced Chemical Concepts, Kentwood, MI

Advanced Chemical Concepts has been designing and developing new products for presentation to the metalworking community. In this presentation we focus on two important types of additives: New types of soluble bases: The new soluble bases deliver very-high performance. They provide excellent emulsification and stability in soft and hard water, multi-metal lubricity, corrosion protection for ferrous metals, stain resistance for non-ferrous metals and generate very-low foam, even in high pressure operations. The above soluble bases are based on readily available raw material. They are free from sulfonates, PIBSA and TOFA. Water Based Rust Preventives: The timely introduction of water-based rust preventives will fill a growing need in the market. ACC has developed water extendable rust preventatives that protect ferrous metals in harsh environments as supported by our salt fog and humidity cabinet testing.

9:40 - 10:00 am
4278048: BYK: Managing Foam, Greases for High-Temperature Applications, and Particle Stability with BYK
Maximilian Boehmer, BYK-Chemie GmbH, Wesel, North Rhine-Westphalia, Germany

The industrial lubricants sector faces critical challenges, including managing foam, manufacturing greases for high-temperature applications, and solid particle stability. BYK understands these challenges and offers a comprehensive portfolio of additive solutions tailored for this market. Our defoamers effectively manage foam in lubricants, hydraulic fluids, and metalworking fluids across both oil-based and water-based applications. BYK also offers organoclays that are designed to increase the viscosity and stability of lubricating greases, ensuring optimal performance under various conditions. Additionally, our dispersing additives stabilize solid particles such as graphite, MoS2, and boron nitride within lubricating oils. They ensure perfect particle dispersion, prevent sedimentation, and maintain viscosity under high loads. BYK provides precisely tailored solutions to the diverse challenges of the lubricants market, delivering reliable performance and stability.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4298974: SEQENS: New Extreme Pressure Additives for More Sustainability in the Lubricant industry
Xavier Semery, SEQENS, Porcheville, Ile de France, France

Relying on its expertise, SEQENS is supporting its customers by extending its Extreme Pressure additives range with new sulfurized esters: SULFAD® 1526 E, SULFAD® 1528 E, SULFAD® 1529 E. This new range of SULFAD has been specifically developed to have more chemical compatibility with group I, II, III, IV and V base stocks, by a tight selection of the raw materials and an optimized manufacturing process. Therefore, from bio sourced and biodegradable origin, these new SULFAD are the best candidates for use in environmentally acceptable lubricant (EAL). They can ideally be used for formulating metalworking fluids dedicated to medium to heavy duty applications and for greases additivation. SEQENS is a global partner in health, personal care, and specialty ingredients. We empower innovation to bring the best solutions to our customers, with a constant concern for sustainability.

11:00 - 11:20 am
4301792: BASF Corporation: Synthetic Esters: Meeting Efficient and Sustainable Immersion Cooling Fluid Demands
Tracy Gadkari, BASF Corporation, Florham Park, NJ; Jan Strittmatter, BASF SE, Ludwigshafen, Germany

Demand for dielectric fluids in thermal management is rapidly growing, driven by the need for efficient heat dissipation, superior thermal conductivity, and effective electrical insulation properties in various immersion cooling applications. Growing emphasis on energy conservation and sustainability further fuels the market's growth trajectory. Low-viscosity, synthetic ester-based dielectric fluids emerge as a compelling choice, offering customizable options that cater to diverse application requirements. These fluids are characterized by high thermal stability, efficient heat transfer capabilities, and excellent dielectric strength. Synthetic esters have proven to provide exceptional lubricity properties, meeting the required specifications in e-driveline fluids. They exhibit remarkable safety features, with low toxicity and volatility. Further, synthetic ester-based fluids are environmentally friendly, biodegradable, and contribute to overall water and energy consumption reduction.

11:20 - 11:40 am
4300858: Sasol: MARLOX RT's for Use as Emulsifiers in Metalworking Fluids
Viktor Kapuvari, Simon Morton, Yi Xi, Sasol Chemical, Houston, TX

Modern metalworking fluids demand high precision, performance, and efficiency, alongside a focus on environmental sustainability. This drives the need for versatile surfactants to help fluid manufacturers and users meet evolving expectations. SASOL's MARLOX RT range of Alkoxylates, are excellent surfactants for use in Metalworking Fluids formulations. These outstanding surfactants will aide in product stability and improve emulsion characteristics. This product range is characterized by the following useful properties: high wetting ability and surface activity, good hard water stability, foam control, and favorable environmental characteristics, advantageous emulsifying power and user-friendly viscosity and storage behavior. These characteristics make these products an ideal raw material building block for todays advanced Metalworking Fluids.

11:40 am - 12:00 pm
4294055: Evonik Corporation; Antifoams and Wetting Agents: Revolutionizing Lubricants
Adam Rice, Evonik Corporation, Richmond, VA

Discover how Evonik's advanced antifoams and wetting agents enhance the performance of lubricants across various mediums. This presentation explores the unique properties and applications that make these additives essential for efficient, reliable, and sustainable lubrication.

5C Hanover D

Contact Mechanics I

Session Chair: Shuangbiao Liu, Northwestern University, Evanston, IL
Session Vice Chair: TBD

8:00 - 8:40 am
4190500: The Prediction of the Coefficient of Restitution Between Impacting Spheres and Finite Thickness Plates Undergoing Elastoplastic Deformations and Wave Propagation
Itzhak Green, Retired, Atlanta, GA

This work fuses two distinct models that predict the coefficient of restitution. That involves the interplay between elastic waves generation and elastoplastic deformations. This resultant model is then compared to recent experimental and FEA results reported by Higgs, et al. The comparison is performed for a wide variation of material property combinations, plate thickness to sphere diameter ratios, and impact speeds. It is shown that a straightforward use of the model herein predicts very accurately the apparent coefficient of restitution.

8:40 - 9:00 am
4183718: Asperity Pressures and Deformations in Elastic-plastic Rough Surface Contacts
Keita Inose, Amir Kadiric, Imperial College London, London, United Kingdom

Asperity pressures and deformations in a rough surface contact are of fundamental concern in understanding most tribological phenomena. Since 1980s, several numerical models have been developed to predict them. Such models rely on crude assumptions as to the maximum plastic pressure that can be caried by an asperity. These assumptions are known to be questionable but are necessary given our lack of understanding of asperity plastic behaviour. To help address this, this study uses a combination of experimental and numerical approaches to observe and investigate the plasticity at asperity level in a rough contact of several metallic materials and over a range of roughness. The results show that asperity plastic behaviour is strongly influenced by the initial asperity slope, and that contrary to common modelling assumptions, asperities can carry pressures in excess of bulk material hardness, a behaviour termed ‘asperity persistence’.

9:00 - 9:20 am
4205467: An Investigation of Axisymmetric Elliptical Indentation
Robert Jackson, Auburn University, Auburn, AL; Shuangbiao Liu, Northwestern University, Evanston, IL

Surface features, asperities, and indenters can vary greatly in shape. This variation in shape can influence the mechanical behavior of these features when they come into contact with other surfaces. This work investigates the deformation of an axisymmetric elliptical geometry using a fully plastic slip line theory technique. The predicted behavior differs significantly from other commonly

assumed feature geometries such as spheres or cones. The ratio between the average pressure (i.e., hardness) to yield strength ratio varies in an interesting way. The results are also compared to finite element predictions.

9:20 - 9:40 am
4204711: Phase-Field Simulations of Capillary Interactions Between Rough Surfaces
Yizhen Wang, Martin Ladecky, Lars Pastewka, University of Freiburg, Freiburg, Germany

At a small enough length scale, surfaces are always rough, regardless of whether they are generated by nature or via artificial process. When two such surfaces are placed close enough, the water molecules in the humid air are absorbed and hence form capillary bridges. Theories for adhesive interactions typically use simple cohesive laws, which are good models for Van-der-Waals interactions but may not be appropriate for capillary adhesion. We here present a phase-field model that explicitly represents water present between two contacting rough interfaces. We show results obtained with this model on synthetic, computer-generated, self-affine rough interfaces. In quasi-static simulation, we observe the merging and splitting of droplets under the normal and shear movement of the interfaces. The overall force is dominated by the perimeter of the droplet, indicating the importance of a detailed understanding of droplet morphology.

9:40 - 10:00 am
4199495: Numerical Simulation of Fast Contact Interface Dynamics
Francesco Massi, Sapienza University, Rome, Italy; Laurent Baillet, Institut des Sciences de la Terre, Grenoble, France; Killian Hollebeke, Anissa Meziane, Université Bordeaux, Bordeaux, France; Mathieu Renouf, Universite De Montpelllier, Montpellier, France

Whenever dry contacts occur, the interactions between surface asperities are favored sites for local ruptures and impacts, acting as sources of acoustic waves propagating along the interface and within the volume. Simulating such phenomena can provide meaningful information on the origin of friction-induced vibrations and the dynamic vibrational response of solids under frictional contact. On another side, waves propagating at the interface can lead to fast transient local evolutions of velocity and stress fields, which need to be further investigated. Simulating such phenomena needs to overcome several difficulties, due to the characteristic space (dimensions of the wavelengths) and time (wave propagation velocities) resolutions, together with the nonlinear contact interaction. This work focuses on recent advancements in simulating fast transient contact dynamics and its role in the evolution of dry contacts.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4200886: Experimental Setup for Nano-Scale Surface Topography and Contact Mapping
Gage Olson, Hamid Ghaednia, Cedars-Sinai Medical Center, West Hollywood, CA

We have developed a new experimental setup for 3D scanning of contact regions using FTIR (Frustrated Total Internal Reflection). The setup uses acrylic as the contact surface and LEDs of 11 different wavelengths trap photons inside the acrylic as objects are pressed against it. Force and displacement are measured using an impedance-based force sensor and Digital Image Correlation. A camera records contact areas at various force levels and LED wavelengths, while a black box covers the setup, preventing external interference. Macro-scale tests involve pressing rubber balls of various properties, while nano-scale tests use 3D-printed samples with known roughness. This low-cost and easily integrable method creates 3D maps of contact regions for comparison with existing contact models. The setup enables more accurate measurement of real contact area, which can significantly enhance our understanding and optimization of friction, wear, and

lubrication in the field of tribology.

11:00 - 11:20 am
4200687: Predicting Load Variation in an Elliptical Contact Overrolling Surface Cavities
Marco Van Zoelen, SKF, Houten, Netherlands

A model is developed to predict load variation in an elliptical contact as it overrolls small surface cavities. Starting from the classic solution for a circular flat punch on an elastic half-space with a central hole, an analytical solution for a spherical cavity in an elliptical contact is derived, showing load independence from cavity position. This solution is validated using a multi-grid dry contact solver.
Contact simulations were done to extend the model to multiple cavities, including clustering scenarios, predicting the load relative to the nominal load. Results indicate a non-linear increase in this load due to cavity clustering. Derived engineering formulas predict the load as a function of the Hertzian contact parameters, the number of cavities, and the cavity radius and depth.
Finally, the model's application to obtain contact load variation is demonstrated, providing input for dynamic simulations in systems like rolling bearings.

11:20 am - 12:00 pm - **Contact Mechanics Business Meeting**

5D Hanover E

Tribochemistry I

Session Chair: Cinta Lorenzo Martin, Argonne National Laboratory, Argonne, IL
Session Vice Chair: Santiago Lazarte, Florida State University, Tallahassee, FL

8:00 - 8:40 am
4205884: How Does Friction Govern Chemistry? - "Catalysis" by Shear?
Seong Kim, Pennsylvania State University, University Park, PA

Tribochemistry deals with chemical reactions facilitated by interfacial friction (or shear). At sliding interfaces, unconventional chemical reactions that do not occur in typical thermal conditions are often observed. When reaction yield or rate is measured as a function of shear stress (calculated from the applied load and friction coefficient) and plotted onto a semi-log graph, the slope is related to so-called 'activation volume.' Although the activation volume can be readily determined experimentally, its physical meaning is still debated. We have investigated the shear-induced polymerization reaction of various types of organic molecules under vapor-phase lubrication (VPL) conditions. In this talk, experimental and computational evidence supports the hypothesis that the deformation of reactant molecules from their equilibrium geometry is the main driving force for shear-induced mechanochemical chemical reactions.

8:40 - 9:00 am
4175007: Advancing Gear Oil Insights - Tribofilm and Subsurface Correlation
Ashutosh Gupta, Allan Matthews, David Matthews, University of Manchester, Manchester, United Kingdom; Ieuan Adams, BP Technology Centre, Pangbourne, United Kingdom

As bearing failures are becoming common inside the wind turbine gear box, this paper focused predominantly on the hardened AISI 52100 steels used as bearing material. Gear oils are particularly designed to provide lubrication and can lower the generation of heat and friction while improving gear performance, which makes them the most significant element determining the

lifespan of wind turbine bearings. The present study investigated the effects of molybdenum and ashless based anti-wear additives in the gear oils on the tribological performance of the contact surfaces and the subsurface changes occurred under reciprocating-sliding conditions. The results demonstrate that low-friction molybdenum tribofilms generated during chemical activation at appropriate bulk oil temperature are primarily responsible for improving surface-additive interaction when compared with ashless based gear oil where the formed polar molecules of phosphorus and sulphur act as a friction modifier.

9:00 - 9:20 am
4188416: The Effect of Lubricity of Calcium Sulfonate on ZnDTP and MoDTC
Yumi Hayashi, Sumitomo Heavy Industries, Ltd., Kanagawa, Japan; Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Tokyo, Japan

This study investigates the effects of calcium sulfonate on the lubricity of zinc dialkyldithiophosphate (ZnDTP) and molybdenum dithiocarbamate (MoDTC). ZnDTP and MoDTC are known for their low-friction properties and may exhibit unexpected synergistic or competitive effects when combined with other additives. In this study, we investigated the effect of calcium sulfonate on the combined use of ZnDTP and MoDTC, focusing particularly on their wear behavior. Friction tests revealed that calcium sulfonate improved antiwear performance. XPS and AFM analyses showed that the tribofilm formed with calcium sulfonate contained CaCO3, which increased film density and enhanced antiwear properties. The aim of this study is to clarify and understand the mechanism of action of these additives through tribofilm formation, wear processes, and surface analysis. These findings provide valuable insights into optimizing lubricant formulations for improved antiwear performance.

9:20 - 9:40 am
4194171: Analysis of the Effect of Phosphorus/sulfur Additives' Concentration on Wear Phenomena using AE Measurements and Study of Additive Reaction Mechanisms
Miho Morita, Takuma Tsuchiya, Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Katsushika, Tokyo, Japan; Takehisa Sato, Technical Committee on Additive Technology for JAST, Funabashi, Chiba, Japan

Recently, the viscosity of oil has been reduced, resulting in thinner oil films and an increased risk of damage to sliding surfaces. It has been reported that the combined use of phosphorus-based (P-based) additives, which are expected to provide anti-wear performance, and sulfur-based (S-based) additives, which are expected to provide anti-seizure performance, improves anti-wear performance compared to when using individual additives. In this study, we propose a comprehensive verification method for additive concentrations by friction tests using a variable additive concentration system as an evaluation method for efficiently determining the optimal combination of P-based and S-based additives. In addition, we perform in-situ evaluation of the damage state of the friction interface by measuring acoustic emission. Together with the results of surface condition observations, we consider the effect of additive concentration changes on friction and wear properties and their mechanisms.

9:40 - 10:00 am
4200800: Interfacial Ice-like Layers Formed on the Two Contacting Silica Surfaces under Water
Yuguang Cai, Joshua Melendez-Rivera, James Batteas, Texas A&M University, College Station, TX; Brandon McClimon, Robert Carpick, University of Pennsylvania, Philadelphia, PA

The tribological properties between two contacting silica surfaces in water is investigated by employing an Atomic force microscope (AFM) tip to contact and slide on a silica surface. We find that the adhesion decreases with increasing loading stress, reaching a minimum at 2 MPa, after which adhesion slightly increases due to the expansion of the contact area by higher loading force.

At 2 MPa, the coefficient of friction (COF) changes from 0.15 to 0.03. Control experiments confirm that these transition behaviors are specific to aqueous environment and hydrophilic silica as the contact surfaces. Our findings suggest that an interfacial ice-like water layer forms on the hydrophilic silica surface in water. Only at pressures above 2 MPa do the measured values represent the true adhesion and friction between the hydrophilic silica surfaces.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4204362: Analyzing the Charge Transfer Mechanisms in Multiple Electrode Droplet Triboelectric Nanogenerators
Oliver Prendergast, Imperial College London, London, London, United Kingdom

Droplet-based triboelectric nanogenerators (TENGs) offer a sustainable solution for harvesting energy from moving water, generating alternating current through triboelectrification and charge transfer. By introducing an additional electrode to the traditional single-electrode configuration, we achieved a 7000% increase in voltage output. Building on this, we are now investigating the effects of electrode geometry, quantity, and placement in multi-electrode configurations and their impact on charge transfer mechanisms. These insights are key to scaling droplet TENGs for real-world applications and advancing the understanding of fundamental charge transfer processes in triboelectric nanogenerators.

11:00 - 11:20 am
4205138: Effect of Electric Fields on the Decomposition of Nanoconfined Lubricant Additives
Zhaoran Zhu, James Ewen, Daniele Dini, Imperial College London, London, United Kingdom

The increasing demands in electric vehicles (EV) has propelled advancements in lubricant technology for new operational environments under electric fields (EFs). However, the triboelectrochemistry mechanism at molecular scale during tribofilm formation are not well understood. Therefore, in this study, we perform nonequilibrium molecular dynamics (NEMD) simulations with a reactive force field (ReaxFF) [2] to study the effect of EFs on tributyl phosphate (TNBP) lubricant additives, in between two iron oxide surfaces, under nanoconfined [3] and sliding conditions. Meanwhile, two charge equilibration methods implemented in NEMD are also investigated and compared, known as QEq [4] and QTPIE [5]. These findings provide an atomistic understanding of the effect of EFs on lubricant additives' behaviours during the redox reactions. Results also suggest the potential discussions on influence on adsorption process before chemical reactions.

11:20 - 11:40 am
4204817: Molecular Assembly of Organic Fluorine Compounds on Water Using Molecular Dynamics Simulations
Hitoshi Washizu, Ryuji Hanano, Takehiro Kobayashi, Ryuichi Okamoto, University of Hyogo, Kobe, Japan; Takeshi Hasegawa, Kyoto University, Uji, Kyoto, Japan

Organofluorine compounds have been used as useful materials that exhibit a variety of excellent properties such as water-and-oil repellence, lubricity, and heat resistance, whereas the physicochemical basis for these properties have long been unclear. Recently the Stratified Dipole-Arrays (SDA) theory has been developed to explain the fundamental physical properties of organofluorides. According to this theory, by separating the physicochemical properties of organofluorides into single molecules and molecular assemblies, we can explain contradictory features such as water repellence and oil repellence. In this talk, we used molecular dynamics simulations to clarify the molecular assembly structure of organofluorides on water. Molecular structures for our study are molecules which a part of the alkyl groups of myristic acid is replaced

by perfluoroalkyl group. The equilibrium structure of 2D crystal and broken one are readily explained by the SDA theory.

11:40 am - 12:00 pm
4282972: Influence of Electrical Polarity and Current Density on Tribofilm Formation
Grigore Cernalevschi, Monica Ratoi, Brian Mellor, University of Southampton, Southampton, United Kingdom; Yuxue Cai, ESSO Deutschland GmbH, Hamburg, Germany

The passage of electrical current across a tribological contact transforms it into an electrolytic cell with positively (anode) and negatively charged surfaces (cathode) separated by the lubricant film. These surface polarities influence the interaction with lubricant additives, which are polar organic molecules dissociated in anion and cation moieties, and thus tribofilm generation and its characteristics. In this study, MTM tests were conducted in boundary lubrication conditions with a gearbox oil, in neutral/cathodic/anodic ball/disc configurations and at various current densities. The tribofilm was formed predominantly on the anode specimen (ball/disc) and its thickness and the COF in contact increased with current density. Both these factors influence the bearing life.

5E — Hanover F

Environmentally Friendly Fluids-Synthetics I

Session Chair: John Fang, Chevron Products Company, Richmond, CA
Session Vice Chair: Selim Erhan, Process Oils, Inc., Trout Valley, IL

8:00 - 8:40 am
4180141: Sustainability and Circular Economy in Lubrication
Michael Holloway, 5th Order Industry, Highland Village, TX

This paper explores the role of the lubrication industry in promoting sustainability and reducing environmental impact. The lubrication industry plays a critical role in supporting economic growth, but they also have a significant environmental footprint. As the world transitions towards a more sustainable future, this industry must adopt practices that minimize their environmental impact. This paper will explore the role of the lubrication industry's impact in promoting sustainability and circular economy principles. By adopting sustainable practices and embracing circular economy principles, the lubrication industry can contribute to a more sustainable future. This paper will provide valuable insights and recommendations for industry stakeholders to drive positive change.

8:40 - 9:00 am
4187411: Novel Antiwear and Antioxidant Additives with a Safe Toxicological Profile Designed for Lubricant Applications
Elio Piras, Gregoire Herve, NYCO, PARIS Cedex 08, France

Evolving regulations are shedding light on the true toxicity of various chemicals, particularly affecting performance additives. The search for effective, non-toxic additive chemistry remains a big challenge for the industry. Our work directly addresses this issue through a holistic approach that combines both modeling and biotesting of anti-wear and antioxidant additives. The outcome? High-performance, label-free lubricants, including greases, with superior safety profiles. The performance of our both safe polyaminic antioxidant and organophosphorus antiwear additives is demonstrated across several stringent applications, including gear oils, turbine oils, and greases. These additives exhibit enhanced thermal and tribological properties compared to existing market lubricants. This research offers new solutions to the formulators that meet both industry and

environmental needs.

9:00 - 9:20 am
4183754: Using Polyalkylene Glycols to Meet Today's Sustainability Needs in Industrial Lubrication.
Lauren Huffman, Cindy Liu, Qian Gou, Dow Chemical Company, Midland, MI

Polyalkylene glycols (PAGs) are well-known synthetic fluids for use in a wide variety of applications like hydraulic fluid, gear oil, compressor fluid, refrigeration lubricant and metalworking fluids. Today, PAGs are finding favor with those who need to meet sustainability goals without sacrificing performance. This talk will cover the use of polyaklylene glycols in sustainable applications for industry including food processing, marine, and mining operations. We will also address ways we are tracking important factors for sustainability, and approaches for using PAGs to address sustainability needs.

9:20 - 9:40 am
4187366: Making the Most of Neopolyol Esters in Non-Toxic, High Temperature Chain Oils
Siegfried Lucazeau, NYCO, Paris, France

High temperature chain oils may be exposed to temperatures exceeding 570°F. In such conditions, the best type of ester to respond to this challenge is neopolyol esters, as they show outstanding resistance to thermo-oxidation, less volatility than other base fluids, improved cleanliness, and fire safety. When designing a neopolyol ester, linear acids differ from branched acids from a performance standpoint. Designing esters for this application therefore consists in smartly combining linear and branched acids to balance volatility, resistance to degradation, cleanliness, and lubricity. In this process, it is important to understand the main tradeoffs. Additionally, formulating with selected antioxidants and metal passivators is essential to maximize the performance of neopolyol esters. Recent advances in formulation and molecular design now allow formulators to develop high performance, non-toxic high temperature chain oils, using carefully designed neopolyol esters and additives.

9:40 - 10:00 am
4202676: Performance Aspects of Novel and Sustainable Secondary Polyol Ester™ Technology
Martin Greaves, Jeff Dimaio, Zach Hunt, Michelle DiMaio, Ben Bergmann, VBASE Oil Company, Pendleton, SC

Synthetic esters are the most versatile of all common base oils used in our industry today. The inclusion of high levels of oxygen built into their molecular architecture has led to the creation of a novel family of Secondary Polyol Ester™ base oils. These oxygen-rich products offer some unique functionalities that enhance modern lubricant formulations. Their thermo-physical properties, in-built detergency and their excellent environmental performance will be presented. Concepts for using them as base oils or performance additives in industrial, marine and metalworking fluid formulations will also be highlighted. Their unique chemistry offers innovative solutions to developing new generations of sustainable lubricants.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4203653: Shear Stable Biobased Thickeners as Alternatives to High Viscosity PAOs in Synthetic Gear and Transmission Fluids
Kevin Duncan, Cargill, Snaith, United Kingdom

The demand for efficient lubricants that tolerate more duty cycles and reduce oil sump capacity is rising in both industrial and automotive sectors. This has increased interest in high-performing synthetic base oils and additives. Simultaneously, there's a push to increase the bio-based content of lubricants, which conflicts with the use of petroleum-based polyalphaolefins (PAOs). Ester-based shear stable thickeners offer a solution, providing excellent friction reduction and formulation efficiency while enhancing bio-based content across a wide viscosity range. This paper presents a 'design of experiments' approach to identify optimal product properties, enabling the development of high viscosity thickeners for ISO 68 industrial gear oil and EV transmission fluid formulations. Performance will be demonstrated through benchtop tribological tests and validated using industry-standard test rigs.

11:00 - 11:20 am
4205253: Chemical and Biological Upcycling of Plastic Waste into Mixed Ester Lubricant Base Oils
Jake Lilly, Battelle Memorial Institute, Columbus, OH

Global annual plastic production is approximately 400 million tons, and demand is projected to continue to increase production to an annual 1.1 billion tons by 2050. (Geyer et al. 2020) Chemical recycling technologies are emerging that offer promise to valorize plastic waste that would otherwise be landfilled, which we view as a rich and underutilized source of organic precursors for high value products, like lubricant base oils. Here, we present hybrid chemical and biological approaches for converting common consumer plastics like polyethylene (PE) and polyethylene terephthalate (PET) into aliphatic bis-esters and fatty acid esters, respectively. We report product composition, viscosity, and pour point data for various plastic conversion conditions. These conversion processes are being developed as mobile and low power valorization technologies in remote settings, but could also adapted for large scale manufacturing of lubricant oils from waste plastics.

11:20 - 11:40 am
4229195: Studies on the Thermal Stability and Kinetics of Bio-Lubricants Derived from Various Vegetable Oils
Majher Sarker, Kalidas Mainali, Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA

The non-biodegradability and toxicity of fossil-based lubricants present environmental problems, whereas biobased ones underperform due to low thermal stability. This study compared chemically modified vegetable and waste cooking oils to their regular versions to determine their bio lubrication potential. High-oleic soybean oil-HOSOY, regular soybean oil-RSOY, and waste cooking oil-WCO were chemically modified where isopropyl groups were attached to the fatty acid chains of the oils producing branched oils, b-HOSOY, b-RSOY, and b-WCO, respectively. Friedman methods calculated activation energies, reaction rates, and pre-exponential factors. Each modified oil had lower volatilization at onset temperature than non-modified samples in an oxidative environment, according to differential thermal gravimetric (DTG) measurement. Comparative kinetic tests showed that chemically modified oils were more thermoxidatively stable than unmodified oils.

11:40 am - 12:00 pm
4203097: Improving the Friction Modification & Wear Protection of Lubricants with Ester Technology
Matthias Hof, Emery Oleochemiclas GmbH, Duesseldorf, NRW, Germany

As lubricant demands continue to evolve, both original equipment manufacturers (OEMs) and end users are increasingly seeking solutions that enhance performance across a wide range of applications, including industrial equipment, automotive systems, metalworking operations, and specialty areas like food-grade lubrication. This presentation addresses the need for high-

performance lubricants capable of reducing friction and wear, thereby achieving key objectives such as increased efficiency, decreased energy consumption, extended maintenance intervals, prolonged equipment life minimized waste + emissions Multiple formulation technologies that leverage both existing and innovative base stock and additive chemistries are explored. By examining the tribological performance of pure esters and their blends with other components, we aim to provide insight into how these formulations can meet the stringent requirements of modern lubrication systems and contribute to improved operational effectiveness.

5F Courtland

Tribotesting I

Session Chair: TBD
Session Vice Chair: TBD

8:00 - 8:40 am
4179944: Development of New 4-Ball Load Ramp Test for Tribological Analysis of Lubricating Greases and Comparison to ASTM D2596
Jacob Bonta, Valvoline Global Operations, Lexington, KY; Dirk Drees, Lais Lopes, Pedro Baião, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium

In this study, a tribological analysis for lubricants is evaluated utilizing a programmable, variable load 4-ball machine. In the lubricants industry, the 4-ball tribological techniques are employed to evaluate lubricant's ability to protect against wear and extreme pressure. Recently, issues related to varied acceleration rate across machines have called into question the use of tests like ASTM D2596. Here a method for evaluation of the scuffing and seizure load of lubricants is presented. First, reference greases are developed for consistent behavior in testing. Second, each material is evaluated: test specimens are run-in at 40kg normal load for 1 minute followed by a fixed rate ramping normal load until failure or the maximum is reached. Finally, these data are compared to data from legacy 4-ball test machines in ASTM D2596. These data suggest this method may provide a comparable rapid tribological analysis, giving critical first guidance on lubricant material properties.

8:40 - 9:00 am
4237303: The New Electrified Tribometry Development for EV Fluid and Lubricants
Jun Xiao, Tushar Khosla, Vishal Khosla, Rtec-Instruments, San Jose, CA

The evolving fields of electric vehicles, wind turbines, and high-speed rail have intensified the need for high-performance lubricants and wear-resistant materials. Conventional tribological testing methods fall short in evaluating lubricant performance within electrified devices. Advancements in research on lubrication and materials under electrified conditions enable the development of optimized formulations that deliver improved stability, durability, and prolonged service life for critical components such as motors and bearings, thereby enhancing system reliability and efficiency.
To address these demands, this presentation introduces several innovative testing methodologies specifically designed for evaluating friction and lubrication under electrified conditions. These methods provide valuable insights into the performance of materials across various applications, driving progress in electrified technologies.

9:00 - 9:20 am
4205233: Mission SLIMpossible - New Analysis Tools for Robust RGB Colorimetric Interferometry of Additive and Lubricant Films
Alexander MacLaren, Matthew Smeeth, PCS Instruments, London, United Kingdom

The Spacer Layer Imaging Method (SLIM) is a widely-used technique for the optical measurement of the thickness of thin lubricant and additive films to nanometer range and resolution. This study, following recent advances in colorimetric analysis of the SLIM interferogram, applies these new methods to experimentally quantify the change in outlet constriction shape in EHL point contacts at high sliding speeds. The influence on film thickness of high entrainment speeds is explored, with important implications for the design of components with large kinematically predefined slide-roll ratios such as gears. The use of new software tools which allow easy-to-use, explicit and robust analysis of large datasets is demonstrated, and salient considerations for optimal accuracy regarding both experiment and analysis are discussed.

9:20 - 9:40 am
4205037: Effect of Current Changes on Wear Values for Different Formulated Lubricants by Tribo-testing
Ameneh Schneider, Optimol Instruments, München, Germany

The electrical current passing through a lubricant can vary depending on the application. In tribological testing, the type (AC, DC) and amount of current are systematically altered, and the corresponding changes in electrical resistance are recorded. Microscopic investigations on wear values and morphology are followed. Focused the investigation were on lubricating oils and greases formulated with and without ZDDP. The chosen Tribo-testing were standard test methods for fretting (ASTM D7594) and Anti-wear (ASTM D5707). Formulations containing ZDDP show higher wear values, highlighting the impact of additive chemistry on performance under varying current conditions.

9:40 - 10:00 am
4237626: Effect of Electric field Application on Micropitting Behavior Using a Rolling/Sliding Friction Tester
Shinya Sasaki, Kaisei Sato, Tokyo University of Science, Tokyo, Japan; Takuto Kunii, Rtec-Instruments K.K., Kashiwa, Chiba, Japan; Tushar Khosla, Jun Xiao, Rtec-Instruments, San Jose, CA

As the electrification of automobiles advances, ensuring the durability of gears and bearings in the reducers of e-Axle units, which are responsible for the vehicle's propulsion, has become a key challenge due to the higher speeds of the motors. To address these challenges, it is necessary to modify gear surfaces and optimize lubricant additive formulations, and a reliable evaluation device for screening these factors through lab testing is required. In this presentation, we report the results of our investigation into the effects of lubrication conditions and electric field application on micropitting, conducted using a rolling/sliding friction tester.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4205166: Algorithms to Automate the Characterization of Triboflim or Wear from Stylus Profilometer Measurements
Tianshi Fang, Oluwaseyi Ogunsola, Shell Global Solutions (US) Inc., Houston, TX

Surface profile measurement is a common methodology to characterize tribofilm or wear. In Stylus Profilometers, because of the infeasibility to precisely locate the boundaries of the wear track, a surface profile measurement typically contains both the wear track and parts of the intact surface

on the two sides. The selection of the wear track from the complete measurement was traditionally implemented manually. It was time-consuming and tedious. It requires significant human hours and delays the progress. Moreover, the results may lack consistency if different measurement results are processed by different people. Shell developed computer algorithms to automate the selection of wear track. The software saves a significant amount of time and human work. The accuracy and reliability of the software has been validated with various types of measurement results.

11:00 - 11:20 am
4204866: Modification of Abrasiveness of SLA Additive Manufacturing Produced Components through Resin Formulation
Kanoa Parker, Miranda Brandt, Leilani Elkaslasy, Gordon Krauss, Harvey Mudd College, Claremont, CA

Additive manufactured/SLA components are advantageous for rapid prototyping, offering benefits over traditional machining with respect to complex geometry and speed. The ability to produce ceramic components broadens SLA's applications. Wear resistance, abrasiveness, and friction of the component surfaces are tribological properties of interest. This study investigated how SLA resin additives can alter ceramic surfaces' abrasiveness and sliding friction against 52100 steel balls. Disk specimens were fabricated using a commercially available 3D ceramic material and a DLP resin printer. These disks had a top layer doped with varying ceramic compositions relative to the rest of the disk body (bulk). Post-firing, the surfaces underwent abrasiveness testing using a Universal Micro-Tribometer (UMT-2) with the Pin-on-Disk method. Three porcelain compositions were evaluated. Results show how different surface ceramic compositions impacted abrasiveness under the same firing conditions.

11:20 - 11:40 am
4204873: Development of a Tribological Testing Method for Engine Lubricants Using OEM-Specific Cylinder-Ring Liner Metallurgy and Its Correlation with Friction Torque Test (FTT)
Rameshwar Chaudhary, Indian Oil Corporation Ltd (R&D Centre), Faridabad, Haryana, India

This study investigates the reduction of frictional losses in lubricants by optimizing viscosity and boundary additives, focusing on enhancing efficiency in hydrodynamic lubrication regimes. A 0W16 viscosity grade oil, designed for better fuel efficiency and longevity, was compared to an industry reference. To assess performance, a Friction Torque Test (FTT) was conducted using a motorized gasoline engine across varying speeds and temperatures. FTT evaluates engine oil, but its long duration limits testing. Therefore, the study introduces a faster screening method utilizing benchtop tribometers, correlating their results with FTT. Low viscosity (0W16) candidates for passenger cars were tested for frictional losses under hydrodynamic and boundary conditions using the HFFM rig and MTM Test rig. The findings revealed a strong correlation with FTT results, suggesting that this faster approach can identify oils with lower friction more efficiently, reserving FTT for top candidates.

11:40 am - 12:00 pm
4200478: Development of a Grease Testing Method Using a Three-Ring-on-Roller Configuration: Optimizing Grease Supply and Evaluating Electrical Effects
Nicholaos Demas, Aaron Greco, Argonne National Laboratory, Argonne, IL

This work presents the development of a method for testing grease using a machine that employs a three-ring-on-roller configuration. Several approaches were tested to introduce grease into the contact area, including packing grease manually and using various holders, but these methods resulted in insufficient lubrication and inconsistent results. A syringe pump was ultimately adopted, providing a controlled and continuous supply of grease. The study explored a wide range

of lubrication regimes, with the most consistent results observed in the boundary lubrication regime. Flow rate optimization was critical for ensuring adequate lubrication, with an optimal supply rate identified. Electricity was also applied between the roller and one of the rings, offering an understanding of its effects on lubrication performance. This method offers a reliable way to test grease, providing valuable insights into grease performance under different lubrication conditions.

5G Regency V

Materials Tribology V

Session Chair: John Curry, Sandia National Laboratories, Albuquerque, NM
Session Vice Chair: Samuel Leventini, University of California Merced, Merced, CA

8:00 - 8:40 am
4194018: From Polymer to Metals Matrices: Enhanced Tribological Behavior Using 2D Nanomaterial-Reinforced Composites
Max Marian, Leibniz University Hannover, Hannover, Germany; Sangharatna Ramteke, Pontificia Universidad Catolica De Chile, Santiago, Chile

The incorporation of two-dimensional (2D) materials into metal and polymer matrices has gained significant attention due to their potential to enhance mechanical and tribological properties in biomedical and industrial applications. This presentation focuses on the fabrication and characterization of composites reinforced with MXenes $Ti_3C_2T_x$ MXenes and MoS_2 in ultrahigh molecular weight polyethylene (UHMWPE), cobalt-chromium (CoCr) alloy, and 316L stainless steel matrices. In UHMWPE, MXene-reinforced nanocomposites demonstrated significant reductions in friction and wear, attributed to the formation of easy-shear transfer films. In metal matrix composites fabricated via additive manufacturing, MoS_2-reinforced 316L steel as well as MXene - reinforced CoCr achieved a remarkable reduction in wear by 72% and 77%, respectively. This highlights the versatility of 2D material-reinforced composites towards improved durability and performance in biomedical and industrial applications.

8:40 - 9:00 am
4199555: Unraveling the Mystery of Water Transport in MoS_2: A ToF-SIMS Investigation
Nicolas Molina Vergara, Andrei Dolocan, Loukas Kallivokas, Gregory Rodin, Filippo Mangolini, The University of Texas at Austin, Austin, TX; Tomas Babuska, John Curry, Michael Dugger, Sandia National Laboratories, Albuquerque, NM

Molybdenum disulfide (MoS_2) coatings find extensive use in applications demanding low friction in inert or vacuum environments. Nonetheless, the water sorption within the coating during handling or periods of dormancy leads to a pronounced increase in friction, which results in reliability issues of sliding components. Despite the number of studies that quantitatively evaluated water sorption/desorption in MoS_2, a quantification of the water diffusivity in MoS_2 and its dependency on the material microstructure/chemistry is still lacking. To fill this knowledge gap, ToF-SIMS depth-profile analyses were conducted after dosing MoS_2 films with a water isotopic tracer. The resulting depth profiles are modelled using a Fickian diffusion model that allows for the quantification of the dependence of diffusion coefficient on coating morphology and depth-dependent chemistry.
Research funded by SNL, managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

9:00 - 9:20 am
4190594: Friction and Wear of Composite MXene/MoS2 Coating Under Low Viscosity Fuels Under Reciprocating Sliding
Ali Zayaan Macknojia, Andrey Voevodin, Samir Aouadi, Diana Berman, University of North Texas, Denton, TX; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Friction and wear-related failures remain major challenges in moving mechanical assemblies operating under various conditions. For example, the components of fuel systems made of AISI 52100 steel are susceptible to scuffing-induced wear when operated in fuel environment. This study demonstrates the decreased friction and wear characteristics achieved by spray-coating 52100-grade steel surfaces with solution-processed multilayer Ti3C2Tx-MoS2 blends. Study analyzed lower friction performance of the coating under high contact stresses and sliding speeds in different fuels. Raman spectroscopy, scanning electron microscopy, and transmission electron microscopy results revealed the formation of an in-situ robust tribolayer responsible for the lower friction performance observed at high contact pressures and sliding speeds, where MXene helps protect the MoS_2 from oxidation and increases its longevity.

9:20 - 9:40 am
4200470: Chromium-Enabled MoS2 Coatings for Enhanced Durability and Reduced Friction in Aluminum
Sujan Ghosh, Nihal Ahmed, University of Arkansas at Little Rock, Little Rock, AR

This study explores the enhancement of tribological properties in aluminum through multifunctional MoS2 thin film coatings, addressing the challenges of high coefficient of friction (COF) and wear. MoS2 coatings, recognized for their lubricating capabilities, often exhibit low adhesion and susceptibility to oxidation at room temperature. A chromium underlayer was introduced between aluminum and MoS2 to improve performance, using physical vapor deposition (sputtering) for the coating application. The chromium underlayer significantly enhanced adhesion and doubled the durability of the MoS2 coating, reducing the COF from 0.7 to 0.28 without compromising performance. However, adding a chromium top layer did not positively affect the coating's durability or COF. This research demonstrates that strategic integration of chromium layers can substantially improve the tribological characteristics of aluminum components for automotive and aerospace applications.

9:40 - 10:00 am
4198557: Effect of Europium and Gadolinium Alloying Elements on the Tribological Response of Low Hydrogen Content Amorphous Carbon
Filippo Mangolini, Camille Edwards, Hsu-Ming Lien, Nicolas Molina Vergara, The University of Texas at Austin, Austin, TX

Dopants and alloying elements are commonly introduced in amorphous carbon (a-C) materials to tailor their mechanical and tribological properties. While most published studies have focused on doping or alloying a-C coatings with metals or metalloids, doping a-C films with rare-earth elements has only recently been explored. Notably, our understanding of the shear-induced structural changes occurring in rare-earth element-containing a-C films is still elusive, even in the absence of any liquid lubricants. Here, the load-dependent friction response of Eu- and Gd-containing a-C films with low hydrogen content was evaluated in open air and at room temperature. Based on the outcomes of NEXAFS spectromicroscopy measurements performed in the wear tracks, a phenomenological model is proposed to account for the observed tribological behavior. These findings open the path for the use of Gd- and Eu-containing a-C under critical conditions for nearly hydrogen-free a-C films (i.e., humid air).

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4202839: Effects of Temperature, Contact Pressure, and Lubricant Type on a CNT Coating's Superlubricity
Seokhoon Jang, Chanaka Kumara, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

In our previous study, a sacrificial coating composed of carbon nanotubes (CNTs) vertically grown on stainless steel disks demonstrated superlubricity (coefficient of friction, COF <0.01) in a macro-scale sliding with a polyalphaolefin oil at the room temperature. This work explores the dependence of the CNT coating's superlubricity on the temperature, contact pressure, and lubricant type. It was observed that the COF generally increased with the temperature, but the superlubricity was restored when the temperature dropped back down. The COF also gradually increased with the load but regained superlubricity after an extended running-in period. The CNT coating's superlubricity was achieved in several lubricating oils though the running-in behavior and steady-state COF varied, which can be correlated to the lubricant chemistry. These findings offer fundamental insights into the applicability and limitations of this sacrificial superlubricity CNT coating.

11:00 - 11:20 am
4203929: Exploring the Impact of Spray Process Parameters on Graphite Coatings: Morphology, Thickness, and Tribological Performance
Adedoyin Abe, Josue Goss, Min Zou, University of Arkansas, Fayetteville, AR

This study examines the effects of process parameters on the morphology, thickness, and tribological performance of graphite coatings sprayed on rough steel substrates. Graphite concentrations and spray flow rates were varied via a full factorial design for coating deposition. Coating morphology, roughness, thickness, coefficient of friction (COF), and wear behavior were analyzed. Low-flow-rate coatings had a porous structure and higher roughness, while high-flow-rate coatings were denser with lower roughness. A COF of 0.09, an 86% reduction from uncoated steel, highlights the coating's friction-reducing potential. Thickness significantly influenced friction and wear resistance, while flow rate affected coating structure and graphite compaction in the wear track. SEM and elemental analysis confirmed that embedded graphite provided effective wear protection. Optimizing graphite concentration and flow rate is essential for tailoring coating morphology and tribological performance.

11:20 - 11:40 am
4206504: The Influence of Resin on the Fretting Resistance of Molybdenum Disulfide
Melissa Mushrush, DuPont de Nemours Inc, Wilmington, DE

Of the solid lubricants commonly used in pastes and antifriction coatings, molybdenum disulfide has superior fretting resistance compared to graphite or PTFE. When these solids are affixed at the contact surface in a resin as an antifriction coating, however, the overall coating does not have the expected fretting resistance. This work aims to look at the influence of the resin on fretting performance as a function of load, speed, and displacement, especially displacement right at the transition regime between fretting and reciprocating wear.

11:40 am - 12:00 pm
4173570: Wide-range Controllable Modulation of Slip Length at MoS_2-Water Interface via Self-Assembled Monolayers
Yishu Han, Dameng Liu, Tsinghua University, Beijing, China

Understanding and controlling slip behavior at solid-liquid interfaces is crucial in fields such as micro/nanofluidics, surface science, and energy engineering. In this work, three self-assembled monolayers with different dipole moments were used to control the electron concentration at the molybdenum disulfide-water interface, resulting in a tunable slip length ranging from 6.6 to 27.1 times compared with the pristine interface. This regulation on slip length offers a novel approach to demonstrating the significance of electrons in slip length. In addition, it was found that the lifetime of electrons dissipated through the A^- exciton channel tends to increase on surfaces with larger slip lengths, leading to a reduction in total electron energy dissipation. This finding establishes a qualitative relationship between the interfacial slip length and the electron energy dissipation, and reveals the electron dissipation mechanism at the solid-liquid interface from the quantum level.

5H Regency VI

Aerospace III

Session Chair: Juan Bosch Giner, The University of Akron, Akron, OH
Session Vice Chair: Abrar Faiyad, University of California, Merced, Merced, CA

8:00 - 8:40 am
4201648: Optimization of Grease Lubrication Tasks for the Chinook H-47 Helicopter through Component Sampling and a Seven Parameter Evaluation Matrix.
Dylan Kletzing, Richard Wurzbach, MRG Labs, York, PA

Operators of the H-47 Chinook heavy-lift helicopters initiated and participated in a grease sampling and analysis effort to optimize historically determined usage-based lubrication tasks. Operators produced over 1100 grease samples obtained using the ASTM D7718 standard for Inservice Grease Sampling. The 1 gram samples were tested using ASTM D7918, along with additional methods that evaluated wear condition, contaminant quantities, changes in grease consistency, and oxidation condition through additive quantification. This resulted in the reduction of the number of greasing tasks per 1000 flight hours being cut nearly in half, and the availability of the aircraft extended from 50 continuous flight hours to 120 flight hours. Other findings confirmed the improved flight safety and sustainability of the aircraft, and the revised greasing maintenance recommendations were accepted by the participating operators, resulting in an estimated savings of US$100 million per year across the fleet.

8:40 - 9:00 am
4212341: AI-Driven Discovery of Low-Vapor-Pressure Lubricants for Aerospace Applications
Daniel Miliate, Ashlie Martini, University of California - Merced, Merced, CA

In space applications, liquid-based lubricants are often chosen for high-cycle, high speed components because of their ability to reflow into contact points. However, there are very few lubricants available with a vapor pressure low enough for the vacuum conditions of space. This work introduces a data-driven approach to discovering new liquid space lubricants with machine learning (ML). Using high-throughput ML models to predict vapor pressure, the discovery process was accelerated compared to traditional computational and experimental approaches. The ML models were trained on data that integrated both molecular dynamics simulations and experimental databases. The models were simplified to enable interpretability of the predictions. Model interpretation revealed the key connections between chemical structure and vapor pressure. New liquid lubricants are proposed that could lead to the next generation of space lubricants.

9:00 - 9:20 am
4200677: Tribological Performance of Gelled Oils for Space Mechanisms Lubrication
Julie Laporte-Fedry, Mikaël Petit, INS, Genay, France

Bearing lubrication is an important point in space applications where lubricants must maintain their performance in very low temperatures and under high vacuum. For this, an innovative test bench was developed to characterize friction torque, noise, and endurance life of lubricants in bearings in high vacuum environment. The bench is used to compare new gelled oils with PTFE greases reference. Currently used greases exhibit frictional torque peaks in bearings at low speeds related to their composition and structure: bi-phasic with PTFE/MoS2 particles in suspension in base oil. Tribological tests performed on gelled oils (oil thicken with soluble polymers allowing it to have higher viscosity than the oil alone) showed performance superior to the reference grease with a rolling bearing behaviour close to the pure oil and a very good stability in the evaluated speed range. The new lubricants are also assessed with long-terms tests representative of the application in our high vacuum bench.

9:20 - 9:40 am
4204964: Optimization of Fabrication Parameters for Spark Plasma Sintered Self-Lubricating Metal Matrix Composites for Aircraft Landing Gear Applications
Will Gray, Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

This work showcases the sintering optimization of an aluminum-based metal matrix composite with embedded silicon carbide and tungsten disulfide, for use in self-lubricated aircraft landing gear bushings. Aluminum acts as a material matrix, whilst the silicon carbide increases the material hardness and tungsten disulfide acts as a solid lubricant to improve friction and wear performance, thus enhancing the mechanical and tribological properties, respectively. Spark plasma sintering was used as the fabrication method, with comparisons performed on the sinter temperature, temperature ramp rate, dwell time, sinter pressure and the sintering DC pulse on-off time. Tribological assessment was performed at room and elevated temperature under a moderate and high load for complete material assessment. This works sets the foundation for future material blend optimizations, and eventually the tribological assessment of full bush testing.

9:40 - 10:00 am
4190809: Tribological Performance of a Novel Aeroengine Bearing Steel - ARCTIC15
Arnaud Ruellan, Jean-Baptiste Coudert, Yves Maheo, SKF Aerospace, Chateauneuf-sur-Isere, France; Samantha Melnik, SKF Aeroengine, Falconer, NY

The development of new generation very high bypass ratio aeroengines requires bearing solutions with increased speed and load capabilities. A temperature-resistant and corrosion-tolerant carburizing steel has been developed to enable a minimum of 15% increase of contact pressure capability compared to conventional aeroengine bearing steels. This novel bearing steel called ARCTIC15 opens the door to smaller engines with reduced fuel consumption and emissions. First industrial melts have been produced and underwent an extensive range of verifications.
Here, the performance of ARCTIC15 are compared to that of conventional M50 and M50NiL bearing steels. A focus is made on the tribological performances and material properties related to bearing reliability, mainly being resistance in rolling contact fatigue, spall propagation, oil starvation and smearing. The correlation between elemental, subscale, and full-scale tests results will be discussed.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4199860: Powder Lubrication Operating Regime of Carbon-Graphite Annular Seals
Mihai Arghir, Ibrahim Diallo, Universite de Poitiers, Futuroscope Chasseneuil, France; Lassad Amami, CETIM, Nantes, France; Mohamed Andasmas, Safran Aircraft Engines, Villaroche, France

Annular segmented seals are made of carbon-graphite and operate with a negligible radial clearance from the rotor surface. Thus, the asperities of the surfaces come into contact and the wear of the segment produces a carbon-graphite powder acting as a solid lubricant. The present paper presents the results of the measurements performed for characterizing the compressibility, the fluidity, the yield stress and the wall friction coefficient of carbon graphite powder. The measurements were conducted on a rheometer following the powder characterization protocol. The powder was obtained by grinding carbon-graphite samples and the particles size distribution was measured by laser diffraction.
The powder was assimilated with a visco-plastic continuum with a rheology described by the Hershel-Bulkley model. A generalized Reynolds equation was used for describing the flow between the rough segment and rotor surfaces. The results show that islands of powder are transferred to the rotor surface.

11:00 - 11:20 am
4201871: The Latest Trends in the Development of Hydrodynamic Mechanical Face Seals for Turbopumps for Reusable Rocket Engines in Japan
Yuichiro Tokunaga, Tadatsugu Imura, Hidetoshi Kasahara, Eagle Industry Co., Ltd., Sakado-shi, Saitama-Ken, Japan; Ato Tazawa, Hiromitsu Kakudo, Satoshi Takada, Japan Aerospace Exploration Agency, Kakuda-shi, Japan

As reusable rocket engines become more common, maintaining long-term performance in repeated engine use is a challenging task. Among them, seals for turbopumps are one of the most important and technically challenging components, which operate in harsh environments of cryogenic temperatures and high-speed sliding conditions. This presentation describes the development of a hydrodynamic mechanical face seal for reusable rocket engines in Japan. This technology enables control of sealing performance and prevention of surface damage by maintaining the sliding surfaces in a non-contacting state. This study presents test results of hydrodynamic mechanical face seals using various cryogenic fluids. The seal performance of the textured geometry, tested in detail under a variety of conditions, shows promising results that are in good agreement with numerical predictions. Stable leakage characteristics and high durability were demonstrated even after 80 cycles of startup and shutdown.

11:20 - 11:40 am
4205159: Optimizing Labyrinth Seals to Minimize Lubricant Evaporation in Space Mechanisms
Josef Pouzar, David Kostal, Ivan Krupka, Brno University of Technology, Brno, South Moravia, Czechia; Lars-Göran Westerberg, Erik Nyberg, Luleå University of Technology, Luleå, Sweden

Surface lubrication in space applications requires either solid or liquid lubricants, selected based on specific boundary conditions. However, liquid lubricants are particularly susceptible to vacuum evaporation in space, where ambient pressure is lower than their vapor pressure. Tribological failures are a leading cause of malfunctions in space technology, and enhancing our understanding of space tribology can help prevent these issues while reducing space debris, costs, and environmental impact. Labyrinth seals play a crucial role in minimizing lubricant loss and ensuring the long-term durability of space systems. This study integrates theoretical analysis, molecular flow simulations, and experimental validation to optimize labyrinth seal geometry and mitigate lubricant evaporation. Our experiments validate the simulation models, demonstrating that an optimized labyrinth seal can significantly reduce lubricant loss, enhancing system reliability and extending mission lifetimes.

11:40 am - 12:00 pm
4203580: A Study on Oil Sealing Performance of Surface Textured Mechanical Face Seals in Vacuum
Noriko Matsuoka, Hiroshi Shiomi, Koji Matsumoto, Japan Aerospace Exploration Agency, Tsukuba, Ibaraki, Japan; Kenta Uchida, Ayami Tokuda, Akihiro Nishiuchi, Hidetoshi Kasahara, Yuichiro Tokunaga, Eagle Industry Co., Ltd., Sakado-shi, Saitama-Ken, Japan

Frictional torque and oil leak amount of surface textured mechanical face seals operated under differential pressure including vacuum were investigated. Especially we focused on the pumping effect of surface texture in vacuum. The mechanical face seals were demonstrated by configuration of a SiC ring and a flat glass disk. Two types of surface textured rings which have different pumping mechanisms were evaluated. The sealing fluid was Polyalphaolefin (PAO). The oil film and the cavity regions generated in the sliding surfaces were observed with an optical method, and the frictional torque was measured simultaneously. Both types of surface textures generated pumping effect in vacuum as well as atmosphere. On the other hand, the frictional torque and oil leak amount were dependent on surface texture pattern and pressure condition. The performance of surface textured mechanical face seals and the mechanism for generation of the pumping effect in vacuum will be discussed in detail.

5I Regency VII

Electric Vehicles V

Session Chair: TBD
Session Vice Chair: TBD

8:00 - 8:40 am
4213627: Lubricant Electrical Properties and their Potential Impact on Bearing Discharge
Chris McFadden, Lubrizol, Wickliffe, OH

Bearing damage due to electric discharge is an old topic. While a bearing is rotating, the rotor and stator are separated by an insulating fluid that can allow a potential difference. This can have many causes, but the most common is from coupling to a motor. If the potential difference between rotor and stator is large enough, it will discharge through the fluid film. This can be an issue for rolling element bearings in the drivetrains of electrified vehicles. Although oils have high dielectric strength (10-40 kV/mm vs ~3kV/mm for air), oil film thickness in rolling element bearings is submicron. So arcing can occur with less than ten volts. OEMs mostly rely on hardware solutions to address bearing discharge. Some are also interested in the electrical properties of the lubricants. In this talk we will present typical values for the electrical properties of EV drivetrain lubricants and discuss whether they can be adjusted sufficiently to have an impact on bearing discharge.

8:40 - 9:00 am
4223991: System-level approach to EV powertrain bearing friction optimization
Jason Brady, Tom Schmitz, Mikael Holgerson, Lars Norrman, SKF, Plymouth, MI

As mechanical complexity has decreased with EV powertrain systems compared to conventional ICE systems, the contribution of rolling element bearing friction to the overall powertrain efficiency has become much more significant. This study presents a case study and methodology to identify and optimize selected bearings in the powertrain to maximize overall system energy savings over the full application duty cycle from conceptual study to hardware verification.

9:00 - 9:20 am
4229207: Bearing Evaluations for High-Speed Electrified Drive Unit Applications
Thomas Wellmann, FEV, Auburn Hills, MI; Bernd Katthoefer, Ruediger Beykirch, FEV Europe, Aachen, Germany

Electric drive units are often operated at high speeds. The bearing system for high speeds needs optimization with respect to cooling, lubrication, and appropriately evaluated throughout the product development. Simulation tools and test benches are required for successful bearing system design. Typical speed ranges of electric motors, and considerations that limit high-speed operation are given. A newly developed bearing test stand is introduced, and capabilities required for bearing tests for the test stand are highlighted. The test stand allows for changing loads of the bearings under high-speed operation, while also altering the lubrication and flow rates. Bearing validation tests, and optimizing the system for efficiency, with focus on the flow and fluid parameters can be performed. Further, simulation methods such as CFD with focus on bearing lubrication and cooling are highlighted. The prediction of drag loss and thermal behavior of the bearing system are discussed.

9:20 - 9:40 am
4180980: Optimizing Bearing Life and Power Loss in Electric Vehicle Gearboxes
Alexander Waye, The Timken Company, North Canton, OH

Electric vehicle (EV) powertrains are becoming increasingly complex, often featuring multiple parallel shafts in thin section aluminum housings. This study varies system parameters for the intermediate shaft and differential and identifies key system features for optimizing bearing life and power loss. System features like bearing K factor, gear helix angles, and gearbox layout were varied. Regression models were fit to the collected data. Key findings indicate that for EV differentials, bearing K factor should be selected to complement helix angle selection, and that optimal gear location is critical for bearing life. For the intermediate shaft, the study found that steeper cup angle could be selected and that mesh angles should be carefully selected to meet both packaging constraints and bearing life. A case study shows how these factors can further impact bearing power loss. These findings can guide the design and configuration of EV gearboxes to enhance performance and durability.

9:40 - 10:00 am
4200736: Twin Disc Evaluation of Scuffing Performance of Lubricants as a Precursor to FZG
Debdutt Patro, Sravan Josyula, Ducom Instruments, New York, NY; Fabio Alemanno, Deepak Veeregowda, Ducom Instruments (EUROPE) B.V., Groningen, Netherlands

In this study, Ducom twin disc RoR 2.0 was used to determine the scuffing capability of oils by replicating ISO 14635-1 conditions used in FGZ test rig. A line contact with flat-on-flat rollers and load steps up to 5 kN corresponding to contact pressure of 2465 MPa was used. Tests were conducted at different slips ratios and a circumferential velocity of 6.5 m/s with lubrication temperature of 80°C (from stage 5). Friction and vibration data was captured in real time during the test. The disc surfaces were examined under a microscope after each load step. Four lubricants, including a base oil and three with additives were tested. While friction results show no significant difference with increasing loads, vibration showed a significant increase. Microscopy revealed surface failures at such load steps. The talk will describe the scuffing method on twin disc and compare the results with FZG tests for oils having different load carrying capability.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4205113: Surface-Functionalized CNT as a PAG Additive for Improved Thermal Properties
Chanaka Kumara, Seokhoon Jang, Wenbo Wang, Harry Meyer III, Michael Lance, Hsin Wang, James Haynes, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN; Xiaoqian Wang, Ning Ren, Jacob Bonta, Edward Murphy, Roger England, Valvoline Global Operations, Lexington, KY

Carbon nanotubes (CNTs) possess outstanding thermal properties, but their limited oil suspensibility hindered the realization of their full potential as an oil additive. Additionally, CNTs are inherently hydrophobic and tend to aggregate in polar oils such as Polyalkylene Glycol (PAG). To address these challenges, polar functional groups were covalently attached to the CNTs to enhance the CNT-PAG compatibilities. As a result, the surface-functionalized CNTs exhibited good suspension and dispersion in a PAG oil at both room temperature and 100 °C. The functionalized CNTs at 0.1wt% concentration were found to increase PAG thermal conductivity up to 19% and volumetric heat capacity up to 29%. Addition of CNTs would increase the oil viscosity, which is detrimental to the heat transfer efficiency. The functionalized CNTs have been found to cause significantly less oil thickening compared with the unmodified CNTs, offering a promising avenue for leveraging CNTs properties for heat transfer.

11:00 - 11:20 am
4199447: New Antifoam Technologies for Non-Aqueous Additive Packages
Stefanie Velez, MUNZING CHEMIE GmbH, Bloomfield, NJ; Safia Peerzada, Munzing North America, LP, Bloomfield, NJ

Foam stabilization is a critical issue in non-aqueous lubricants which can be heavily impacted by the additive packages' components in these lubricants. The higher molecular weight components such as detergents, dispersants, friction modifiers, and viscosity modifiers can directly impact the foam and entrained air tendency of the fluid. Antifoams can be used in these additive packages to inhibit the foam formation and entrained air. Traditional polyacrylate antifoams have been used in additive packages due to their excellent stability, but typically additional antifoam is required once fluid is formulated and used in real world application. Based on the ever-changing technology in the market, new additive packages are being introduced to the market. This allows for new antifoam technology to be introduced into the additive packages. A comprehensive study using new antifoam chemistries that provide similar or improved foam control while maintaining good stability will be presented.

5J — The Learning Center

Gears I

Session Chair: Xue Han, Cummins, Inc., Columbus, IN
Session Vice Chair: Aaron Isaacson, Gear Research Institute, Penn State University, State College, PA

8:00 - 8:40 am
4233367: SB>1 DEFIANT JMR Technology Demonstrator Aircraft Main Rotor Gearbox Technology Insertions & Teardown Results
Scott Bouwer, Kevin Ignatuk, The Boeing Company, Ridley Park, PA

The Sikorsky Boeing SB>1 DEFIANT is a technology demonstrator aircraft that was built under the Joint Multi-Role Technology Demonstrator (JMR TD) program to address the next generation performance requirements of the US Army Future Vertical Lift (FVL) initiative. The Main Rotor

Gearbox (MRGB) incorporated several low Technology Readiness Level (TRL) technologies to improve power density and meet challenging program requirements for gearbox empty weight fraction. After the conclusion of the flight test program the ground test Main Rotor Gearbox was disassembled and evaluated to raise the TRL level of these technologies. The technology insertions, teardown observations, and laboratory test results are discussed.

8:40 - 9:20 am
4233346: Evaluation and Implementation of Low Core Hardness Gears in the SB>1 DEFIANT JMR Technology Demonstrator Aircraft
Scott Bouwer, Kevin Ignatuk, The Boeing Company, Ridley Park, PA

The Sikorsky Boeing SB>1 DEFIANT is a technology demonstrator aircraft that was built under the Joint Multi-Role Technology Demonstrator (JMR TD) program to address the next generation performance requirements of the US Army Future Vertical Lift (FVL) initiative. During the development of the SB>1 DEFIANT technology demonstrator aircraft several manufacturing lots of gears were produced with a core hardness that was 10-30% below the minimum engineering requirement. The defect was not detected until a large population of gears was near completion. To prevent significant program cost and schedule impacts, a safe load capacity for the discrepant gears was determined via test and the SB>1 DEFIANT technology demonstrator aircraft entered qualification testing with the low hardness gears. The low hardness issue, root cause, and test method to establish a safe operating load limit are discussed.

9:20 - 10:00 am
4209664: Experimental Evaluation of Gear Tooth Bulk Temperature via In-situ Gear Tooth Temperature Measurement
Cody Wassel, Aaron Isaacson, Matthew Wagner, Penn State University, University Park, PA

Dynamic tests were conducted on a four-square or power-circulating gear test rig. Six thermocouples, positioned at two roll angles and three depths below the surface were embedded in the specimen gear. The thermocouple readings were recorded in-situ using a slip ring. Two sets of gears were used in the testing, one as-ground, one with processed with isotropic superfinishing. Each set was run in 60 different combinations of speeds, contact stresses, oil temperatures, and lubrication types (oil sump, oil jet, and oil mist). The temperature data collected in these tests was used to calculate the oil bulk temperature, followed by the flash and contact temperature. This contact temperature was compared against legacy calculation methods, which use an estimated bulk temperature.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4191181: Development of a New Type of FZG high-Speed Gear Tension Test Rig for Testing and Characterizing High-Performance Lubricants
Sebastian Preintner, Thomas Tobie, Karsten Stahl, Technical University of Munich, Garching, Germany

Due to the rapid advancements in E-Mobility, there is an increasing demand for lubricants specialized for usage under operating conditions in battery electric vehicle (BEV) drivetrains. Electric motors, particularly those designed for high speeds, impose rigorous requirements on these lubricants. The fluids used, must not only reduce friction and wear but also contribute to the thermal management of both the gearbox and the electric motor. Consequently, lubricants for E-Mobility applications are typically characterized by very low viscosities to minimize gearbox losses. Despite this, they must still effectively protect against gear scuffing, a type of wear that can cause sudden and catastrophic damage. As a result, the demands on the corresponding test

methodology and the test rigs used for this purpose are also increasing. In a cooperation project between the Gear Research Center (FZG) and Strama-MPS, a new type of FZG high-speed gear test rig was developed.

11:00 - 11:20 am
4203134: Localization of Gear Pitting Damage During Operation
Lukas Merkle, Martin Dazer, University of Stuttgart, Stuttgart, Germany

Gear pitting usually only occurs on individual or adjacent teeth on a gear wheel. Particularly in applications with large gearbox dimensions such as wind, mining or steel production, the precise localization of damage in the complex tribological systems can be the gamechanger towards a more sustainable operation of the plant. Operation can be adapted and the load on the damaged area can be reduced in a targeted manner. The aim of the study is to develop and evaluate various methods for localizing a damaged tribo-contact on the circumference of a gear wheel. For this purpose, an extensive series of tests is carried out on an electrical load test bench with two electric motors. A single stage spur gear box is tested with different operating conditions. The localization will be carried out by special evaluation methods of high-frequency vibration data. Localizing the damage during operation enables great potential for increasing service life through the application of PHM strategies.

11:20 - 11:40 am
4184834: An Investigation into the Correlation Between Gear Wear and the Presence of Deposits Located Just Beneath the Tooth Surface.
Kenji Matsumoto, Tokyo Denki University, Adachi-ku, Tokyo, Japan; Takeo Kiuchi, Toyo Corporation, Taito-ku, Tokyo, Japan; Yuji Mihara, Tokyo City University, Setagata-ku, Tokyo, Japan

Comprehensive observations utilizing transmission electron microscopy (TEM) indicated that the behavior of precipitates located just beneath the tooth surface of gears subjected to prolonged use significantly influences wear. Specifically, it was observed that precipitates alter the path of crack propagation and significantly influence the release of wear debris. In this presentation, I will discuss the structural changes in metals, with a particular focus on TEM images.

11:40 am - 12:00 pm
4176314: Repair of Helical Gear Teeth with Notched Substrate by Laser-Directed Energy Deposition
Igor Ortiz, Diego Montoya-Zapata, Piera Alvarez, Maria Azpeleta, Ikergune, Elgoibar, Gipuzkoa, Spain; Marta Garcia, Talens Systems, Guipuzkoa, Spain; Francisco Cordovilla, José Luis Ocaña, Universidad Politécnica de Madrid, Madrid, Spain

Gears are useful for changing rotational speed and power by transferring the power generated by the engine. The whole replacement of a wind power gear transmission can be between $150000-$500000. Previous studies have shown that Laser powder direct energy deposition (LP-DED) has the capability to repair, and manufacture worn gear straight teeth. Helical gears, on the other hand, have a more complex geometry than straight gears which hinders the toolpath generation for the repair process. In this work, we study the toolpath to repair helical gear teeth in a notched geometry substrate that mimics the substrate for the manufacturing of the new tooth. Multiple gear teeth were manufactured to study toolpath and slicing strategies in helical gear teeth repair. We used AISI 316L with previously optimized parameters validating the strategies. We also performed metallographic analyses to check for manufacturing faults. We are currently studying specific powders for gear repair and manufacturing

Power Generation I

Session Chair: Elaine Hepley, Solana Consulting Services LLC, Indianapolis, IN
Session Vice Chair: TBD

8:00 - 8:40 am
4204317: Impact of Fluid Selection on Hydraulic Pump and Motor Efficiency: A Study Using ASTM D7721-22
Paul Michael, Pawan Panwar, Milwaukee School of Engineering, Milwaukee, WI; Ricardo Gomes, Frank-Olaf Maehling, Evonik Oil Additives, Horsham, PA

The standard method for determining the effect of fluid selection on hydraulic pump and motor efficiency is ASTM D7721-22. This method was used to study friction and flow losses in a dynamometer that incorporated an axial piston pump and axial piston motor. The dynamometer was operated under various conditions of pressure, speed, and temperature. The performance of ISO VG 32 and 46 straight- and multigrade fluids was compared. Differences in friction and flow losses were observed, depending on operating conditions. Fluid properties were characterized at the beginning and conclusion of testing. High-shear viscosity and low-speed traction coefficient measurements were found to correlate with system flow losses and motor torque losses. These results provide an insight into the interactions between hydraulic system operating conditions, lubrication regimes, and the fluid properties that impact efficiency.

8:40 - 9:00 am
4184936: Study of Additive Chemistry in Low Varnish Turbine Oils for High Bearing Temperature Applications and Its Impact on Tribological Properties
M N K Prasad Bolisetty, Chanakya Tripathi, Kavita Rai, Rahul Meshram, Subinoy Paul, A Arora, Mukul Maheshwari, Indian Oil Corporation Limited, Faridabad, Haryana, India

Modern gas and steam turbines place increasing demands on lubricants, exposing them to higher bearing temperatures, reduced reservoir sizes and critical varnish deposit issues. Selecting a high-performance, long-life turbine oil can help to mitigate future problems and the onus is on the turbine oil formulators to strike a balance between low varnish and antiwear/EP performance at elevated bearing temperatures. The present research paper deals with the effect of different categories of additives on varnish formation tendency, oxidation life and tribological properties for geared turbines by different techniques like Dry TOST analysis (ASTM D7873), MPC (ASTM D7843), RPVOT (ASTM D2272) and scuffing load carrying capacity (FZG), respectively. This paper also highlights the synergistic and antagonistic effect of additives on the important performance properties of turbine oil which will help to formulate turbine oils for high bearing temperatures up to 250° C in modern turbines.

9:00 - 9:20 am
4205602: Universal Lubricant Additives for Varnish and Deposit Mitigation
Justin Kontra, Justin Langston, Frank-Olaf Maehling, David Eckes, Evonik Oil Additives, Horsham, PA

Varnish and deposits present significant challenges in the operation and maintenance of industrial equipment, leading to reduced efficiency and increased downtime. This study explores the beneficial role of dispersant additives in mitigating these issues. Dispersant additives enhance the solubility of insoluble particles, preventing agglomeration and subsequent deposit formation. We demonstrate that these additives effectively reduce varnish and deposit buildup, particularly in high-temperature environments. The findings indicate a marked improvement in equipment

performance, longevity, and reliability.

9:20 - 9:40 am
4202494: Integrated Simulation of Hydrodynamic Plain Bearings in Wind Turbines
Hannes Grillenberger, Matthias Schubert, Mario Kittsteiner, Marcel Indenbirken, Michael Plogmann, Schaeffler Technologies AG & Co KG, Herzogenaurach, Bavaria, Germany

Hydrodynamic plain bearings are becoming an emerging bearing solution for wind turbine gearboxes – especially at the planet bearing position. To fully simulate and design the bearing including its profiles, an integrated simulation of the complete gearbox is important to capture the interactions of bearing, gears and elastic housings, planet carriers and shafts. The implementation in the simulation tool considers factors like exact geometry, materials, and load scenario, and is fully integrated in the gearbox simulation. This integration ensures a detailed and reliable bearing design process, crucial for enhancing the torque-density of wind turbine gearboxes. The presentation shows the general implementation of the method. Analysis and interpretation of design and performance properties for plain bearings like hydrodynamic pressure or edge pressures are discussed. The talk closes with the validation of the implemented method with other simulations and tests.

9:40 - 10:00 am
4173886: Updates and Developments in the Turbine Generator Lubrication System Maintenance Guide from the Electric Power Research Institute
Dylan Kletzing, Richard Wurzbach, MRG Labs, York, PA

The Electric Power Research Institute publishes many guidelines in support of the Power Generation industry. With the advancements in lubricant formulations, analysis and sensor options, and lubricant filtration and reclamation technologies, a recent effort was undertaken to update from the 2012 publication of this guide. The author and editor of this update shall present the key changes in this version to help those responsible for such systems to best utilize this document to achieve operational, maintenance and reliability goals for Turbine Generator Lubrication Systems.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4199376: Enhancement of Filtration Performance Characteristics of Glass Fiber-Based Filter Media. Part 1: Mechanical Modification with Electrospun Nanofibers
John Duchowski, Laura Weiter, HYDAC FluidCareCenter GmbH, Sulzbach, Saar, Germany; Stephan Leyer, University of Luxembourg, Luxembourg, Luxembourg

Modifications of glass fiber filter media through incorporation of electrospun PA66 nanofibers (NF) are described. PA66 NF were selected because of ready commercial availability and relatively low cost. Other polymers (PP, PET and PBT) could likewise be used. Two sample sets were prepared: the first with various wt% of NF mixed into the fiber matrices, the second by lNF deposition onto the downstream side of the substrate. The aim was to improve the separation efficiency, differential pressure and dirt holding capacity. The modified media were evaluated with textile characterization techniques and filtration performance evaluation procedures. The results showed several tens of percentage points difference achieved with the modification methods. Differences were also observed with percentage of NF admixed to the substrate. The results strongly suggest that new filter media with enhanced properties can be prepared by incorporating NFs directly into the matrix.

11:00 - 11:20 am
4199523: Enhancement of Filtration Performance Characteristics of Glass Fiber-Based Filter Media. Part 2: Chemical Modification with Surface-Active Treatment
John Duchowski, Laura Weiter, HYDAC FluidCareCenter GmbH, Sulzbach, Saar, Germany; Stephan Leyer, University of Luxembourg, Luxembourg, Luxembourg

Standard glass fiber filter media were chemically modified with surface active agents with the aim to improve separation efficiency, differential pressure dirt holding capacity. The increase in separation efficiency was determined quantitatively in terms of work of adhesion between the contaminant and the substrate. The behavior was confirmed experimentally by an increase in separation efficiency especially for particles in the smaller size ranges well below the mean porosity of the original substrate. In addition, the effect of different surface modifications, especially those of the opposite ends of the surface energy values, has clearly manifested itself in separation efficiency results shown in the multiphases test evaluations. Collectively, the obtained surface energy and separation efficiency results are indicative of a wide range of performance enhancements that can be achieved through suitably applied surface-active modifications of the standard materials.

11:20 - 11:40 am
4205630: Reducing Power Losses in Tilting Pad Bearings
Michael Blumenfeld, Weixue Tian, Harry Hawkins, Exxon Mobil, Annandale, NJ; Bruce Fabijonas, Kingsbury, Inc., Philadelphia, PA

Bearing losses are significant in the power generation sector where small changes in efficiency can scale rapidly. In fluid film bearings, losses are related to the Hersey number μ(T)●V/L , where μ(T) is the temperature dependent viscosity, V is the sliding velocity of the collar, and L is the applied load. We will discuss in this talk the potential for achieving efficiency improvements in fluid film bearings by reducing the Hersey number through viscosity reduction in the lubricant. Modeled data will be compared to experimental determinations of power loss and bearing pad temperature measured on a test rig. Finally, novel approaches to turbine lubricant design will be proposed that may enable step-change improvements in efficiency while still maintaining the durability required for reliable operation.

11:40 am - 12:00 pm
4200370: Conclusions from Hydraulic Fluid Dynamometer Testing and Correlation with Excavator Performance Demonstrations Data
Ricardo Gomes, Frank-Olaf Maehling, Thilo Krapfl, Evonik Oil Additives, Horsham, PA; Paul Michael, Pawan Panwar, Milwaukee School of Engineering, Milwaukee, WI

The fluid power industry sees an increasing need for reliable energy-efficient solutions driven by rising energy costs and environmental awareness. The efficiency of hydraulic fluids can be quantitatively compared according to ASTM D7721 which defines technical requirements for conducting tests with two or more hydraulic fluids, in particular, the last revision describes equipment investigations in the field.
A comparative investigation of hydraulic fluids was completed with a dynamometer test rig and an excavator in the field. This presentation draws conclusions from the findings with results comparing monograde and shear stable high VI hydraulic fluids. The selection of a shear stable high VI hydraulic fluid is key to reduce power losses and maximize equipment efficiency over long drain intervals. HF dynamometer results show that shear stable high VI fluids allow equipment to make highly accurate movements and to run at optimum controllability and consequently high productivity.

Lubrication Fundamentals II

Session Chair: Chanaka Kumara, MSTD, Oak Ridge National Laboratory, Oak Ridge, TN
Session Vice Chair: Kuldeep Mistry, Chevron Oronite Company, Richmond, CA

1:40 - 2:20 pm
4189998: Atomic-Scale Modelling of Lubricants at High Pressure: On the Competition of Shear Thinning, Thermal Thinning and Wall Slip
Michael Moseler, Stefan Peeters, Lars Kruse, Franziska Stief, Thomas Reichenbach, Gianpietro Moras, Kerstin Falk, Fraunhofer IWM, Freiburg, Germany

A fundamental understanding of the rheological properties of lubricants in narrow gaps under high pressures and elevated temperatures is mandatory for a predictive modelling as well as a knowledge-based design of boundary lubricated devices. Especially, the identification of the relevant velocity accommodation mode is a challenging task, since it results from an intimate interplay of pressure-induced viscosity increases, temperature-induced and shear-induced viscosity decreases as well as shear-induced wall slip. Molecular dynamics simulations are ideally suited to shed light into and study the balance of these different mechanisms [A.Codrignani et al. , Science Adv. 9, eadi2649 (2023)]. This presentation reports our activities for the predictive modelling of the high pressure rheology of mineral oils and water bases lubricants – including the calculation of viscosities at high pressures and shear rates as well as wall slip under extreme confinement and pressures.

2:20 - 2:40 pm
4186167: Optimizing EHL Performance with Slip Conditions
Rayan Ajeeb, Tomaz Pozar, Mitjan Kalin, University of Ljubljana, Ljubljana, Slovenia

Elastohydrodynamic lubrication is vital for reducing friction and enhancing mechanical system performance. Slip has emerged as a key mechanism for friction reduction, particularly with diamond-like carbon (DLC) coatings, that have low surface energy and promote slip at the lubricant-coating interface [1]. Experimental evidence indicates that DLC coatings significantly decrease the coefficient of friction [2]. However, investigating slip in EHL experimentally is challenging due to nanoscale contact accessibility. This research utilizes a computational approach, applying the Navier-Stokes equation to analyze EHL fluid domain with slip. The slip model used is the one proposed by Spikes [3], it indicates that both lyophobic and lyophilic substrates exhibit slip yield stress, with lyophobic substrates showing lower values. Findings reveal critical variables affecting EHL contact behavior and provide insights for optimizing coatings to reduce friction while avoiding asperity contact.

2:40 - 3:00 pm
4203066: Transient Effects in EHL Contacts in High Entrainment Speed Conditions
Roland Jones, Hugh Spikes, Amir Kadiric, Imperial College London, London, United Kingdom; Guillermo Morales-Espejel, SKF AB, Houten, Netherlands

EHL film thickness behaviour under steady-state conditions is well understood and predictable using conventional theories. However, in many practical situations, lubricated contacts are subjected to transient conditions which may include rapid acceleration as well as changes to the inlet supply conditions. Such conditions increase the risk of reduction and potential collapse of the EHL oil film leading to surface damage.
In this research, a new high-speed ball-on-disc optical interferometry rig was used to investigate

the effect of acceleration as well as varying lubricant supply in the inlet on the EHL films at entrainment speeds of up to 20 m/s. The results are presented to quantify EHL film thickness and illustrate the film shapes over a wide range of transient speeds and oil supply conditions.

3:00 - 3:40 pm - **Break**

3:40 - 4:00 pm
4188714: Choosing Right Viscosity Modifier Based on PSSI and Shear Rate of Application
Jacob Scherger, Functional Products Inc, Macedonia, OH

Viscosity modifiers (VM) are additives used to enhance VI, provide thickening in low viscosity oils, and provide better low temperature fluidity than heavy oils. The industry trend toward highly refined base stocks with lower initial viscosities demands more VMs to reach target ISO VGs. The trade-off in using VMs for performance is the added complexity of shear effects. PSSI or “permanent shear stability index” is an industry standard benchmark for classifying the tendency of polymers to undergo mechanical damage and loss of viscosity. It is a rule-of-thumb to help formulators select an appropriate VM for a given application. This study investigates the fundamental material science between: 1) polymer molecular weight and PSSI rating; 2) thickening efficiency and VI improvement; and 3) permanent and temporary shear thinning characteristics. This work will answer the question of when and where is it appropriate to use low cost, high PSSI polymers versus more shear stable chemistries.

4:00 - 4:20 pm
4175248: Demystifying Minimum Film Thickness in Elastohydrodynamic Lubricated Conjunctions
Wassim Habchi, Lebanese American University, Byblos, Lebanon; Sperka Petr, Brno University of Technology, Brno, Czechia; Scott Bair, Georgia Institute of Technology, Atlanta, GA

Till now, minimum film thickness in elastohydrodynamic lubricated (EHL) conjunctions was believed to be governed by lubricant low-pressure rheology. This is because two fluids with the same low-pressure response, but a different high-pressure one would produce the same film thickness. In here, it is shown that this is only true for theoretical line contacts, where there is no out-of-contact lateral flow. In real contacts, though central film thickness is governed by low-pressure rheology, minimum film thickness is also affected by the high-pressure response of the lubricant. The greater the high-pressure viscosity, the lower the minimum film thickness, because of reduced out-of-contact lateral flow. Narrow/slender elliptical contacts have a higher sensitivity to this phenomenon, compared to circular or wide elliptical contacts. Machine learning is then used to identify the governing parameters of EHL minimum film thickness, to be used in analytical formulae or machine learning models.

4:20 - 4:40 pm
4243300: Assessing Engine Oil Formulations to Mitigate Aeration
Eliane Gendreau, Robert Mainwaring, Sarah Matthews, Shell Research Limited, London, Please select, United Kingdom

While low levels of oil aeration are not problematic, excessive aeration can be detrimental to the performance of lubricants. The current trend in numerous applications is to engineer lubrication systems that are more compact, utilize a reduced volume of oil, and can operate at higher speeds with lower viscosity lubricants. These conditions exacerbate air handling concerns, so there is a need for robust formulations that can eliminate aeration as a problem while preserving the lubrication efficacy. In this project, we focus on low viscosity engine oils. Formulation levers are examined with a statistical analysis of engine test results. The effect of antifoam additive technology, antifoam treat rate, base oil selection, and oil aging, will be presented. The

fundamental insights obtained in this study are relevant to other applications where aeration poses a challenge.

4:40 - 5:00 pm
4177331: Modeling the Mixed-EHL Performance of the Plunger-bore Interface of a Radial Pump
Henry Soewardiman, Shuangbiao Liu, Yip-Wah Chung, Wei Chen, Q. Jane Wang, Northwestern University, Evanston, IL; Jie Chen, Virginia Tech, Blacksburg, VA; Nikhil Murthy, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

The plunger of a high-pressure radial pump is a critical component for efficient and reliable fuel delivery. To minimize leakage, the plunger has a clearance with the bore of at most a few micrometers. However, the combination of tight tolerance along with misalignment of the plunger during operation causes the plunger to be vulnerable to scuffing during reciprocating motion. A numerical model of the pump plunger-bore interface has been developed to understand and quantify the behaviors of contact and lubrication at the plunger-bore interface during a full pumping cycle. This model was created to comprehensively analyze the fuel pumping mechanism and critical rubbing conditions within the plunger-bore interface, including the impact of elasticity of the plunger and the bore caused by the hydrodynamic fluid pressure and solid-solid contact. The interface performance was evaluated through the film thickness, pressure, asperity contact area, and leakage for several candidate fuels.

5:00 - 5:30 pm – Lubrication Fundamentals Business Meeting

6B Hanover C

Commercial Marketing Forum VI

Session Chair: TBD

1:40 - 2:00 pm – Simerics Presentation

2:00 - 2:20 pm – Maintonia Presentation

2:20 - 2:40 pm – On Hold
2:40 - 3:00 pm - Available

3:00 - 3:40 pm - Break

3:40 - 4:00 pm - Available
4:00 - 4:20 pm - Available
4:20 - 4:40 pm – Available
4:40 - 5:00 pm - Available

Fluid Film Bearings-Seals I

Session Chair: Amruthkiran Hegde, Kingsbury, Inc, Philadelphia, PA
Session Vice Chair: Bruce Fabijonas, Kingsbury, Inc., Philadelphia, PA

1:40 - 2:00 pm
4182328: Experimental Rotordynamic Response of a Rotor Supported on Simple Rigid Surface Gas Bearings
Keun Ryu, Youngseok Song, Hanyang University, Seoul, Republic of Korea

Gas bearings offer significant advantages in rotating machinery, including compact size, light weight, extended speed limits, and longer lifecycles compared to traditional rolling element bearings. This work presents experimental measurements of the rotordynamic response and drag torque of a small, rigid rotor supported on simple, cost-effective gas journal and thrust bearings. The rotor was driven by a high-speed automotive turbocharger up to 150,000 RPM. Experimental results demonstrate the stability of the rotor-gas bearing system, with no observed subsynchronous instability. Rotordynamic predictions for imbalance response amplitudes and rigid-mode damped natural frequencies show close agreement with the experimental data. These findings highlight the reliability and favorable rotordynamic characteristics of simple rigid surface gas bearings, making them well-suited for compact, high-speed rotating machinery applications.

2:00 - 2:20 pm
4202492: A Multi-Level Coupling Model for Stiffness and Damping Analysis of Ship Stern Bearings under Mixed Lubrication Conditions
Zhenjiang Zhou, Xincong Zhou, Shaopeng Xing, Wuhan University of Technology, Wuhan, Hubei, China; Konstantinos Gryllias, KU Leuven, Leuven, Belgium; Lun Wang, School of Transportation and Logistics Engineering, Wuhan University of Technology, Wuhan, Hubei Province, China

In ship stern bearing systems, the lubrication film reduces wear by isolating the shaft journal from the bearing surface and provides essential stiffness and damping. Under mixed lubrication, decreased film thickness and localized solid contact make traditional methods for calculating stiffness and damping coefficients inadequate for dynamic load responses. This study proposes a multi-level coupling model based on hydrodynamic lubrication and contact theories, solved using finite difference and small perturbation methods. A harmonic test measured lubrication film stiffness and damping with a maximum error of 11.89%, validating model accuracy. Finally, the effects of varying eccentricities and surface roughness on bearing damping and stiffness were analyzed. Results show that radial stiffness and damping initially increase slowly, then rapidly with higher eccentricity, and increase with surface roughness, with amplified effects as eccentricity grows.

2:20 - 2:40 pm
4202525: Analytical Solution for an Infinitely Long Journal Bearing Lubricated by a Power Law Fluid
Austin Zapata, Andrea Vacca, Purdue University, Lafayette, IN

In the simulation of external gear machines, predicting the gear positions is crucial for determining both the displacing action of the fluid volumes and the configuration of the lateral lubricating gaps. Journal bearings typically support the gears in the radial direction, whose load with respect to eccentricity and squeeze is typically predicted by solving the Reynolds equation. When EGMs are operating with non-Newtonian fluids, though, further assumptions on the fluid must be made to

derive a Reynolds-type equation, and thus to provide an accurate estimate of the load. This study seeks to establish the accuracy of different Reynolds-type equations for power-law fluids by examining the case of an infinitely-long journal bearing, for which an analytical solution is derived, and provide a novel approach for finding the load supported by a finite-width journal bearing lubricated by a non-Newtonian journal bearing with applications to external gear machine simulations.

2:40 - 3:00 pm – Open Slot

3:00 - 3:40 pm - Break

3:40 - 4:00 pm
4205158: Enhancing Plain Bearing Performance: The Role of Isotropic Superfinishing in Optimizing Friction Behavior and Expanding Application Limits
Benjamin Klinghart, Georg Jacobs, Florian König, RWTH Aachen University, Aachen, Germany

Achieving climate goals and mitigating climate change are among the greatest challenges of our time. Increasing efficiency is therefore pursued in all areas. In the field of drive technology, plain bearings offer a significant opportunity to save resources, costs, and installation space. Compared to rolling bearings, they offer a particularly good ratio between load capacity and size. However, they only work effectively when the contact surfaces are fully separated by lubricant. At varying speeds and extreme forces, such as in an engine with a start-stop system or in a wind turbine, plain bearings reach their limits. In order to extend the range of applications, it is necessary to increase the range of optimum operating conditions. Therefore, this study investigates the influence of isotropic superfinishing on the friction behavior and the transition to mixed lubrication in plain bearings.

4:00 – 4:20 pm
4204920: Solid Particle Wear in Hydrodynamic Thrust Bearings
Jean Bouyer, Haykal Bouajila, Bálint Pap, Pprime Institute, Futuroscope Chasseneuil Cedex, France; Pascal Jolly, Institut Pprime - CNRS - Université de Poitiers, Chasseneuil du Poitou, France

Hydrodynamic thrust bearing are well-known for their longevity and reliability due to the absence of contact between the stator and rotor during normal operation. During their service life, (that can be measured in tens of years) they can be damaged even in normal operation: the solid particle pollution of the lubricant can impact the thrust bearings behavior [1, 2, 3 4], thus reducing its service life. In the present study, solid particles were injected in the thrust bearing during lubricated operation and the resulting damage was analyzed through different optical and physical measurements. The influence of thrust bearing geometries, operating conditions (rotational speed, film thickness), particle materials (steel, hardened steel, ceramic) and thrust bearing coating (soft, hard and uncoated) show the importance of understanding particle wear mechanisms in hydrodynamic thrust bearings in order to improve their service life.

4:20 - 5:00 pm - **Fluid Film Bearings/Seals Committee Meeting**

6D Hanover E

Tribochemistry II

Session Chair: Nicolas Molina Vergara, University of Texas at Austin, Austin, TX
Session Vice Chair: John Curry, Sandia National Laboratories, Albuquerque, NM

1:40 - 2:20 pm
4203796: Simulation of Film Reorientation in Vertically Aligned Polycrystalline MoS_2 Films Due to Shear
James Schall, Shima Karimi, North Carolina Agricultural and Technical State University, Greensboro, NC; Brandon Krick, Florida State University, Tallahassee, FL

PVD MoS2 films are found in wide range of structures. The size and orientation of the film depends on the growth kinetics set by the deposition parameters. Growth along the edges is energetically favored relative to highly passivated basal plane which leads to vertical alignment. During sliding, the films reorient to form horizontal layers. Here we will present MD simulations of the reorientation process during contact and sliding between vertically aligned MoS2 films. We observe that bonding between the exposed edges of the opposing surfaces drives pull-out of individual MoS2 sheets from the surface. These flakes are then entrained into the sliding interface and are reoriented horizontally during subsequent sliding which results in lowered friction. This effect is more pronounced in films with larger grain sizes. We hypothesis that the disorder present in smaller grain sized films produces a higher degree of initial passivation which in turn reduces sheet pull out and reorientation.

2:20 - 2:40 pm
4187580: Resistance to Oxidation of MoS_2 Nanoparticles under Severe Oxidizing and Stress Conditions: Relationship Between Chemical Composition and Lubricating Properties.
Fabrice Dassenoy, Jules Galipaud, LTDS/ECL, Ecully, France; Marina Benmansour, Ecole Centrale de Lyon, Ecully, France; Pavel Afanasiev, IRCELYON, Lyon, France; Lucile Joly-Pottuz, MATEIS/INSA, Lyon, France

The purpose of this work was to investigate the tribological behavior of MoS_2 nanoparticles when subjected to severe oxidizing and stress conditions. Friction tests were conducted in dry and strictly controlled environments with an environmentally controlled analytical tribometer. The effects of the oxygen pressure and the temperature on the chemical composition of the nanoparticles and their tribological properties were investigated. XPS was used to follow the evolution of the composition of the MoS_2 nanoparticles during friction tests. Results show a good chemical stability of the nanoparticles from the ultra-high vacuum up to 1 mbar of oxygen, together with stable tribological performance. At higher pressures (i.e., 200 mbar), a slight increase in the friction coefficient associated to a pronounced oxidation is observed. By comparing the results to lubricated environment conditions, it is concluded that the oxygen of the air is not the only oxidation source of the nanoparticles.

2:40 - 3:00 pm
4205110: Origin of Superlubricity of Diamond-Like Carbon (DLC)
Seokhoon Jang, Seong Kim, Pennsylvania State University, University Park, PA; Zhe Chen, Zhejiang University, Hangzhou, China

Hydrogenated diamond-like carbon (H-DLC) is produced as a thin film using plasma-enhanced chemical vapor deposition. H-DLC often exhibits superlubricity, but is this an intrinsic property? This talk suggests that while H-DLC itself is not inherently superlubricious, its structure enables the interface to transform into a superlubricious state under certain shearing conditions. Thus, its superlubricity is considered extrinsic. To support this, the frictional behavior of graphite, amorphous carbon, and diamond is analyzed, along with the run-in process and environmental sensitivity of H-DLC friction. While the superlubricious state is typically associated with a graphitic structure, its exact structure remains unclear and requires further investigation. Understanding the mechanisms behind superlubricity in H-DLC offers valuable insights for developing other lubricious carbon-based materials using alternative synthesis methods.

3:00 - 3:40 pm - B**reak**

3:40 - 4:00 pm
4187660: Effectiveness of a Succinimide Dispersant on the Dispersion of MoS_2 Nanoparticles in Base Oil: Impact on the Tribological Performances.
Fabrice Dassenoy, Marina Benmansour, Jules Galipaud, Beatrice Vacher, LTDS/ECL, Ecully, France; Pavel Afanasiev, IRCELYON, Lyon, France; Lucile Joly-Pottuz, MATEIS/INSA, Lyon, France

Nanoparticles are considered as a real alternative to the use of traditional friction-reducing and anti-wear lubrication additives. They have shown to have exceptional friction-reducing performances allowing them to be considered in many applications, particularly in extreme environments. However, the formulation of lubricants containing nanoparticles involves ensuring the good dispersion of the nanoparticles in the base oil as well as their long-term stability. In this work, we propose to study the effectiveness of a PIB succinimide dispersant on a dispersion of MoS_2 nanoparticles in a PAO base oil and to understand its influence on the tribological performances of the lubricant. For this purpose, an important characterization work of the rubbed surfaces (XPS, TEM, etc.) was carried out.

4:00 - 4:20 pm
4189898: Shear-induced Surface Aromatization as a Superlubricity Mechanism of Amorphous Carbon
Takuya Kuwahara, Osaka Metropolitan University, Sakai, Osaka, Japan; Gianpietro Moras, Michael Moseler, Fraunhofer IWM, Freiburg, Germany

Amorphous carbon (a-C) exhibits superlubricity, friction coefficient below 0.01, in various environments and conditions. However, underlying atomic-scale mechanisms remain controversial. Here our quantum mechanical molecular dynamics simulations propose shear-induced surface aromatization as an alternative superlubricity mechanism and highlight the importance of doping of a-C with low-valent elements. Low-valent elements such as hydrogen, oxygen, and nitrogen lead to the formation of pore embryos and thus non-aromatic sp^2 carbon walls under shear. Subsequently, these pore embryos can be stabilized and grow by local accumulation of dopants. Further growth of pores and formation of aromatic sp^2 carbon walls trigger the formation of a superlubric interface. Interestingly, non-, and silicon-doped a-C do not undergo surface aromatization since these tetravalent elements cannot stabilize pore embryos. Hence, this study paves the way for mechanochemical synthesis of superlubric 2D materials.

4:20 - 4:40 pm
4199923: Enhanced Tribological Performance and Durability of Nanocrystalline Coatings Deposited on 52100 Steel via Tribocatalytic Interactions with Hydrocarbon Lubricants
Zaid Al Hassan, Q. Jane Wang, Yip-Wah Chung, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

We present the development and tribological evaluation of Ni-Cr-Mo nanocrystalline coatings deposited on AISI 52100 steel via physical vapor deposition. The coating composition was designed to enable continuous formation of wear-protective tribofilms through tribocatalytic interactions between the coating and lubricant. To increase hardness and tribocatalytic behavior, the coating architecture was optimized to achieve an average grain size of 20 nm and eliminate columnar domains. Reciprocating tribotests using F-24 lubricant demonstrated a consistent 35% reduction in friction compared to uncoated AISI 52100. Post-test Raman spectroscopy confirmed the formation of carbon tribofilms at the contact surfaces, contributing to the observed friction reduction. This development underscores the potential of nanocrystalline coatings to significantly enhance the tribological performance of steel components with base hydrocarbon fluids, reducing the need for lubricant additives.

4:40 - 5:00 pm
4190004: Atomic-Scale Mechanisms Behind Macroscopic Superlubricity: The Case of Glycerol Lubrication
Thomas Reichenbach, Gianpietro Moras, Michael Moseler, Fraunhofer IWM, Freiburg, Germany; Takuya Kuwahara, Osaka Metropolitan University, Sakai, Osaka, Japan

Achieving superlubricity (friction coefficient < 0.01) in mechanical components is a challenge with clear energy-saving implications that has been recently undertaken by many research groups. Stable superlubricity over a wide range of operation conditions has been recently achieved at Fraunhofer IWM in plain-bearing test rigs. Robust results were obtained for glycerol lubrication of diamond-like carbon and silicon nitride. I will present an atomistic simulation study that analyses different superlubricity mechanisms proposed so far for these tribological systems. We estimate that hydrodynamic lubrication at high speed and lubricant films thinner than 100 nm is only possible at high temperature and in the presence of water. However, tribochemical reactions involving glycerol can produce aromatic carbon surface regions that are smooth and unreactive. These enable superlubricity also when asperity contacts run dry or are separated by nanometric, highly viscous glycerol films.

5:00 - 5:30 pm - **Nanotribology Technical Committee Meeting**

6E Hanover F

Environmentally Friendly Fluids-Synthetics II

Session Chair: Daniel Garbark, Battelle Memorial Institute, Columbus, OH
Session Vice Chair: Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA

1:40 pm - 2:20 pm
4220055: Environmentally Acceptable Lubricants: HEES vs HEPR
John Fang, Nathan Knotts, Christina Li, Chevron Products Company, Richmond, CA

Environmentally Acceptable Lubricant (EAL) market has been growing rapidly due to increased government mandate and public awareness. Major types of EALs are vegetable oil, synthetic ester, polyglycols, and PAO-related hydrocarbons; while they all have their own pros and cons, unsatisfactory performance, such as hydrolytic, thermal, and oxidation stability, product longevity, seal compatibility, et al, has been restraining the growth of this market. This presentation will provide an overview of major regulatory specifications for EAL and introduce a new type of HEPR EAL, which offers significantly improved performance, as well as its application as hydraulic fluids.

2:20 - 2:40 pm
4202771: Innovative Sustainable Additives: Renewable Technology for Lubricants
Kathleen Havelka, Richard Butler, Advancion, Algonquin, IL

Amino alcohols and their derivatives offer a range of structures, including water and oil-soluble amino alcohols, amides, and oxazolines. The versatility, performance and structural diversity of these chemistries make them ideal for various applications where improved sustainability is essential, such as metalworking, chain lubricants, and hydraulic fluids. The sustainability profile of these materials is further enhanced by incorporating renewable raw materials into the production process to create an environmentally responsible amino alcohol technology platform. These innovative additives offer performance that frequently exceeds that of traditional additives while reducing reliance on petroleum. This talk will explore how this environmentally responsible amino

alcohol technology platform can serve as a high-performance, cost-effective solution for developing more environmentally responsible additives and can be leveraged to facilitate market adoption of more sustainable lubricants.

2:40 - 3:00 pm
4178581: Cutting Fluids from Soybean-based Lubricants and Emulsifiers
Jeff Cafmeyer, Daniel Marzolf, Battelle Memorial Institute, Columbus, OH

Metalworking or cutting fluids play crucial roles in lubricating and facilitating heat transfer during the machining of metal substrates. Soybean oil, with its sustainability profile, film-forming properties, and biodegradability, presents a compelling base oil option for this application. Cutting fluids benefit from various traits inherent to soybean oil and its variants (e.g., commodity and high oleic) as well as the chemical modifications Battelle has made to address performance characteristics (e.g., viscosity, pour point, surface tension) and potential issues such as oxidative and hydrolytic stability. Battelle has recently shown that soy-based lubricants and surfactants can perform effectively when cutting cold-rolled steel in both oil-based and water-based formulations. This presentation will offer an update on the efforts to develop a sustainable, soy-based alternative for cutting fluid applications.

3:00 - 3:40 pm - **Break**

3:40 - 4:00 pm
4200533: Hydrolytic Stability of VSP Esters Compared to Standard Diesters and Polyol esters
Andy Johnson, Zschimmer-Schwarz, Ivey, GA

Synthetic esters are well known for their high performance and environmentally friendly characteristics such as lubricant additives and base stocks. Diesters and Polyol esters are widely used in industrial and automotive lubricant applications due to their ability to improve viscometrics, reduce deposits and enhance the solubility of additives in paraffinic oil mixtures. The molecular structure and residual acid composition of certain standard esters leads to hydrolytic stability concerns. The molecular structure of VSP esters based on secondary alcohols results in ester groups with high steric hindrance and resistance to hydrolysis.
Hydrolytic stability test data has been generated comparing VSP esters to a variety of commercial dibasic acid esters and polyol esters. The data presented will support the use of VSP esters in environments where the presence of water demands good hydrolytic stability, such as metalworking, hydraulic fluids, marine, tractor fluid and engine oil applications.

4:00 - 4:20 pm
4201460: Impact of Seawater Content in Lubricants without and with Eco-friendly Ionic Liquids on Chemistry, Viscosity, Wettability, Corrosion, and Tribological Performance
Wenbo Wang, Huimin Luo, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Recently, eco-friendly ionic liquids (ILs) were successfully invented as additives for tidal turbine lubrication, showing encouraging lubricating performance in lab-scale tribological tests compared with baseline gear oils and commercial additives. However, seawater contamination resulting from moisture penetration due to seal aging and long maintenance intervals is a potential challenge. To study the impact, the lubricant chemistry, viscosity, wettability, corrosion, as well as the tribological behavior of PAG oils without and with ILs were investigated when contaminated with seawater at a range of 0.5-3 wt.%. The ILs helped the seawater solubility in PAG and significantly reduced the seawater-induced corrosion.

4:20 - 4:40 pm
4202837: Volatility Characteristics of VSP Esters Compared to Standard Diesters and Polyol esters.
Andy Johnson, Zschimmer-Schwarz, Ivey, GA

Synthetic esters are widely used as base stocks in high temperature lubricant applications due to their low volatility characteristics. Esters can be designed to provide better low temperature viscometrics and lower volatility compared to hydrocarbons of similar viscosity at 40°C and 100°C. The novel molecular structure of VSP esters based on secondary alcohols results in lower volatility compared to standard dibasic acid esters ad polyol esters with similar viscosity.
The data presented will support the use of VSP esters in applications where Noack volatility drives formulation design. VSP esters offer a combination of performance advantages including oxidative and hydrolytic stability combined with natural energy efficiency advantages of low density and high viscosity index.

4:40 - 5:00 pm – **Environmentally Friendly Fluids Committee Meeting**

6F Courtland

Tribotesting II

Session Chair: TBD
Session Vice Chair: TBD

1:40 - 2:20 pm
4189975: Assessment of Stick-Slip Behaviour of Hydraulic Oils using a Tribometer
Arman Mohammad Khan, Shell, Bengaluru, India

Stick-slip phenomenon in hydraulic systems is a detrimental occurrence, wherein two surfaces fail to slide smoothly due to fluctuations in frictional forces. This results in vibrations, noise, and oscillations leading to erratic machine operation. An optimized hydraulic fluid formulation can reduce stick-slip behaviour; however, lack of a standard stick-slip screening test method presents a significant challenge in evaluating the efficacy of formulations during the development phase. Custom test rigs are often employed for this purpose, but they tend to be complex and introduce considerable variability in results. The authors here propose a simple yet effective test method that utilizes a standard tribometer to evaluate stick slip behaviour of lubricants in a reproducible manner. This method, in turn, enables correlating dependency of different components in a hydraulic oil formulation on its stick-slip control. Few examples are shown to demonstrate the effectiveness of this method.

2:20 - 2:40 pm
4205564: Grease Tribological Performance in Electrified Conditions Evaluated Using Four-Ball Tests
Alex Hartzler, Amani Byron, Ashlie Martini, University of California Merced, Merced, CA; Christina Cheung, Anoop Kumar, Chevron, Richmond, CA

Electrified conditions can affect the interactions between mechanical components and lubricants. To better understand these effects, we conducted four-ball tribotests with grease under both electrified and unelectrified conditions. We observed and recorded trends in electrical contact resistance, friction, wear scar diameter, and wear volume. Scanning electron microscopy was used to identify potential wear mechanisms. Results revealed differences in grease performance based

on the presence of applied current or voltage and grease formulation. These findings contribute to optimizing grease formulations for use in electrified environments, offering insights into improved lubrication strategies for electric vehicles and other machinery exposed to electrical conditions.

2:40 - 3:00 pm
4200299: Effect of Ammonia Degradation on Anti-Scuffing Performance of Marine Engine Oil.
James Morley, George Plint, Suresh Chhetri, Phoenix Tribology, Kingsclere, United Kingdom

Ammonia is fast becoming a fuel used in marine applications as a replacement for other fuels. The effect of using ammonia both from unburnt fuel and combustion products on the tribological properties of the lubricating oil is not well known. It is known (Tornatore et al., 2022) that ammonia engines must run high compression ratios, increasing piston-ring blow-by. Marine oils generally contain a variety of anti-wear additives, and are alkaline, in order to minimize corrosion caused by NOx. The aim of this research is to evaluate how a marine oil, exposed to ammonia for periods of time behaves in a simulated ring-liner contact in boundary and mixed lubrication. The experiments used a tribometer to run line contact tests, running nitrided steel against a hard and ground cast iron plate.
Lubricant pre-conditioning was carried out using a proprietary preconditioner, with gas of ammonia/ nitrogen mix (2000 ppm ammonia) bubbled through a fixed volume of oil for times of 1, 2, 5 and 10 hours.

3:00 - 3:40 pm - **Break**

3:40 - 4:00 pm
4200840: Identifying Extreme Pressure Additive Activation via the Mini Traction Machine
Simon Morton, Victoria Parker, Sasol, Westlake, LA

Extreme pressure (EP) additives are an important component of applications performing in the boundary lubrication regime. Additives which are considered EP are molecules such as chlorinated paraffins and sulfur-based EP additives which have varying affinities for the metal surface. These molecules activate at different temperatures and pressures. Once activated they form a tribofim to prevent cold-welding and galling. The activation and performance of these additives can also be affected by other additives in the system. This paper considers methods to identify the activation of these EP additives and determine if other additives are enhancing or deteriorating the system.

4:00 - 4:20 pm
4200523: High-Throughput Metal Analysis of In-Service Oils and Coolants with a Nitrogen-Based Plasma Optical Emission Spectrometer
Mike Plantz, Radom Corporation, Pewaukee, WI

Performance of elemental tribology is typically performed on hundreds of samples at a time, demanding high-speed sample throughput from the laboratory instrumentation. This talk focuses on the use of a novel nitrogen ICP -OES system coupled with advanced autosamplers optimized for the fastest sample handling capabilities. The Radom MICAP-OES 1000 microwave ICP-OES system operates with a highly cost-effective nitrogen plasma system that eliminates the need for a water chiller. Its simultaneous, high-resolution spectrometer provides quick and accurate results for in-service oils and coolants. Unique sample handling automation techniques utilized deliver the ultra-high throughput ICP sample introduction performance required by these laboratories.

4:20 - 4:40 pm
4239350: Elucidation of Molecular Structure and Frictional Properties at Solid-Liquid Interfaces Using FM-AFM and LFM
Kaisei Sato, Yuya Yamaguchi, Shinya Sasaki, Tokyo University of Science, Tokyo, Japan

We developed a system that integrates Frequency Modulation Atomic Force Microscopy (FM-AFM) with Lateral Force Microscopy (LFM), enabling high-sensitivity measurement of lateral forces with molecular resolution. Using this FM-AFM-LFM system, we aimed to elucidate the relationship between the structure of adsorbed molecules at frictional interfaces and their frictional properties

4:40 - 5:00 pm
4178030: Mini Traction Machine-Pin on Disc Test Method to Evaluate the Clutch Friction Properties of Two-wheeler Lubricants and Establishing Correlation with SAE No 2 - JASO T903 Friction Test
Bhupender Singh, TotalEnergies Marketing India Pvt Ltd, Mumbai, India

Passenger cars have separate lubrication systems for engine and transmission, but a motorcycle relies on the same oil (balance of desirable friction and lubricity properties) to lubricate the engine, clutch and gearbox. The SAE No. 2 machine with globally recognized standard JASO T903 is used to evaluate clutch friction properties of motorcycle lubricants and categorizes lubricants into MA & MB. MA and MB indicate high and low frictional performance, respectively. The JASO T903 is a time consuming and costly method and hence could not be used for formulation optimization therefore, a method on MTM2-Pin on Disc is developed to screen MA & MB lubricants. Coefficient of friction is measured using steel on steel contact in MTM2-POD to find a correlation between dynamic and static friction Index results of lubricants tested on SAE2. Correlation established indicating POD test as an efficient screener for JASO T903 saving time and cost during formulation optimization of motorcycle lubricants.

5:00 - 5:30 pm - **Tribotesting Committee Meeting**

6G — Regency V

Materials Tribology VI

Session Chair: Nikhil Murthy, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD
Session Vice Chair: Mary Makowiec, Pratt & Whitney, East Hartford, CT

1:40 - 2:20 pm
4204551: Do Oxide Coatings Strengthen Metal Nanoparticles?
Tevis Jacobs, Ruikang Ding, University of Pittsburgh, Pittsburgh, PA; Ashlie Martini, University of California Merced, Merced, CA

Technology-relevant nanoparticles deform at low loads, impairing their use in industrial applications. While much is known about the effect of particle size on strength, relatively little is known about the effect of coatings. Prior work has suggested that oxide coatings on the surface could impede deformation mechanisms (dislocation nucleation and surface diffusion), thus strengthening nanoparticles. In this investigation, we coated platinum nanoparticles in silicon oxide and compressed them inside of a transmission electron microscope. We coupled the instantaneous stress and strain measurements to real-time high-resolution video of the shape and structure of the particle. The results reveal the separate but interacting influences of size and surface coating.

2:20 - 2:40 pm
4200400: In Situ Formation and Durability of Tribocoatings using $BaTiO_3$ Nanocrystal Additives
Pezhman Palahang, Parker LaMascus, Andrew Jackson, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Marjeta Fusha, Dedrick Morgan, Robert Wiacek, Pixelligent Technologies LLC, Baltimore, MD

Protective surface coatings are typically applied using resource-intensive methods. We have discovered that $BaTiO_3$ nanocrystals (NCs) can form surface-bound antiwear "tribocoatings" via stress-driven sintering at temperatures below 5% of their melting point, where scuffing protection is needed. Using 5 nm ligand-capped $BaTiO_3$ NCs dispersed in base oil in a rolling-sliding ball-on-disc tribometer (a mini-traction machine - MTM), we found that higher temperature enhances the growth rate, thickness, and durability of the coatings, ensuring continued wear protection even without NCs in the oil. We hypothesize that high surface diffusivity allows NCs to sinter together to create the coating. We employed multiple techniques to assess the structure, composition, and piezoelectric properties of the coatings, showing that $BaTiO_3$ NCs offer a promising alternative to pre-deposited coatings on tribological components.

2:40 - 3:00 pm
4189547: On the High Temperature Tribology of Ceramics and Composite Systems
Surojit Gupta, University of North Dakota, Grand Forks, ND

There is an urgent need for materials which can be used in different types of complex tribological environment like fluidic and high temperature conditions. This presentation will be divided into two parts. In the first part, high temperature tribology of ceramics-based materials will be studied. In the second part, high temperature tribology of polymeric systems like PEEK will be presented. Detailed microstructural and wear rate kinetics will be presented for both cases. It is expected that such fundamental studies can be used for bearings and gears which can be used in complex environment.

3:00 - 3:40 pm - **Break**

3:40 - 4:00 pm
4235586: Effects of Powder Reuse on Tribological Properties in Electron Beam Powder Bed Fusion Process of Ti6Al4V
Mohammad Sayem Bin Abdullah, University of Washington, Seattle, WA

Powder resume in Electron Beam Powder Bed Fusion (EB-PBF) process is key to the sustainability of the process to additively manufacture titanium alloy, i.e., Ti6Al4V. The characteristics of the spherical titanium powder changes with due to oxidation and particle deformation, which results in decreased ductility and mechanical anisotropy in EB-PBF Ti6Al4V. As the tribological properties is dependent on mechanical properties, the powder reuse may impact the tribological properties as well. To understand the effects of powder reuse, tribological experiments, sliding wear and erosive wear, were conducted. The EB-PBF Ti6Al4V specimens have been evaluated through advanced microscopy, optical profiler, and microstructural analysis to understand the influence of powder reuse on tribological properties. The paper will also discuss the associated mechanism in the light of powder reuse.

4:00 - 4:20 pm
4200709: Triboelectrification Mechanisms: A Computational Approach to Advanced Material Engineering
Giulio Fatti, Daniele Dini, Imperial College London, London, United Kingdom

Triboelectrification, the generation of static charges through friction, plays a critical role in various industrial and energy applications, from damaging electronics and pharmaceutical processes to sensors and energy harvesting technologies. Despite this relevance, its underlying mechanisms remain elusive. Here, we explore how first-principles simulations offer valuable insights into triboelectrification processes at the atomistic level. Using ab initio methods, we uncover the influence of tribochemical reactions and strain effects on charge transfer, providing a detailed understanding of these interactions. By elucidating these mechanisms, simulations can guide the design of advanced materials that optimize triboelectric properties, leading to more efficient and sustainable engineering solutions. The results offer promising pathways for innovation in tribology and material science.

4:20 - 4:40 pm
4204826: Tribological Behavior of Borided Steel under Inert Gas Atmosphere and Electrical Conditions
Merve Uysal Komurlu, Ali Erdemir, Texas A&M University, College Station, TX; César David Reséndiz Calderón, Leonardo Israel Farfan Cabrera, Tecnológico de Monterrey, Monterrey, Mexico

In this study, we investigated the effects of boriding on the tribological behavior of AISI 4140 steel under electrified sliding conditions. Boriding was performed by the pack-boriding process at 950°C for 3 hours, producing 120-150 µm thick Fe_2B layers. Pin-on-disc tests were conducted in open air (45% RH) and dry Argon with and without contact electrification. When tested in ambient air, borided samples exhibited very low friction coefficients (~0.15) while unborided test pairs had friction coefficients of ~0.8 in air but increased to ~0.9 in Argon. Boriding reduced wear losses dramatically, especially during tests under electrification up to 3 A in air. Raman analysis confirmed severe tribo-oxidation in control samples, while borided samples showed the formation of a slick tribolayer. Low-friction behaviors of borided steel are due to this layer. When tested in argon, minimal tribochemistry or slick layer formation was observed.

4:40 - 5:00 pm
4199972: Material Characterization Using Replicated Low-lubricity Interfaces for Diesel Engine Fuel Delivery Systems
Caleb Matzke, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Nikhil Murthy, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

An experimental tribology method to represent a fuel lubricated piston-cylinder interface was designed to characterize the best material pairs for use in diesel engine fuel delivery systems. Flat cylindrical specimens were run against cylindrical pins using a reciprocating line contact sliding parallel to the pin's center axis as opposed to the more common perpendicular motion. AISI 52100 steel flat pucks and pins were used, as well as 52100 coated with CrN, DLC, and various WC coatings. The interfaces were lubricated with either aviation fuel or fuel components such as decane or ethanol. The interfaces were analyzed using optical microscopes, SEM, EDS, and white light Interferometer to determine the wear performance of each material pair. The top material pairings were determined out of 18 different material pair combinations for piston-cylinder interface in diesel engine fuel delivery systems.

5:00 - 5:30 pm - **Materials Tribology Committee Meeting**

AI and Machine Learning V

Session Chair: Prathima Nalam, SUNY at Buffalo, Buffalo, NY
Session Vice Chair: Nick Garabedian, Datin Company, Karlsruhe, Germany

1:40 - 2:20 pm
4186400: Clustering of Wear Characteristics from Measured Forces with Machine Learning Models
Philipp Sieberg, Shuai Zhu, Morteza Abedini, Stefanie Hanke, University of Duisburg-Essen, Duisburg, Germany

As a system's response, wear behavior is influenced by material properties and additional factors such as lubrication conditions. Modeling and predicting a material's wear behavior with traditional numerical methods is difficult due to the complexity. Recent developments in machine learning offer the possibility of solving higher-order nonlinear problems. In the DFG funded project (525173005), the complex pattern of the wear test data will be used for the categorization of wear mechanisms with data-driven methods. Wear tests are carried out with different materials for data acquisition. Several statistical analyses are then performed on the recorded forces and friction coefficient to extract appropriate features. Clustering algorithms are implemented to categorize the wear behavior. For each cluster, similar equations are formulated based on the statistical distribution of the features. As a result, the wear behavior of unseen samples can be categorized based on the existent clusters.

2:20 - 2:40 pm
4199743: AI, Data-driven Design of Surface Textured Face Seal.
Iwa Ou, Eagle Industry Co., Ltd., Sakado-shi, Saitama-Ken, Japan; Kentaro Yaji, Osaka University, Suita, Osaka, Japan

A face seal with both low leakage and low friction was realized by surface texturing technology. A surface texture consists of several micro-grooves. The friction coefficient and leakage rate are estimated by pressure distribution solved by the Reynolds equation. Since the operating conditions differ for each application, shape optimization based on generic algorithm is performed for each case, and a large amount of analysis data (big data) is generated. The author has shown that it is possible to support or accelerate the design process by utilizing these big data using machine learning. Several examples will be presented: shape optimization based on surrogate model and prediction of pressure distribution by machine learning. Recently, generative AI has been a hot topic. The author has also verified it's usage and present preliminary results combined with genetic algorithm and topology optimization.

2:40 - 3:00 pm
4205221: A Data-Driven Approach to Relating as-Built Surface Topography Parameters to Additive Manufacturing Process Parameters
Samsul Arfin Mahmood, Virginia Tech., Blacksburg, VA; Bart Raeymaekers, Virginia Tech, Blacksburg, VA

LPBF is an additive manufacturing process that enables fabricating parts with complex geometry. However, costly post-processing to modify the microstructure and surface topography drives the need for tailored as-built surfaces. This study presents data-driven models linking the surface topography to LPBF process parameters. Inconel 718 specimens was printed with varied build orientation, laser power and scan speed, and energy density. Areal, deterministic, and hybrid

topography parameters were measured to characterize the as-built surfaces. Machine learning algorithms capture the non-linear relationships between process and topography parameters in both forward and inverse data-driven models. The forward model (XGBoost) results in the highest prediction accuracy where the build orientation and laser power are the primary drivers of the surface topography. Additionally, inverse model (ANN) predicts viable process parameter ranges that print surfaces with tailored as-built topography.

3:00 - 3:40 pm - **Break**

3:40 - 5:00 pm - **Special Data Session**

6I Regency VII

Engine & Drive Train VI: Engine Oil, HEV, and Water-Based

Session Chair: TBD
Session Vice Chair: TBD

1:40 - 2:20 pm
4200829: New Dispersant with Improved Oxidative Stability
Tim Coffy, Wayne Ouellette, TPC Group, Houston, TX

Automotive OEMs have been developing smaller engines that are more powerful, fuel efficient and have lower emissions. These smaller engines have tighter tolerances and run at higher temperatures, so they require lower viscosity oils that allow engine components to move with less resistance. Over time, high engine temperature combined with high shear while under oxidation conditions will thicken formulated engine oil, lower fuel efficiency and can be detrimental to engine components. These conditions especially challenge engine oil dispersants as they are known to increase viscosity under such conditions.
TPC Group has developed a new polyisobutylene (PIB) based dispersant that has shown significantly improved oxidation stability compared to the commonly used dispersant, polyisobutylene succinimide (PIBSI). TPC's new technology was evaluated under CEC-L48 oxidation testing conditions The dispersant structure, characterization and testing performance will be described.

2:20 - 2:40 pm
4200806: Structure-Performance Correlations of Substituted Diphenylamines as Lubricant Antioxidants
Mary Jane Felipe, SI Group, Houston, TX

Lubricating oils are susceptible to oxidative degradation when exposed to oxygen and metal surfaces, leading to the formation of acidic compounds resulting in many issues such as corrosion, deposit formation and viscosity impacts. Substituted diphenylamine antioxidants (SDPAs) are commonly used to enhance the oxidative stability of engine oils. Given rising regulatory concerns surrounding commercially available SDPAs, it is essential to continuously develop and understand the drivers of antioxidant performance. This study investigates the structure-property correlations of various synthesized SDPAs focusing on the impact of alkyl chain length, molecular architecture of substituents, and nitrogen content on oxidation induction time and other performance metrics, including deposit analysis. Furthermore, we will discuss how these correlations vary across different base oil groups, contributing to a deeper understanding of effective antioxidant design for next generation lubricant formulations.

2:40 - 3:00 pm
4187434: What's in your Cylinder Bore? Surface Texture Control in a Most Demanding Application
Mark Malburg, Digital Metrology Solutions, Columbus, IN

Engine cylinder bores require extreme sealing, low-friction sliding, and long-term durability ...all inside one of the most demanding environments. As a result, these bores surfaces are among the most engineered surfaces in the world. Yet there is still much to be learned and performance to be gained. In this talk we will review the common textures and methods for describing, analyzing and ultimately controlling these surfaces for optimal performance.

3:00 - 3:40 pm - **Break**

3:40 - 4:00 pm
4200633: Evaluation of FEI Performance of Ex-High VI Formulations with MoDTC in HEVs and Large Pickup Trucks
Kenji Yamamoto, Koichi Takano, Shinji Iino, Yukiya Moriizumi, ADEKA Corporation, Tokyo, Japan

HEVs will be a major powertrain segment in the coming decades. Since the engine in an HEV operates at relatively low temperatures, high viscosity index oil is crucial for enhancing fuel economy without sacrificing surface protection by the oil film at high temperatures. The FEI performance of extremely high viscosity index (Ex-high VI) formulations with MoDTC was evaluated in two engines: one for an HEV and the other for a pure ICE large pickup truck. Both motored engine tests and chassis dynamo tests were conducted. The measurement points for the motored engine test were selected from the chassis dynamo test conditions under WLTP using the k-means method. The results indicated that Ex-high VI formulations with MoDTC can improve FEI performance not only for HEVs but also for large pickup trucks across a wide range of engine operating conditions.

4:00 - 4:20 pm
4202895: Influence Of Surface Texture On Cylinder Liner / Piston Ring Contact Friction & Wear
Lake Speed, Total Seal, Phoenix, AZ

Extensive testing of various cylinder liner honing techniques revealed interesting effects on both friction and wear depending upon the piston ring face material. Different honing techniques were employed to create Rough, Plateau and Smooth cylinder liner surface textures. These liner sections were tested with stainless steel rings with and without face coatings. Of those face coatings, two PVD applied, one CVD applied and one post lapped hard chrome faced ring were tested in select tribo-pairs. The performance in terms of both friction and wear shifted dramatically between different pairings. These results yield value insights which can be utilized to improve efficiency and durability of internal combustion engines.

4:20 - 4:40 pm
4189901: Understanding the Mechanisms of Surface Damage with Aqueous Based Lubricants Pertinent to EV Applications
Haochen Yao, Amir Kadiric, Imperial College London, London, United Kingdom; Christine Matta, Frank Berens, SKF Research and Technology Center, Houten, Netherlands

Effective lubrication of electric vehicle drive units (EDUs) presents unique challenges in lubricant formulation. The key requirements for an EDU fluid are surface protection at high torque - low speeds, low churning loss at high speeds, and optimum motor cooling. The last two of these can in theory be satisfied by water-based lubricants (WBLs) better than conventional oils. In addition, WBLs exhibit very low friction in full film regime. However, the low pressure-viscosity coefficient of

WBLs leads to poor hydrodynamic film formation while the presence of water can affect boundary lubrication performance. This paper investigates surface damage mechanisms with WBLs using a triple-disc fatigue rig and a high-pressure ball-on-disc tribometer with SLIM, in combination with a set of surface analysis techniques. Results indicate that WBLs can exhibit a complex set of damage mechanisms where the competition between adhesive wear and surface fatigue is key to determining contact reliability.

4:40 - 5:00 pm - **Engine Oil and Drivetrain, Business Meeting**

6J The Learning Center

Gears II

Session Chair: Aaron Isaacson, Penn State University, State College, PA
Session Vice Chair: Xue Han, Cummins, Inc., Columbus, IN

1:40 - 2:20 pm
4177258: Thermal Modeling of Aero Engine Gear Pair under Injection Lubrication: An Investigation of Oil Filtration Effects
Bahadir Karba, Uludağ University, Ankara, Turkey; Burak Kaplan, Yildirim Beyazit University, Ankara, Turkey; Ahmet Yavuz Kanyilmaz, Gazi University, Ankara, Turkey; Ali Furkan Inceel, Istanbul Technical University, Istanbul, Turkey

The thermal behavior of aero engine gear pairs under injection lubrication is not yet understood, particularly when considering particles flow into the pump or last chance filter, where some are captured, and others return to the reservoir where they continue to recirculate. Oil debris have conducted as a solid particle on gear contact zone within in-mesh and out of mesh to understand injection lubrication friction phenomenon either coloumb or viscous state. This study presents a comprehensive thermal modeling approach to investigate the performance of a gear pair under injection lubrication, incorporating the impact of filtration. FEA have simulated the heat balance in the gear pair, considering effects of lubricant flow, oil viscosity, and filtration efficiency using outputs of particle-based solver. This research provides valuable insights into the thermal management of aero engine gearboxes, enabling the optimization of injection lubrication systems and oil filtration designs.

2:20 - 2:40 pm
4205051: Simulating Gear Micropitting Wear on a 3 Ring on Roller Rig
Marc Ingram, Ingram Tribology Ltd, Carmarthen, United Kingdom; Thomas Baldwin, National Physical Laboratory, London, United Kingdom; Clive Hamer, Matthew Smeeth, Thomas Welham, Benjamin Wainwright, PCS Instruments, London, United Kingdom

Micropitting is a type of surface fatigue mechanism where small pits are formed on the surface of gears. The formation of pits leads to a loss of material and a change of geometry on the surface of the gear tooth. This can cause macropits to form and ultimately failure of the part. In this paper we describe the development of a new micropitting test to evaluate the ability of lubricants to prevent micropitting. A three ring on roller test machine is used to investigate the mechanism and accelerate the micropitting process on case carburized 16MnCr5 parts. The test conditions are chosen by first calculating the contact conditions of a gear contact and then emulating these as closely as possible on the screening test rig. Multiple iterations of the screening method have been investigated, with the aim of producing a good correlation to the FZG gear test as defined in FVA 54/7. The screening methods are found to give good correlation in terms of the mechanism and

extent of micropitting.

2:40 - 3:00 pm
4194432: Roll Slide Contacts Simulated with Gear-Cam Modification – Prescreening Lubricants for High Speed Roll-Slide Contacts.
Dirk Drees, Lais Lopes, Pedro Baião, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Mike Anderson, Falex Corporation, Sugar Grove, IL

Several applications in industry rely on rolling-sliding contacts that need to be lubricated to prevent scuffing, wear and also pitting or micropitting. Conventional test setups may use gears (FZG), rollers (such as the MPR) or ball-on-disk configurations (MTM) but each of them have their limitations. The FZG and MPR methods require fairly complex test pieces, whereas the simpler MTM does not reach typical pressures or speeds that can be found in some applications. This presentation shows a middle way to approach the roll-slide mechanism, using a non-definite two-roller on two-ring contact in a multicontact MCTT test machine. Here, a slide-roll ratio in the range of 0.3 to 0.4 can be achieved with fairly simple means and test pieces, so that different lubricants can be quickly compared directly under varying test conditions of speed and contact pressures. A start is made with correlating some results of this method with FZG test results, as well as with pitting and micropitting events.

3:00 - 3:40 pm - **Break**

3:40 - 4:00 pm
4200233: Effect of Tooth Root Fillet on Tooth Root Stress in Short-Fiber-Reinforced Plastic Gears - and What We Can Learn From Biology
Oliver Koch, Wassiem Kassem, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany; Manuel Oehler, Ruhr-Universität Bochum, Bochum, Germany

The geometry of plastic gears used today is usually based on conventional steel gears, which are bound to the restrictions of the machining production of gears. The injection molding process provides more design freedom here. In this work, simulative results are shown for the occurring tooth root stress in plastic gears with various tooth root fillet designs. The simulation method is based on finite element analysis and takes into account the different fiber orientation as well as the complex material behavior of short fiber reinforced plastics.
The analysis includes fully rounded, elliptical and bionic tooth root fillets. The calculation is carried out with homogeneous material as well as with short-fiber reinforced plastics. In addition to the tooth root stress in the initial state, results are also presented for the geometry changed by abrasive wear during operation. It is possible to reduce the tooth root stress by up to 24% by bionic inspired tooth root fillets.

4:00 - 4:20 pm
4307686: A Multi-sensor Framework for Gearbox Diagnostics and Prognostics: integrating Vision-based Inspection with Condition Monitoring Techniques
Toby Verwimp, Hao Wen, Rui Zhu, Achilleas Achilleos, Konstantinos Gryllias, KU Leuven, Heverlee, Belgium

This contribution presents a novel multi-sensor framework for diagnostic and prognostic tests on commercial gearboxes, integrating vision-based inspection with traditional and state-of-the-art condition monitoring techniques. The visual inspection unit captures direct measurements (gear tooth surface images), serving as a ground truth for the indirect measurements (vibrations, temperature, torque, speed). By comparing these, various health indicators can be assessed in terms of early fault detection and fault size tracking. The system was implemented and tested on a gearbox setup consisting of multistage commercial gearboxes and it captures synchronized multi-

modal data to analyze gear pitting initiation and progression. Experimental results demonstrate the framework's ability to initiate, detect and track gear pitting. This research further supports advancements in automated fault detection, sensor fusion strategies, and enhanced prognostic models for industrial gearbox applications.

4:20 - 5:00 pm - **Gears Committee Meeting**

6K Dunwoody

Power Generation II

Session Chair: Elaine Hepley, Solana Consulting Services LLC, Indianapolis, IN
Session Vice Chair: TBD

1:40 pm - 2:20 pm
4199905: A Journey of Varnish Formation and Mitigation - Case Study
Elaine Hepley, Solana Consulting Services LLC, Indianapolis, IN

This presentation will go over a case study of a Hydraulic Forge System that has been experiencing varnish symptoms for the past 8 years, will review test methods, review of data interpretation and timeline of varnish mitigation.

2:20 - 3:00 pm
4232186: Tackling WEC With Copper Filming Lubricant Technology
Leyla Alieva, Sergei Mamykin, Neol Copper Technologies Limited, London, United Kingdom

Numerous studies on the causes of the significant number of early failures in the bearing assemblies of large electric machines have shown that the primary cause is White Structure Flaking (WSF) caused by axial cracking and White Etching Cracks (WEC), with corresponding microstructural changes known as White Etching Areas (WEA). This is believed to result from a combination of mechanical, tribochemical, and electrical effects. Despite ongoing research on these phenomena in various fields of science and technology over the past decades, the driving forces and mechanisms of their formation remain highly controversial. We will describe the mechanics of the underlying tribochemical process through the lens of scientific knowledge about hydrogen wear. We will also describe a method of protecting friction surfaces from micro and macro-pitting, WSF, WEC, and WEA by introducing oil-soluble copper salts into the lubricant resulting in nano-film being formed from copper, which solves the issue.

3:00 - 3:40 pm - **Break**

3:40 - 4:20 pm - **Power Generation Panel Discussion**

4:20 - 5:00 pm - **Power Generation Committee Meeting**

Discussion Roundtable and Ideation Event

5:00 – 6:00 pm

The ideation event will be held in the format of discussion round tables. This format enables both an open discussion with many participants and an easy recap and documentation. For every table, a host proposes a topic for his discussion round table and the participants will discuss and share their opinions on this. The benefit for the host is that they may propose a topic of interest and receive the opinions and views of all other participants. The Ideation Session typically takes 60 minutes but is open ended.

4303820: New Challenges for Tribological Contacts - Additional Electrical Loads
Simon Graf, RPTU Kaiserslautern Landau, Kaiserslautern, Germany

Additional electrical loads in tribological contacts are increasingly becoming a critical issue, particularly in key technologies such as wind turbines and electric vehicles. Rolling bearings in electric machines (motors and generators) as well as gear transmissions are particularly affected, often leading to premature component failures in practice. A key factor in this phenomenon is the complex interaction between the applied electrical field and the tribological conditions within the contact zone.
Join us to exchange insights on mitigating electrical loads in tribological systems and enhancing the reliability and longevity of critical components.

4301843: Ideation Session: Role in Assisting Lubricant Companies with Improving Their Manufacturing Efficiency
STLE Sustainability Committee, Park Ridge, IL

A representative from the STLE Sustainability Committee will lead a practical discussion on sustainability's role in improving the operational efficiency and effectiveness of lubricant companies. Topics that can be covered in the discussion include: expand the use of renewable raw materials, process innovations that can be conducted to reduce the consumption of energy in the manufacture of lubricants, and the use of sustainable packaging for lubricants. The objective of this ideation session is to have participants present ideas on what their organizations are doing or intend to do to accomplish these objectives. Hopefully, cross-fertilization of these ideas will lead to new approaches that contributors can take back to their workplaces and use to benefit their organizations. Input from Ideation Session attendees will be documented for further review and guidance for the STLE Sustainability Committee and STLE Membership.

4301839: Ideation Session: Role of Sustainability in Tribology Innovation
STLE Sustainability Committee, Park Ridge, IL

A representative from the STLE Sustainability Committee will lead a visionary discussion on the role of sustainability in tribology innovation now and into the future. The purpose of this ideation session is for participants to engage in a discussion about how the tribology field can develop innovative products and services that will enable users to achieve sustainability through reducing production carbon footprints for their processes, improving their plant efficiencies, reducing energy usage, and reducing operating costs. A key element of the discussion will be how can lubricants, derived from synthetic, renewable, and re-refined sources, be better employed to provide superior performance in a wide range of automotive and industrial applications. Input from Ideation Session attendees will be documented for further review and guidance for the STLE Sustainability Committee and STLE Membership.

4291481: The State of Tribology Education in Academia and Industry
Robert Jackson, Auburn University, Auburn, AL

Education is essential for increasing the workforce and the general understanding of the importance of tribology. At this roundtable discussion the state of education in tribology will be the focus topic. The discussion includes but is not limited to the following questions. What is the current state of tribology education in academia and industry? Are tribology topics still required in many institutes, such as in Machine Design courses in Mechanical Engineering? What practices are currently employed to improve tribology education? What current research in improving tribology education in academia is being conducted? What the differences between regions of the world? What are possible new approaches to improve tribology education representation in academia and industry?

4180126: Global Energy Transition and Its Impact on Fuel and Lubrication
Michael Holloway, 5th Order Industry, Highland Village, TX

This work focuses on analyzing the implications of the shift towards renewable energy sources on the fuel and lubricant industry. The global energy landscape is undergoing a profound transformation, driven by the urgent need to address climate change and reduce reliance on fossil fuels. This shift towards renewable energy sources, such as solar, wind, and hydropower, is reshaping the fuel and lubricant industry in significant ways. This keynote paper will delve into the implications of this energy transition on the fuel and lubricant sector, including Market Dynamics, Technological Advancements, Regulatory and Policy Implications, Supply Chain and Logistics. The paper will discuss the potential disruptions to the supply chain and logistics of fuels and lubricants as the industry transitions to new energy sources. It will explore the challenges and opportunities associated with the shift towards decentralized energy production and distribution.

7A Hanover AB

Lubrication Fundamentals III

Session Chair: Xin He, Syensqo, Levittown, PA
Session Vice Chair: Kuldeep Mistry, Chevron Oronite Company, Richmond, CA

8:00 - 8:40 am
4184313: Antiwear Additive Behaviour in Zero and Low Oxygen Atmospheres
Hugh Spikes, Jie Zhang, Vojin Lukic, Janet Wong, Imperial College London, London, United Kingdom

The strategy of inerting lubricants in nitrogen gas supplied by a nitrogen concentrator offers enormous opportunities for increasing the sustainability of lubricants by preventing their oxidative degradation. However, it is important to ensure that lubricant additives that have developed over many years to be effective in an air environment with 21% oxygen are still effective when little or no oxygen is present. This talk outlines the concept of lubricant inerting and then describes research to measure the influence of oxygen level in the lubricant on the tribofilm-forming properties and thus friction and wear response of a range of antiwear additives. As well as furthering the introduction of lubricant inerting, the study also provides new insights into the mechanisms by which antiwear additives control wear.

8:40 - 9:00 am
4189838: Friction and Wear Behaviour of Volatile Fuels using a Sealed Tribometer
Jie Zhang, Hugh Spikes, Janet Wong, Imperial College London, London, United Kingdom

The quest to reduce CO_2 emissions is leading to increased use of fuels based on gasoline/ethanol blends. In practical terms it is quite difficult to measure the tribological properties of these fuels because they undergo selective evaporation and thus change composition during testing at realistic temperatures. In this presentation we describe the use of a sealed tribometer, an HPR, to measure the friction and wear properties of these fuels over a range of temperatures and pressures. Based on the results obtained, the ability of these fuels to form tribofilms and their underlying mechanisms of action are discussed.

9:00 - 9:20 am
4199601: Surface Asperity-Enhanced Micro Electrical Discharge in Lubricated Contact Interfaces
Xiaoman Wang, Shuangbiao Liu, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL; Ning Ren, Valvoline Global Operations, Lexington, KY

Electrically induced bearing damage (EIBD) is a major problem for lubricated interfaces of machine elements subjected to an electric field, especially in applications such as electric vehicles (EVs). When the electric field across a non-conducting lubricant film exceeds its dielectric strength, an electrical discharge occurs, causing surface damage. Surface asperities enhance the local electric field, which can lead to microscale discharge, causing micro-pitting in regions corresponding to the minimum film thickness within the elastohydrodynamic lubrication (EHL) regime. This work analyzes the enhancement of asperities of a rough surface on electric field, from which a field enhancement parameter is defined to quantify the influences of different asperity shapes. The field-enhancement effect of multiple asperities is also numerically studied. The findings are integrated into an EHL model to establish criteria for electrical discharge in lubricated elements exposed to an electric field.

9:20 - 9:40 am
4215761: Fast and Accurate Models for Tribology-centred Design
Daniele Dini, Suhaib Ardah, Imperial College London, London, United Kingdom; Francisco Profito, Polytechnic School of the University of São Paulo, São Paulo, Brazil

Lubrication modelling necessitates a balance between computational efficiency and accurate representation of physical phenomena, particularly when bridging microscale surface effects with macroscale system responses. This work introduces a robust computational framework that integrates novel, geometrically flexible, mass-conservative formulations with advanced homogenization strategies, enabling a unified treatment of the interplay between microscale surface features and macroscale tribodynamics effects. This framework provides effective macroscale representations while preserving critical small-scale fluid-solid interactions that govern lubricated interfaces. Links to newly-developed methodologies that preserve molecular-level details complete the picture and capture chemo mechanical interactions. By leveraging this multiscale approach, we establish a robust predictive platform that enhances tribosystem modelling and drives innovations in surface engineering and lubrication technology.

9:40 - 10:00 am
4215763: Digital Twins of Lubricated Systems and Their Evolution - Digital Mini Traction Machine
Filimonas Kaliafetis, Suhaib Ardah, James Ewen, Daniele Dini, Imperial College London, London, United Kingdom

This research focuses on replicating a mini traction machine (MTM) in the virtual environment. The MTM is a ball-on-disc instrument used to measure the frictional properties of tribological contacts and provide the user with data regarding the performance of the lubricant used. Thus, the MTM has been widely used for lubricant screening and testing. A digital model of the MTM would allow faster lubricant screening and testing as it would eliminate or at least reduce the need for performing physical experiments. A digital shadow or digital twin of the MTM would also serve as a proof of concept for creating digital twins of any lubricated system which would ultimately allow full remote monitoring and prediction of system conditions. During the presentation, the framework being developed to build the model and shadow of the MTM will be discussed and initial results will be presented.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4204943: Mechanism of Low Friction of Fullerene-Added Oil Under Boundary/Mixed Lubrication
Tomomi Honda, University of Fukui, Fukui, Japan

Fullerenes are attracting attention as a new multifunctional additive. In the case that such fullerene-added oils are used in actual equipment, it is important to elucidate the mechanism by which fullerenes inhibit the autoxidation reaction of lubricating oil such as the amount of reaction per molecule, changes associated with the reaction, and evaluation of the reactants. In this study, we evaluated the friction and wear properties of the fullerene reactants after their antioxidant function to elucidate the antioxidant mechanism of fullerenes. As a result, it was clarified that the fullerene reactants contribute to low friction and wear. To confirm the existence state of fullerene in a solvent like the state in oil, we performed observations using FE-SEM. From the observation, it was found that a layered aggregate was formed. The reactants of fullerenes after the antioxidant function contribute to low friction and wear.

11:00 - 11:20 am
4201925: Preventing Premature Wear - The Critical Role of Oil Flushing in Pre-Commissioning
Anshuman Agrawal, Minimac Systems Pvt Ltd, Pune, Maharashtra, India

A newly bought appliance or machinery is expected to function smoothly and efficiently from the first use, which it fairly does. But the world of manufacturing runs on a different principle. While we expect it to run flawlessly, industrial machinery requires proactive care; and the first step to it is a pre-commissioning activity called - OIL FLUSHING. This cleaning process removes contaminants like rust and debris from the pipelines and equipment. This critical step ensures optimal performance and longevity by preventing premature wear and tear.
This paper discusses the process of oil flushing and determines its importance, advantages, case studies, and risks of neglecting it. It also discusses the best practices for optimizing this process.

11:20 - 11:40 am
4204984: Friction Reduction Performance of Nanodiamonds and MXenes in Presence of Organic Friction Modifier
Afrina Khan Piya, Liuquan Yang, Ardian Morina, University of Leeds, Leeds, West Yorkshire, United Kingdom; Nazanin Emami, Lulea University of Technology, Lulea, Sweden

Tribological performance of nanodiamonds with Ti_3C_2Tx Mxenes in presence of glycerol monooleate (GMO), an organic friction modifier, has been investigated with PAO: polyalphaolefin synthetic oil by using a pin-on-disc reciprocating tribometer at 80 °C. This noble additive formulation showed friction and wear reduction of approximately 75% and 46% in comparison with base oil. This significantly improved frictional performance was due to the tribochemical interaction between the additives present in the lubricant formulation. A synergistic mechanism was observed due to adsorption of GMO on steel surface and embedment of nanodiamonds inside the tribofilm. A robust and chemically reactive tribofilm was formed due to mechanical interlocking of nanodiamonds, which interacted with MXene nanoflakes to form the tribofilm confirmed by the higher resolution TEM. This study is essential to further developing efficient lubricant without using harmful sulphur and phosphorus-containing additives.

11:40 am - 12:00 pm
4180134: International Cooperation and Standards in Lubrication
Michael Holloway, 5th Order Industry, Highland Village, TX

This paper covers the importance of global collaboration and standardization in promoting quality and safety. The global lubricant industry is highly interconnected, with products and services traded across borders. To ensure the quality, safety, and compatibility of these products, international cooperation and standardization are essential. This paper will explore the importance of global collaboration and standardization in promoting quality and safety within the lubricant industry. By fostering international cooperation and standardization, the lubricant industry can enhance product quality, improve safety, and promote sustainable development. This paper will provide valuable insights into the importance of global collaboration and the benefits it can bring to the industry.

7B Hanover C

Environmentally Friendly Fluids - Synthetics III

Session Chair: Selim Erhan, Process Oils, Inc., Trout Valley, IL
Session Vice Chair: Kathleen Havelka, RDA, Advancion, Buffalo Grove, IL

8:00 - 8:40 am
4204780: Cool, Clean, and Green: Innovations in Synthetics Driving the Future of Data Centers
Shubhamita Basu, Amir Farzaneh, Logan Tseng, Perstorp, Taipei, Taiwan

Immersion cooling is rapidly transforming data centers, driven by the growing demand for energy efficiency and high-performance computing. Among the emerging cooling solutions, synthetic esters stand out for their exceptional dielectric properties, material compatibility, and long-term stability. The breakthrough development of PFAS-free liquids with low global warming potential (GWP) and zero ozone depletion potential (ODP) marks a crucial step towards greener, more sustainable data centers. This presentation will explore the cutting-edge innovations reshaping the future of data centers, enabling them to meet tomorrow's performance needs while advancing global environmental goals.

8:40 - 9:00 am
4205689: Sustainability in Motion
Rishabh Shah, Acme-Hardesty, Blue Bell, PA

This study focuses on enhancing the eco-friendliness of metal working fluids by substituting traditional synthetic additives with sustainable alternatives. These alternatives are derived from natural sources such as castor oil, palm oil, and soy-based derivatives. The critical challenge addressed is the compatibility of these sustainable fluids with improved performance and enhanced hydrolytic stability. The objective of this research is to evaluate sustainable metal working fluids that not only mirror the polarity and hydrophobicity of synthetic alternatives, but also match their performances. To validate the efficacy of these sustainable metal working fluids, the study conducts a series of critical performance evaluations, while understanding sustainable processes and product characteristics. The outcome of these assessments will enable us to better evaluate sustainable practices, promote a greener and more sustainable future for metal working operations

9:00 - 9:20 am
4243040: On Razor’s Edge: Balancing Performance and Sustainability for Next-Generation Hydraulic Fluids
Leon Maser, ADDINOL Lube Oil GmbH, Leuna, Saxony-Anhalt, Germany

Developing high-performance lubricants that meet both demanding operational requirements and stringent environmental regulations remains a critical challenge in tribology and lubrication engineering. The development of a new hydraulic fluid, engineered to deliver exceptional performance while adhering to rigorous environmental standards, is explored. The fluid passed the Bosch Rexroth hydraulic fluid test, a stringent industry benchmark for performance, showcasing its stability and efficiency under high-pressure and high-temperature conditions. In parallel, it earned the prestigious EU Ecolabel, underscoring its status as an environmentally acceptable lubricant that minimizes ecological impact without compromising functionality. The technical hurdles encountered are discussed and it is demonstrated how innovative formulations bridge the gap between industrial performance and environmental stewardship, exemplifying the role of lubricant technologies in sustainable engineering.

9:20 - 9:40 am
4216786: Chemical Modification of Regular and High Oleic Soybean Oil
Brajendra Sharma, Majher Sarker, Sevim Erhan, USDA/ARS/NEA/ERRC, Wyndmoor, PA; Sougata Roy, Iowa State University, Ames, IA; Piash Bhowmik, University of North Dakota, Grand Forks, ND

Environmental regulations are accelerating the development of biobased lubricants in total loss applications. Natural oils like soybean oil have poor thermo-oxidative stability and low-temperature flow properties. These limitations must be addressed to perform reasonably in low and high-temperature applications. One of the ways to overcome these limitations is to attach branching at double bond sites of fatty acids present in triacylglycerol. In this work, isopropyl groups are added at the double bonds of fatty acids present in soybean oil resulting in double bond saturation as well as the addition of branched structures. This approach was extended to both regular soybean oil and high oleic soybean oil. The presentation will discuss the structural and tribological characterization of modified regular soybean oil and high oleic soybean oil.

9:40 - 10:00 am
4203786: Hydrolytic and Oxidatively Stable Esters – Fit for the Demands of the Modern World
Kevin Duncan, Cargill, Snaith, United Kingdom

Since the implementation of the European Ecolabel and the Vessel General Permit legislation, esters have become the preferred choice as base fluids for environmentally acceptable lubricants (EALs) due to their high biodegradability and low environmental toxicity. However, this biodegradability often reduces product life due to hydrolysis. Historically, this trade-off has been accepted, but there is now a demand for lubricants that offer extended fluid life and excellent sustainability. In response, we have developed groundbreaking technology that meets stringent environmental standards and significantly reduces hydrolysis potential to the level of synthetic mineral oils. Additionally, this technology exhibits unprecedented oxidation stability, reducing reliance on conventional antioxidants. In this paper, we present the theoretical framework and performance data of this disruptive technology, demonstrating its potential to revolutionize the industry by providing high-performance, EALs

10:00 - 10:40 am - **Break**

7C — Hanover D

Fluid Film Bearings-Seals II

Session Chair: Bruce Fabijonas, Kingsbury, Inc., Philadelphia, PA
Session Vice Chair: Amruthkiran Hegde, Kingsbury, Inc, Philadelphia, PA

8:00 - 8:40 am
4205485: Controlling Seal Vibration Using Lubricant Composition
Tom Reddyhoff, Imperial College London, London, United Kingdom; Sorin-Cristian Vladescu, King's College London, London, United Kingdom

Hydraulic seals are key industrial components that can suffer from unwanted friction induced vibration (FIV). The types of FIV mechanism that occur in these components, and how they may be controlled, are not well known. To address this, we conducted sliding friction tests on contacts between seal materials, lubricated by hydraulic fluids, under speeds and contact pressures typical of hydraulic machines. FIV that occurred under certain conditions was captured and analyzed. The results shed light on the FIV mechanisms that are occurring, and how these depend on friction characteristics, which in turn can be controlled by varying lubricant composition. The dependences of FIV on test conditions such as load, speed, and temperature were studied revealing further insights in to the under underlying FIV mechanisms and how they may be controlled.

8:40 - 9:00 am
4205238: Influence of Wear on the Threshold Speed of Hole Entry Hybrid Conical Journal Bearing Compensated with Capillary Restrictor
Vikas Phalle, Vishwadeep Handikherkar, Veermata Jijabai Technological Institute (VJTI) Mumbai, Mumbai, Maharashtra, India; Sanjay Pawar, Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India

Nowadays, Hybrid journal bearing are used mostly to take advantages of both hydrostatic and hydrodynamic actions simultaneously. Also, they have significant advantages of carrying radial and axial load simultaneously. As they are used for high-speed application, they may be subjected to change in speed during their long duration of service life. These bearings are also subjected to wear, so this paper presents an analytical approach is to study the effect of wear on the threshold speed of hole entry hybrid conical journal bearing compensated with capillary restrictor. The modified Reynolds equation governing the laminar flow of is viscous incompressible lubricant in the clearance space of conical journal and bearing is solved by Finite Element Method. Numerically simulated results indicate that appreciable change in the threshold speed of worn hybrid conical journal bearing as compared to unworn bearing of same configuration.

9:00 - 9:20 am
4182912: Elasto-hydrodynamic Lubrication Analysis of a Porous Misaligned Crankshaft Bearing Operating with Nanolubricants
Benyebka Bou-Saïd, INSA Lyon, Villeurbanne, France; Mustapha Lahmar, Reda Hamel, Guelma University, Guelma, Algeria

The combined effects of the characteristic size and concentration of inorganic fullerene-like tungsten disulphide nanoparticles (IF-WS2 NPs) on the nonlinear dynamic behavior of a gasoline engine crankshaft bearing are theoretically and numerically investigated using the V. K. Stokes micro-continuum theory. It is assumed that the crankshaft is rigid and the main bearing consists of a thin poroelastic liner. The Krieger-Dougherty law is included in the proposed EHD model to account for the viscosity variation with respect to the volume fraction of nanoparticles. The Reynolds equation is derived in transient conditions and modified to account for the size of nanoparticles and the bearing-liner permeability property. According to the obtained results, the combined effects of the size and concentration of fullerene-like nanoparticles on the dynamic behavior of a compliant dynamically loaded crankshaft bearing operating with dynamic misalignment are significant and cannot be overlooked.

9:20 - 9:40 am
4192700: In-Situ Observation of a Radial Seal Under the Grease Lubrication and Oscillating Operation by Fluorescence Induced Microscopy
Takao Horiuchi, Ayako Aoyagi, Yohei Sakai, NOK Corporation, Fujisawa-shi, Japan; Syunsuke Sato, NOK KLÜBER Co.,Ltd., Kitaibaragishi, Japan

Radial seals are used in the joints of industrial robots with oscillating movements, to prevent leakage from the reduction gear’s grease lubrication. The sealing mechanics have not been completely clarified due to the non-Newtonian properties of grease and the complexity of oscillating operations. In this study, the sealing performance of radial seals was investigated in grease lubrication and oscillating operations to clarify the mechanism. Film thickness and thickener distribution on the sealing surface were observed using a fluorescence method. Li-soap grease served as a lubricant, and Pyrene and Coumarin 6 were used as fluorescence agents. Pyrene was used to observe film thickness, while Coumarin 6 was used to observe thickener. The results suggest that sealing performance varies with grease base oil viscosity and operating conditions, as the fluorescence observation also indicate differences between the film thickness and thickener distribution on the sealing surface.

9:40 - 10:00 am
4194178: Experimental Test rig to Investigate Gaseous Mixed Lubrication Regime
Julian Le Rouzic, Oumaima Nakiri, Mihai Arghir, Universite de Poitiers, Futuroscope Chasseneuil, France

Designed to minimize the leakage of the fluid and have low friction, gas seals often have to operate in mixed regime. Despite the fact that they are critical components in many mechanical systems, there is a lack of understanding of how mixed regime operates with compressible fluids. This shortcoming motivated this project to study this regime fundamentally, both experimentally and theoretically, in order to provide a thorough description of the interface.
A dedicated instrumented tribometer has been developed to allow pressurized air to flow between rough surfaces while monitoring the interface with sensors. The assumptions that both waviness and roughness play a role in lift generation and modify the flow rate have been investigated on several configurations for rough surfaces. Results are compared with numerical modelling based on multiscale approach.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4194182: Elastomer Shaft Seals in Oscillating and Low-Temperature Wind Turbine Blade Pitch Control Applications
Max Marian, Bengt Wennehorst, Mousa Amro, Gernot Bayer, Gerhard Poll, Leibniz University Hannover, Garbsen, Germany

This contribution provides a summary of two research projects focusing on the elastomer shaft seal operating performance at low temperatures and under conditions of oscillating shaft rotation. Experimental results were obtained for model systems with plain elastomer shaft seals made of NBR and FKM, both lubricated with mineral and polyglycol oils, respectively.
The main findings are applied to the protective seals of the widely used individual blade pitch control system of modern multi-megawatt wind turbines, the grease-lubricated rolling element bearings of which are subject to a combination of both slow oscillating rotations and longer standstill periods; in these applications, further challenges arise from outdoor exposure and low operating temperatures in combination with large and continuously changing elastic deformations of the blade bearing components due to high bending moments.

11:00 - 11:20 am
4199802: Sealing of Water-Based Gear Fluids with Radial Shaft Seals: Opportunities and Challenges
Jens Kondratiuk, Hilti Corporation, Schaan, Liechtenstein; Balasubramaniam Vengudusamy, Klüber Lubrication München GmbH & Co. KG, München, Germany

Compared to traditional gear oils, water-based gear fluids significantly reduce friction and enhance gearbox efficiency. However, sealing the gear box inlet by means of a radial shaft seal is challenging. This is especially the case when high sliding speeds, small shaft diameters, and occasional starved lubrication conditions are present, which lead to elevated temperatures at the sealing contact. FKM radial shaft seals are preferred in these scenarios but show weaknesses in contact with water or water vapor. This study explores the benefits and challenges associated with different FKM and NBR materials in the presence of water-based gear fluids, especially regarding sealing performance and wear behavior. The study is conducted on a custom-built test rig designed to simulate sealing conditions found in machinery operating in all orientations.

11:20 - 11:40 am
4200605: Contact Evaluation of Sealing Surface with Concentrated Polymer Brush
Takeya Aoki, Yuichi Aoyagi, Ayako Aoyagi, NOK Corporation, Fujisawa, Kanagawa, Japan; Koichiro Ishida, Yoshinobu Tsujii, Institute for Chemical Research, Kyoto University, Uji, Kyoto, Japan

End-grafted polymer chains in ultrahigh density are called concentrated polymer brushes (CPBs). CPBs exhibit a highly extended chain conformation in a good solvent, which provides remarkable tribological properties. We investigated the feasibility of CPBs for the usage as sealing material, since the demands on long durability and low friction of dynamic seals are growing due to environmental issues. Fabricating CPBs on seal faces significantly reduced friction torque and improved fundamental sealing performance. However, the mechanism of sealing performance by swollen polymeric materials like CPBs is not clarified. To understand this, fluorescent observation of surfaces was carried out. The fluorescent molecules were dissolved in an ionic liquid as a lubricant or copolymerized with poly (methyl methacrylate) brush. The fluorescence intensity was measured as a function of the contact load. This result will lead to an understanding of brush conditions under which CPB seals perform well.

11:40 am - 12:00 pm
4200685: Low Temperature Friction Response of High-Frequency Reciprocating Elastomer-Steel Tribosystems
Daniel Korn, Jens Kondratiuk, Hilti Corporation, Schaan, Liechtenstein

Understanding the friction effects in high-frequency sealing systems is crucial for the robust design of diverse machine components. One notable challenge is the recurring start-stop events along the stroke length, which cause continuous variations in lubrication conditions. This study investigates the high-frequency friction of an O-ring and a steel-cylinder-segment tribosystem at both room temperature and sub-zero conditions. The frictional responses by changing PAO lubricant viscosities and surface topographies are examined. Experiments are conducted using a linear oscillating tribometer equipped with a custom-built sample holder for cooling. Experimental findings are compared with numerical simulations to provide a comprehensive understanding of frictional behavior under different conditions.

7D — Hanover E

Biotribology I

Session Chair: Kartik Pondicherry, Anton Paar GmbH, Graz, Austria
Session Vice Chair: Quentin Allen, Brigham Young University, Provo, UT

8:00 - 8:40 am
4200539: Lubricating Response of a Novel Synthetic Mucin Molecule
John McClimon, Sumit Kumar, Ben Alexander, Margaret Lin, University of Pennsylvania, Conshohocken, PA; Manuel Lema, Farhana Khan, Adam Braunschweig, City University of New York, New York, NY; Robert Carpick, University of Pennsylvania, Philadelphia, PA

Mucus secretions provide numerous functions, including lubrication. A major component in mammalian mucus is mucins. We use a synthetic mucin that mimics the structure of glycosylated mucin domains. Lubrication of SiO_2-PDMS contacts by aqueous solutions of this mucin are studied with triborheometry and colloidal atomic force microscopy (AFM). Macroscale triborheometry shows that the synthetic mucin lubricates across a wide speed range and improves with increasing mucin concentration. AFM shows that lubrication is accomplished by reducing both the

PDMS/SiO_2 adhesion and the interfacial shear stress, attributed primarily to the formation of a tribofilm on the SiO_2, whose thickness and morphology depend on the mucin concentration. Thicker, more durable tribofilms with nearly complete coverage are observed at higher concentrations, which may help explain the better macroscale lubrication seen at higher concentrations.

8:40 - 9:00 am
4188604: Modeling Cartilage Rehydration: A Numerical Approach
Arshad Kalathil Ashik, Daniele Dini, Imperial College London, London, United Kingdom; Carmine Putignano, Politecnico di Bari, Bari, Italy

Articular cartilage is a porous, soft tissue present in the synovial joints that distribute the load and lubricate the joint for smooth body movements. The interstitial fluid within the cartilage and the synovial fluid bath outside the cartilage contribute to its extremely low frictional properties. During static loading, the interstitial fluid exudes from the cartilage tissue and flows back during sliding induced loading. However, degenerated cartilage fails to recover the interstitial fluid upon unloading, leading to improper lubrication, resulting in conditions like osteoarthritis. In this study, we present a fluid-solid interaction fully coupled model that tackles cartilage lubrication at multiple scales and accounts for the surface roughness, cartilage permeability and porous flow. The results of this study provide insights into cartilage rehydration, outlining the parameters that contribute to sliding lubrication during joint articulation and fluid flow along the contact region.

9:00 - 9:20 am
4200069: Synovial Fluid Is Not Unique in Its Ability To Drive Articular Cartilage Superlubricity
Emily Lambeth, Sean Farrington, Brooklyn Tyndall, Ann Thomas, Norman Wagner, David Burris, Christopher Price, University of Delaware, Newark, DE

Articular cartilage easily sustains superlubricity-sustaining friction coefficients (μ)£0.004 in vivo. This lubricity has been attributed, in part, to aspects of its bathing (synovial) fluid (SF). Our recent work indicates the SF component hyaluronic acid (HA) can sustain cartilage μ£0.004 under physiological benchtop sliding conditions. However, whether such μ are due to HA-specific or other more generalizable lubricant properties remains unclear. Therefore, bovine osteochondral explants underwent tribomechanical characterization with multiple lubricants, including SF constituents and non-physiological/natural lubricants of comparable rheologic behaviors as HA (e.g., polyethylene oxide & mucin). Of the SF constituents, only HA sustained biofidelic μ (~0.004). Unexpectedly, all HA-like non-physiological lubricants demonstrated quite low μ (<0.01) suggesting that cartilage's superlubricity is not unique to SF/HA, providing new insights into possible mechanisms of cartilage's lubrication.

9:20 - 9:40 am
4198749: Role of Gold Nanoparticle Capping Ligands in Modulating Gelation and Friction of Polyacrylamide Hydrogels
Meagan Elinski, Brianna Couturier, Gloria Kozak, Anna Zini, Hope College, Holland, MI

Nanomaterials in healthcare applications are likely to be subjected to dynamic environments that are sensitive to interfacial interactions, making it crucial to understand how chemical features affect key processes. This study examines gold nanoparticle capping ligands with varying hydrogen bonding capabilities and molecular weights, interacting with a polyacrylamide (PAM) hydrogel under oscillatory motion to monitor gelation, and during sliding to assess friction control. Ligands include citric acid, polyacrylic acid, polyvinylpyrrolidone, and cetyltrimethylammonium bromide. We find that gold nanoparticles in the PAM matrix accelerate gelation. During sliding, pure PAM hydrogels in nanoparticle solutions show friction trends based on a balance of hydrogen bonding and molecular weight. However, in PAM-gold composites, molecular weight dominates. These

findings highlight how ligand functionality influences chemical-mechanical interactions based on the dynamic environment.

9:40 - 10:00 am
4205152: Bio-Inspired Gradient Hydrogels
Ahmed Al Kindi, Nemea Courelli, Angela Pitenis, University of California, Santa Barbara, Santa Barbara, CA

Surface gel layers can be created by polymerizing hydrogels in molds made of low surface energy materials near oxygen-rich interfaces. These gel layers exhibit a gradient in polymer density, resulting in soft and lubricious surfaces. Mucin, a biopolymer secreted by epithelial cells, serves as a prime example of a naturally occurring gradient hydrogel. Our research aims to explore the dynamics of both synthetic and natural, bio-inspired gradient gel networks using microrheological tools. This approach will provide deeper insights into the structural and functional characteristics of bio-inspired gradient gel networks, potentially leading to enhanced applications in biomedical engineering and material science.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4203632: Establishing In Vitro and Ex Vivo Oral Friction Testing System
Hsu-Wei Fang, Chen-Ying Su, National Taipei University of Technology, Taipei, Taiwan

Saliva is the key component for maintaining oral health, but Xerostomia patients cannot maintain good quality of life due to a reduction in the lubricating property of saliva resulting in an increased irritation among oral organs. An in vitro and ex vivo oral friction testing system was established to understand the biotribological functions of saliva and its relationship with tongue. The result showed distinguished frictional behavior of polydimethylsiloxane (PDMS) under dry and lubricating condition by using an in vitro oral friction testing system. Porcine tongue-PDMS materials were used for ex vivo friction tests. The result demonstrated that higher roughness of porcine tongue resulted in lower friction coefficient under dry condition, but opposite result was observed under lubricating condition. The in vitro and ex vivo oral friction testing system established here may contribute to develop a longer-lasting artificial saliva that can benefit Xerostomia patients in the future.

11:00 - 11:20 am
4220621: From Cooking Eggs to Spreading Cheese - Tribological Testing of Food and Beverages
Kartik Pondicherry, Anton Paar GmbH, Graz, Austria; Paul Staudinger, Anton-Paar GmbH, Graz, Austria

Targeted studies have proven highly effective in addressing issues and enhancing the performance of classical tribological systems. They have also significantly reduced the reliance on trial-and-error methods, minimizing guesswork. The knowledge gained from these studies can be applied to other tribological interfaces, including the relatively newer ones, such as those in the human oral cavity. Such studies are partially fueled by the need to enhance consumer experience, and also to find alternatives to the time- and cost-intensive human sensory panels. In this current work, the authors discuss the processes involved in the development of tribological test methods to evaluate the food and beverage samples. These range from eggs to spread cheese, including plant-based alternatives. The challenges faced during this process, such as the choice of surrogate surfaces, test parameters, and the handling of samples, is also discussed here.

11:20 am - 12:00 pm - **Biotribology Committee Meeting**

Surface Engineering I

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

8:00 - 8:40 am
4204544: Physics-Informed Machine Learning to Improve Manufactured Surfaces
Tevis Jacobs, Luke Thimons, Lars Pastewka, Surface Design Solutions, Inc., Pittsburgh, PA

Surface topography controls the performance and reliability of surfaces in applications from automotive and aerospace to medical devices and consumer electronics. Yet too often our strategies to find the optimal surface finish rely on trial-and-error testing. While great strides have been made in the theory and simulation of roughness-dependent surface performance, it remains difficult to translate this into the design and control for manufacturing. Recently, significant advances have been made in the science-guided optimization of surface topography. First we will review the physical models that predict performance relevant to real-world manufacturing scenarios. Then we will present recent advances in the use of physics-informed machine learning to improve surfaces. The use of AI eliminates the dependence on traditional roughness parameters and enables the direct modification of key performance indicators such as production efficiency, product lifetime, and product performance.

8:40 - 9:00 am
4186165: Fabrication of 3D Tribofilms from ZDDP and APTES Using Multi-asperities Contact Surfaces
Alaaeddin Al Sheikh Omar, University of Leeds, Leeds, United Kingdom

The study has proposed a new method to fabricate 3D films on surfaces using multi-asperities contact surfaces. This provides an alternative method that can be used in Micro/Nanoelectromechanical systems (MEMS/NEMS). In this study, two different additives Zinc Dialkyl Dithiophosphate (ZDDP) and 3-Aminopropyl triethoxysilane (APTES) in the PAO have been used to run tribological tests. The MTM tribometer was conducted to fabricate the APTES and ZDDP tribofilms on steel surfaces. The chemical and physical analysis of the rubbed area confirmed the ability to print thick and conductive APTES film (300 m) compared to 100 nm of nonconductive ZDDP tribofilm.

9:00 - 9:20 am
4205251: Frictional Performance of Lubricants Under Different Regimes: Impact of Laser Surface Texturing
Mohd Syafiq Abd Aziz, Universiti Teknikal Malaysia Melaka, Durian Tunggal, Melaka, Malaysia; Mohd Syafiq Abd Aziz, Imperial College London, London, England, United Kingdom

This study examines how modifying contact surfaces through surface texturing can enhance tribological performance by decreasing friction and wear. While extensive research has been conducted on textured surfaces, primarily focusing on geometric aspects, the role of lubricant composition has been largely overlooked. To fill this gap in knowledge, we perform novel experiments comparing the friction-reduction capabilities of textured surfaces against a smooth reference surface using a variety of commercial and model lubricants. Our findings demonstrate how specific lubricant additives interact with textured features, providing insights into the underlying mechanisms. These discoveries open up possibilities for optimizing lubricants to further maximize the advantages of textured surfaces.

9:20 - 9:40 am
4191433: Analysis on the Film Forming Characteristics of Water Lubrication Assisted by Small Amount of Secondary Lubricating Oil
Xiaohan Zhang, Qingdao University of Technology, Qingdao, China

This study explores the film forming mechanism of lubrication with a small amount of lubricating medium underwater environment, a roller-on-disc lubrication film test rig along with the fluorescent approach are used to directly measure and observe the film formation behaviour when a small amount of lubricating medium is injected into water environment. Moreover, a surface modified disc is also used to investigate the influence of wettability gradient on the film forming ability of the lubricating medium. Results show that the film thickness between the roller and the disc increases as the injection of lubricating oils to the water under different disc speed for the original disc and the modified disc. Moreover, surface modified disc can increase the film thickness compared with the original disc, and viscosity has become an important factor restricting the film-forming ability of lubricating oil when the disc speed becomes higher for both discs.

9:40 - 10:00 am
4202749: Comparing a Portable Contact Angle Goniometer Vs. a Lab-style Research Goniometer for Wettability and Surface Energy Results on Various Substrates
Paul Simutis, DataPhysics Instruments USA Corp., Charlotte, NC

The market demand to replace dyne pens for faster, more accurate contact angle and surface energy results which can be made directly in production has fueled the development of sophisticated portable, handheld contact angle goniometers. These devices are growing in popularity and allow immediate measurement of contact angle and surface energy requiring minimal operator expertise or training. However, the question arises as to how results obtained using a handheld device with two test liquids will compare in accuracy and repeatability to the more traditional, lab-scale devices which offer the ability to make high-speed movie measurements of droplet spreading and use as many as three or even four different test liquids. This lecture will compare, and contrast contact angle and surface energy results obtained using both a handheld versus a lab-style research-grade contact angle goniometer. Real-world advantages and disadvantages of these two types of measurement devices will be presented.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4204760: Surface Adhesion Measurements of Functionalized Silica Nanoparticle Coatings for Solar Photovoltaic Applications
Robert Fleming, Landon Rogers, Arkansas State University, Jonesboro, AR

Accumulation of particulate soils on the front cover glass of solar photovoltaic (PV) modules results in optical transmission losses that reduce the overall power output of PV installations. Nanoparticle coatings are often applied to the cover glass of PV modules to provide antireflective properties, as well as anti-soiling functionality by modifying the coating surface energy. In this study, nanoindentation-based surface adhesion measurements are performed on functionalized nanoparticle coatings composed of either hydroxylated silica nanoparticles or methylated silica nanoparticles, along with X-ray photoelectronic spectroscopy (XPS) and water contact angle (WCA) measurements to characterize the relationships between coating surface chemistry, morphology, and surface adhesion. These results are further correlated with optical transmittance and accelerated soiling/cementation testing to better understand the anti-soiling properties of functionalized silica nanoparticle coatings.

11:00 - 11:20 am
4204994: Innovative Quasi-Liquid Surfaces for Enhanced Friction Reduction in Under Various Loads
Zaid Al Hassan, Q. Jane Wang, Northwestern University, Evanston, IL; Deepak Monga, Xianming Dai, The University of Texas at Dallas, Richardson, TX

The study investigates the effectiveness of a quasi-liquid surface aimed at minimizing friction in metal-to-metal interactions involving industrial steel with varying surface roughness. Quasi-liquid surfaces are easily made by chemically bonding flexible molecular chains on a solid substrate. The substrate-independent grafting results in a quasi-liquid interface that provides minimal adhesion and exceptional durability. Experimental findings demonstrate a significant reduction in the coefficient of friction across different roughness levels, with peak performance observed under intermediate roughness and load conditions. The key to this reduction in friction is the quasi-liquid lubrication provided by the highly mobile polymer chains and the decreased contact area between the surfaces. This work underscores the potential of quasi-liquid surfaces to enhance the efficiency and durability of industrial steel components across various applications.

11:20 - 11:40 am
4199851: A Hybrid Additive Manufacturing Approach to Fabricate Austenitic Stainless Steel with Enhanced Tribo-Mechanical Behavior
Uday Venkat Kiran Kommineni, Sougata Roy, Iowa State University, Ames, IA

Laser directed energy deposition (L-DED) is a promising additive manufacturing (AM) technique due to its rapid build rates and scalability. However, the high thermal gradients observed in L-DED process can result in significant residual stresses and coarse columnar grain structures, negatively affecting mechanical and tribological properties. Ultrasonic impact treatment (UIT) can induce and accelerate dynamic recrystallization, leading to a finer, equiaxed grain structure. This study explores a novel hybrid AM process combining L-DED with UIT to fabricate nitrogen strengthened austenitic (nitronic-60) stainless steels which are widely used in high temperature applications. Fretting wear behavior of fabricated samples were captured with exploration of dominant wear mechanisms relevant to nuclear energy applications. Materials characterization, including surface topography, and EBSD analyses were used to interpret surface quality, microstructure, and tribo-mechanical properties.

11:40 am - 12:00 pm - **Surface Engineering Business Meeting**

7F Courtland

Tribotesting III

Session Chair: TBD
Session Vice Chair: TBD

8:00 - 8:20 am
4180132: Unveiling the Mystery Behind Designed Experiments
Michael Holloway, 5th Order Industry, Highland Village, TX

From the first application of fire to the development of the Large Hadron Collider, proper experimentation has been the reason for success, yet many do not know what goes on behind the scenes of a research desk. Experiments can be painstakingly slow with thousands of trials carried out, yet many successful R&D efforts utilize designed experiments with statistical analysis

methods to reduce the time of development and increase the efficiency of resources. This presentation touches upon the use of some common as well as not-so-common designed experimental methods used to develop and perfect products and processes. A historical examination provides a backdrop of the foundation by which present day work is carried out. Anyone involved in research development, applications, operations, and production will find this presentation exceptionally helpful regardless of the market or product.

8:20 - 8:40 am
4204031: An Experimental Study on the Influence Ambient Viscosity has on Load-Dependent and Load Independent Power Losses for an Automotive Application
Anthony Ngo, Nickolas Hutchison, Michael Handschuh, The Ohio State University, Columbus, OH

In power transmission applications, efficiency dominates design decisions and results in a compromise of efficiency and strength. Mechanical drivetrain components, such as gears, contribute losses for which tribologists have engineered low-viscosity lubricants to mitigate. Ambient viscosity affects fluid shear in the contact zone and viscous drag while rotating. Higher viscosity lubricants promote larger film thickness, which can support greater loads, reduce asperity contact, and extend contact fatigue life at the cost of increased friction and churning losses. In this study, load-dependent and independent losses are measured using a twin-disk tribometer and a single gear efficiency tester, respectively, using a typical and low-viscosity ATF. Traction performance indicates minute differences in efficiency, while churning losses are higher for the higher viscosity fluid. Results indicate efficiency gains are achieved without compromising contact fatigue life using low-viscosity fluid.

8:40 - 9:00 am
4204867: Modification of Abrasiveness of SLA Additive Manufacturing Produced Components through Metal and Ceramic Additives
Miranda Brandt, Kanoa Parker, Leilani Elkaslasy, Gordon Krauss, Harvey Mudd College, Claremont, CA

Additive manufacturing/SLA enables rapid creation of custom parts with complex geometries and unique materials. Modifying a component's surface through metal and ceramic additives can alter wear resistance and abrasiveness. This study characterizes the abrasiveness and sliding friction of components made from commercially available denture resin and metal powder and ceramic additives. Surface modification of dental resin may enhance wear resistance without compromising bulk properties. Disk test specimens were fabricated using commercially available denture resin and a DLP resin printer. The top layer of these disks were doped with varying metal or ceramic compositions. The specimens are tested using a Universal Micro-Tribometer (UMT-2) with the Pin-on-Disk method. Three metal or ceramic compositions were evaluated for abrasiveness and wear. The results demonstrate how varying compositions of metal additives in denture resin affected the abrasiveness properties.

9:00 - 9:20 am
4204864: Influence of SLA Additive Manufacturing Patterning Techniques on the Wear of Metal Countersurfaces for 3D Printed Ceramics
Leilani Elkaslasy, Miranda Brandt, Kanoa Parker, Gordon Krauss, Harvey Mudd College, Claremont, CA

Additive manufacturing has advanced the development of custom parts with complex geometries. The mechanical properties of these parts can vary based on printed patterns and materials used. This study investigated the impact of AM-patterned ceramics on abrasive wear of metal counterparts. Patterning an AM-printed surface is expected to reduce wear through trapping of debris. The objective was to identify surface patterns that enhance wear resistance while

minimizing the amount of ceramic material needed. In this study, disk test specimens were fabricated using a commercially available 3D ceramic material and a DLP resin printer. The disks were subjected to wear testing via a Universal Micro-Tribometer (UMT-2) using the Pin-on-Disk method. Three different surface patterns were evaluated. The tests evaluate changes in abrasiveness of the test specimen running against 52100 steel balls. Change in the abrasiveness of each test system is measured through the number of cycles of wear testing.

9:20 - 9:40 am
4199582: Development of Innovative Low-Friction Suspension Fluids Using Relevant Benchtop Testing Methods.
Ryan Hippman, Fuchs Lubricants, Harvey, IL

The development of automotive suspension fluids like shock absorber fluids (SAFs) and active suspension fluids (ASFs) is often challenging as it requires collaboration with OEMs and tier suppliers to identify which factors are most important for their respective applications. These projects can require a significant amount of time and resources. This highlights the need to have a series of reliable, reproducible, and relevant bench tests to pre-screen candidates, which supports development and focuses resources. This work seeks to create a series of test methods to aid in the development of innovative low-friction suspension fluids with improved wear and performance longevity. Through this methodology, we generated profiles of each fluid to allow for the ranking of screened candidates. Several of these methods utilize SRV and MTM systems to generate results relevant to the requirements for modern shock absorber and active suspension fluids.

9:40 - 10:00 am
4203917: Tribological Performance of Surface Textures Fabricated with Additive Manufacturing in Boundary Lubrication
Tobias Martin, Conor Porter, Q. Jane Wang, Jian Cao, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Textured surfaces affect friction and wear behavior in multiple ways, including controlling lubricant availability, micro hydrodynamics, interrupting adhesion, and trapping wear debris. As additive manufacturing (AM) becomes a more popular fabrication technique, its ability to create texture on as-built surfaces for tribological impact should be investigated. This work focuses on the performance of as-built AM surfaces in boundary lubrication and investigates the relationships between texture pattern and tribological performance. Analyses of the friction curves and wear tracks from reciprocating ball-on-flat tribotests provide insights into how textures affect patterns of friction and wear evolution. AM textures are able to achieve similar steady-state friction performance to polished surfaces, while additionally trapping wear debris and changing the shape of the wear track. As these relationships are defined, guidelines for AM part surface design for tribological benefit are explored.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4200093: Evaluating Abrasiveness of Biomass Particulate Materials
Cinta Lorenzo Martin, Jacob Lasso Garifalis, Yasleen Munoz, Emma Letourneau, Robert Erck, Oyelayo Ajayi, Argonne National Laboratory, Argonne, IL

Bio-derived energy, such as sustainable aviation fuel (SAF), is needed for global decarbonatization goals. Production of bioenergy often involves preprocessing of the biomass feedstock materials in the form of agricultural waste residues such as wood and corn stover, as well as municipal waste consisting of paper and plastic recyclable materials. Wear of the grinding tools used for process of these feedstock materials is a challenge for the industry. To address the problem and evaluate

possible solutions, there is a need to effectively evaluate the abrasiveness of these biomaterials. The ASTM G65 test protocol for dry sand rubber wheel abrasive wear test procedure was modified to evaluate the abrasiveness of 2mm pine loblolly and paper particles on 1045 steel samples. Measurable abrasive wear was produced by all the biomass particles evaluated. Results of the study provide a viable approach to evaluating plausible wear prevention strategies in biomass processing equipment.

11:00 - 11:20 am
4205096: Unraveling the Complex Interactions in Tribotesting: A Critical Analysis of Input and Output Dynamics
Felix Zak, Optimol Instruments Prüftechnik GmBH, Munich, Bavaria, Germany

This study examines the challenges of tribotesting by critically analyzing the interactions between input parameters (load, temperature, sliding speed) and measured outputs (friction force, wear, electrical conductivity etc.). It explores how variations in one input can influence others, leading to complex, non-linear effects on the tribological system. Additionally, the research addresses the interdependencies within the input and output parameters, highlighting potential measurement artifacts and inconsistencies. The aim is to provide a comprehensive overview of these complexities, offering a critical evaluation of current tribotesting methodologies and their limitations in accurately simulating real-world conditions, thus guiding improvements in tribological assessments.

11:20 - 11:40 am
4200706: Thermoviscous EHL Traction Behaviour of Lubricating Oils Using a New Ultra-High-Speed Tribometer
Alexander MacLaren, Matthew Smeeth, Clive Hamer, PCS Instruments, London, United Kingdom

Elastohydrodynamic (EHL) traction is a key contributor to energy losses in high-speed components such as motor bearings, gearboxes and electric vehicle (EV) drive units. Entrainment speeds in these drive units reach an order of magnitude higher than those so far attained by single-contact tribometers able to measure EHL traction. In this study a novel high-speed tribometer is used to characterize several base fluids far into the thermoviscous traction regime, achieving entrainment speeds up to double the current maximum speeds found in EV drive units, and mean shear strain rates exceeding 10^8 reciprocal seconds. Additive tribofilm formation is also monitored under high-entrainment, high-sliding-speed conditions using the Spacer Layer Imaging Method. The accuracy and repeatability of these measurements compared to existing instruments is demonstrated. This combination of capabilities positions this instrument to have significant impact in the drive to optimize traction for EV fluids.

Materials Tribology VII

Session Chair: Mark Sidebottom, Miami University, Oxford, OH
Session Vice Chair: Tomas Babuska, Sandia National Laboratories, Albuquerque, NM

8:00 - 8:40 am
4202911: Effects of Thermal Processing on the Wear and Friction Behavior of PTFE-PEKK Blends
Kylie Van Meter, Brad Jones, Sandia National Laboratories, Albuquerque, NM; Victoria Yang, Catherine Fidd, Brandon Krick, Florida State University, Tallahassee, FL; Christopher Junk, CJ Ideas LLC, Wilmington, DE

Polytetrafluoroethylene (PTFE) is of great interest to the field of tribology due to its exceptionally low friction coefficient (<0.1). Its high wear rate (~10^{-4} mm^3/Nm) limits the use of PTFE as a solid lubricant under typical engineering sliding conditions. Blending or filling PTFE with other polymers, metals, and metal oxides has been a successful way to decrease the wear rate of PTFE alone by as much as 10,000x. In this work, we investigate a blend of PTFE and polyether ketone ketone (PEKK). This blend shows promise as an ultralow wear and low friction composite for inert environments. The properties and tribological behavior of the blend were found to vary significantly based on processing conditions, including sintering 1) temperature, 2) duration, and 3) cooling rate. In this study, the effects of processing parameters were investigated through tribological and thermomechanical characterization, along with analysis of the formation of tribofilms through IR spectroscopy.

8:40 - 9:00 am
4205243: In Situ Neutron Reflectivity for Friction Measurements
Kathryn Shaffer, Angela Pitenis, Julia Ong, Brendan Bagorio, Ahmed Al Kindi, University of California, Santa Barbara, Santa Barbara, CA; Erik Watkins, Oak Ridge National Laboratory, Oak Ridge, TN; Alexander Alexeev, Georgia Institute of Technology, Atlanta, GA

Hydrogels are a material commonly used in biomedical applications due to their high-water content and mechanical properties, which can be tuned by controlling polymer concentration and crosslink density. Following oxygen-rich polymerization conditions, hydrogels exhibit lower friction due to lower density within a ‘surface gel layer’ compared to the bulk. However, the polymer density within this layer during compression and sliding remains unknown. Difficulties in characterizing the surface gel layer with traditional techniques arise due to the layer being thin, delicate and hydrated. Neutron reflectivity is a surface technique particularly suited to non-destructively measuring the polymer density of the surface gel layer. However, neutron observation of samples during sliding remains an open challenge. This work explores the design considerations necessary for constructing a tribometer to align with a neutron reflectivity beam and presents preliminary neutron and friction data.

9:00 - 9:20 am
4229206: Effect of Fibrillation on PTFE Transfer and Wear
Subrata Saha, David Burris, Chelsea Davis, Farida Koly, University of Delaware, Newark, DE; Ben Gould, The Chemours Company, Newark, DE

Polytetrafluoroethylene (PTFE) is widely used as a solid lubricant but limited by high wear rates. Different fillers are used to mitigate wear, but one alumina nanoparticle in particular reduced PTFE wear by 4 orders at 5 wt%. Interestingly, this filler preserved fibrillability of the PTFE following

sintering, which may help stabilize transfer films and reduce further wear. This study aims to determine the effect of fibrillation in the absence of the nanoparticles using a pure PTFE hybrid comprising fibrillating PTFE fine powder in a matrix of non-fibrillating melt-processed PTFE. The inclusion of fibrillating PTFE into a traditional PTFE matrix radically increased transfer film coverage and stability, reduced wear by 95%, and reduced friction by 30%. This paper is the first to isolate the effects of fibrillation on PTFE wear and successfully demonstrates a significant positive role. It also offers yet another tool for ultra-low wear PTFE-based composite materials.

9:20 - 9:40 am
4229283: Exceptional Adhesion of PTFE Fine Powder for Dry Cathode Applications
Abdulmalik Yusuf, David Burris, University of Delaware, Newark, DE; Benjamin Gould, Chemours Discovery Hub, Newark, DE

Fibrillated polymer binders like polytetrafluoroethylene (PTFE) offer a cost- and energy-efficient alternative to solvent-based cathode manufacturing, but it's unclear how a traditionally non-stick material can serve as a binder. We propose that PTFE's fibrillar structure is inherently adhesive and, like gecko setae, overcomes low surface energy limitations. To test this hypothesis, we measured the adhesion of fibrillating PTFE fine powder versus non-fibrillating sintered control particles. Remarkably, fibrillating particles exhibited strong adhesion with a 100-fold increase in effective surface energy from 20 mJ/mm2 to 2,000 mJ/mm2 under zero shear. Adhesion strength improved with shear, increasing to 13,000 mJ/mm2 at maximum shear. Reduced molecular weight and polymer modifiers slightly decreased adhesion. Contrary to its non-stick reputation, we show that fibrillated PTFE has exceptional adhesive properties, making it an ideal candidate for dry-cathode battery applications.

9:40 - 10:00 am
4205552: Fit and Friction Force as a Function of Printing Process for FFF 3D Printed Shaft-Hole Pairs
Quentin Allen, Philippe Passeraub, Brigham Young University, Provo, UT

Fused filament fabrication (FFF) 3D printing can quickly create low-cost mechanical parts but is limited for dimensional accuracy and surface roughness without post-processing. Low-friction axial mobility is often desired for 3D printed shafts and holes. We present a study on parameters of significance and their effects on sliding and running fits as well as their friction forces for such FFF assemblies. We performed experiments with multiple factors, including the position or layout of printed objects, layer thickness, material used, seam, and printer type. Shaft-hole pairs were printed, measured, assembled, and tested using a tensile test frame. A mathematical model was developed to describe the observed oscillating friction force behavior. This study presents the feasibility and limitations of producing shaft-hole assemblies with reduced play and friction when using appropriate conditions. It also gives recommendations to obtain and better control a desired running and sliding fit.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4200900: Self-Lubricating Polyimide for EV Wear and Friction Applications
Hau-Nan Lee, Ruth Jackowiak, Lucas Amspacher, DuPont, Wilmington, DE; Yasuaki Mashimo, Takuya Miyauchi, DuPont Japan, Utsunomiya, Japan

The automotive industry is moving toward vehicle electrification, which demands low-wear and friction materials capable of withstanding higher pressure and velocity (PV) due to increased e-Axle RPM and torque output. Vespel® High PV Grade is designed to perform under extreme conditions while eliminating costly surface treatments associated with metal components. These polyimide-

based, self-lubricating materials demonstrate low wear and friction, effectively removing metal-to-metal contact while providing lubricity for mating components, resulting in better power transfer efficiency. We report on the tribological performance of these materials through block-on-ring and pin-on-disk tests. Our results reveal that these new materials exceed current polyimide offerings, achieving over 5 times higher PV limit in dry environments and 70% higher PV limit in lubricated conditions. Additionally, we will present comparative tribological testing results of other engineering polymers and metals.

11:00 - 11:20 am
4200464: Evaluation of Polyimide Materials Synthesized Through Multiple Chemical Pathways
Dane Miller, Mark Sidebottom, Miami University, Oxford, OH; Christopher Junk, CJIdeas LLC, Wilmington, DE

Polyimide (PI) materials are known for having excellent thermal, mechanical, and electrical properties. They are often used in high temperature operations that require robust wear resistance. Most literature focuses on the mechanical properties of PI materials create them through thermal imidization of polyamic acid. When the polyamic acid is thermally imidized, water is evaporated. This process can cause pinhole and void defects. Another process to creating PI is through a polyisoimide pathway. This process creates PI through chemical imidization and can be dissolved, applied, and cured. This process eliminates the evaporation of water, therefore avoiding the pinhole and void defects. PI made through both processes will be investigated using surface characterization and tribological testing. Improvement in the materials properties through this new manufacturing process could increase the application of polyimide materials in many different industries.

11:20 - 11:40 am
4200414: The Influence of Water Lubrication on the Friction and Wear Behavior of UHMWPE–Stainless Steel Systems: An Experimental and Molecular Dynamics Approach
Nazanin Emami, Julian Somberg, Luleå University of Technology, Luleå, Norrbotten, Sweden; Vahid Naeini, Department of Engineering Sciences and Mathematics, Lulea, Norrbotten, Sweden

The friction and wear behavior of UHMWPE–stainless steel friction pairs under dry and water-lubricated conditions were investigated experimentally and through simulations to address the observed increase in the coefficient of friction under water lubrication. Experimentally, a thin transfer film formed under water lubrication, unlike dry sliding, where no uniform film was observed, regardless of sliding direction. FTIR analysis revealed polymer chain scission and oxidation, which increased surface energy and affinity for transfer to the counter surface, resulting in significantly higher friction and wear. Reactive molecular dynamics simulations were conducted on three polyethylene systems—and their water solutions on a Cr2O3 (001) surface. The coefficient of friction from the simulations closely matched experimental data, helping explain the increased friction observed in water-lubricated systems, particularly due to enhanced surface interactions.

11:40 am - 12:00 pm
4175716: Tribological Performance of Hard Coatings ATSP Vitrimer-Coated Surfaces under Simulated Lunar Dust Conditions
Muhammad Akif Rahman, Jack Sorrell, Andreas Polycarpou, University of Tulsa, Tulsa, OK; Saifur Rahman, ATSP Innovations, Inc., Houston, TX

Excellent durability and enhanced tribological performance of hard coatings and inherently low friction of polymers have made them excellent choices for space applications. In this study, we investigate the tribological performance of hard coatings, Ti-MoS2, DLC, PS400 when they are self-tested and tested against ATSP vitrimer coated samples under abrasive lunar dust conditions. The aim is to analyze the frictional & wear behavior of these solid lubricants. Our results show that both

Ti-MoS2 and DLC exhibit low COF and “zero” wear during self-tests. Interestingly, increasing the thickness of DLC results in an improved frictional behavior against ATSP. However, PS400 shows significant wear & high COF during self-test, which reduces against the ATSP coating. These results are crucial for understanding the interaction between different tribological surfaces, as the combination of low-friction ATSP and durable hard coatings can offer an optimized balance of flexibility and durability.

7H Regency VI

Nanotribology I

Session Chair: Pranjal Nautiyal, Oklahoma State University, Stillwater, OK
Session Vice Chair: TBD

8:00 - 8:40 am
4299727: Mechanocatalytic Formation of Lubricious Films on Pt-Au from Isopropanol and Ethanol Vapor (Invited)
Filippo Mangolini, Camille Edwards, Nicolas Molina Vergara, The University of Texas at Austin, Austin, TX; Tomas Babuska, N. Scott Bobbitt, Michael Chandross, Michael Dugger, John Curry, Sandia National Laboratories, Albuquerque, NM

Nanocrystalline Pt-Au alloys have emerged as a promising class of hard and wear-resistant materials for various applications, including electrical contacts and electromechanical devices. While the formation of carbonaceous surface layers on Pt-Au alloys has been reported to decrease friction in tribological tests carried out with different countersurface materials, remarkably little is known about the effect of gas pressure and chemistry on their structure and properties. Here, we performed gas (i.e., ethanol and isopropanol) pressure-dependent sliding experiments on $Pt_{0.9}Au_{0.1}$. The results of the multi-technique analytical characterization of the mechanocatalytically-formed, carbon-rich surface layers, combined with the outcomes of atomistic simulations, allowed for establishing links between the precursor gas chemistry and the properties of films formed on $Pt_{0.9}Au_{0.1}$ as a result of mechanocatalytic reactions. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

8:40 - 9:00 am
4180164: Why and How Does Structural Superlubricity Persist under Ambient Conditions?
Mehmet Baykara, Wai Oo, University of California Merced, Merced, CA; Hongyu Gao, Martin Müser, Saarland University, Saarbrücken, Germany

We present combined atomic force microscopy experiments and molecular dynamics simulations of gold nanoislands on graphite to investigate why and how structural superlubricity persists under ambient conditions [1]. Measurements conducted within a few days after sample synthesis reveal intriguing phenomena: rejuvenation (a drop in friction of an order of magnitude shortly after the onset of sliding), aging (a significant increase in friction after a rest period of 30 minutes or more), and switches (spontaneous jumps between distinct friction branches). These three effects are drastically suppressed a few weeks later. Imaging of a contamination layer and simulations provide a consistent picture of how adsorbed molecules underneath the gold nanoislands as well as surrounding contamination affect structural superlubricity without leading to its breakdown.

9:00 - 9:20 am
4182082: Study on the Lubrication Characteristics of Al/GO/ZnO Tripartite Hybrid Nanofluid for Machining of TC4 using Minimum Quantity Lubrication.
Yusuf Dambatta, Qingdao Binhai University, Qingdao, Shandong, China

Machining-induced damages encountered during the grinding of titanium alloys are a major setback for processing different components from these kinds of materials. Recent studies have shown that nanofluid-based MQL systems improved the machining lubrication, and subsequently the machinability of the titanium alloys. In this work, we have investigated the performance of tripartite hybrid palm oil nanofluid. The lubrication performance of the developed lubricants, when used in MQL systems, was studied during the grinding of the TC4 alloy. The tripartite hybrid nanofluid was observed to exhibit superior tribological and physicochemical properties compared to the pure palm and monotype-based NFs. More so, the machining results indicate that the tripartite hybrid NF lowered the surface roughness and specific grinding by 42% and 40% respectively. Hence, it was affirmed that tripartite based nanofluid outperformed the mono-type and pure biolubricants.

9:20 - 9:40 am
4182641: Anisotropy and Stress-Assisted Thermal Activation Kinetics of Graphene Fracture Revealed by Atomic Force Microscopy
Cangyu Qu, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Diwei Shi, Li Chen, Zhanghui Wu, Jin Wang, Songlin Shi, Zhiping Xu, Quanshui Zheng, Tsinghua University, Beijing, China; Enlai Gao, Wuhan University, Wuhan, China

The fracture properties of graphene are critical for applications that require robust mechanical properties such as low-friction coatings, but conflicting results on fracture anisotropy and limited work on fracture initiation remain challenges. We developed an AFM-based method to determine graphene's fracture anisotropy and studied the kinetics of fracture initiation by sliding the tip against atomic step edges on graphite. Using naturally-formed atomic steps from exfoliating graphene, this method enables precise, high-throughput measurements. We show that zigzag (ZZ) direction has slightly lower fracture toughness than the armchair (AC) direction, with an anisotropy factor of 0.971. The dependence of fracture initiation rate on applied normal and shear stresses and the temperature agrees with stress-assisted thermal activation kinetics, as described by the Eyring model. This is used to determine the activation energy and activation volume for the fracture initiation process.

9:40 - 10:00 am
4194524: Synergistic Effects of ZDDP and TiO_2 Nanoparticles on Wear Protection in Electrified Contact Conditions
Adam Nassif, Frédéric Georgi, Pierre Montmitonnet, Imène Lahouij, MINES Paris | PSL Research University, Sophia Antipolis, France

Recent studies have shown that combining nanoparticles with boundary lubricating additives offers great potential in enhancing the tribological performances of lubricants, particularly the wear protection. These combinations could be useful in electric vehicles (EVs), where severe contact conditions arise in the transmission system due to the motor's ability to deliver maximum torque at low speeds. In this study, we explore the synergy between Zinc dialkyldithiophosphate (ZDDP) and TiO_2 nanoparticles through tribological tests at boundary regime, supported by XPS analysis and SEM observations. This combination reduces wear more effectively than the individual components, forming a thick tribofilm at both 25°C and 100°C. We investigate how stray currents in EV transmissions affect friction, wear, and tribofilm stability, finding that while it significantly impacts these factors, the ZDDP-TiO_2 mixture mitigates the effects better than individual additives, ensuring tribofilm formation.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4200143: Tribo-Oxidation and Unique Frictional Properties of MXene Materials
Philip Egberts, Chaochen Xu, Zuhaa Khan, University of Calgary, Calgary, Alberta, Canada

nano-sheets are renowned for their low frictional properties, making them promising candidates for lubrication and tribological applications. Here, we observed the tribo-oxidation of MXene lubricants while examining their frictional behavior on freshly prepared films. Friction measurements revealed an initially high surface friction that rapidly decreased with increasing applied normal force. Further repeated scanning of MXene at a constant load of 5 nN also led to a drastic reduction in friction, dropping to just one-tenth of the initial value. Observations of topographic imaging showed changes in surface morphology, particularly a gradual increase in height. Additionally, the phase and surface potential of the scanned regions were lower compared to the unscanned areas, consistent with results observed on highly oxidized MXene surfaces formed after one week of environmental exposure, suggesting that the scanned areas oxidize faster than unscanned regions of the surface.

11:00 - 11:20 am
4200212: Influence of Substrate Periodicity in 2D Materials on Preferential Solvation and Tribological Properties of Linear and Cyclic Organic Solvent Mixtures: An Experimental Approach
Prathima Nalam, Bhadrakalya Pathirannehelage, Luis Velarde, SUNY at Buffalo, Buffalo, NY; Brian Morrow, Judith Harrison, US Naval Academy, Annapolis, MD; James Schall, North Carolina Agricultural and Technical State University, Greensboro, NC

Surface forces induce molecular organization of liquid molecules at solid interfaces, resulting in structures that differ substantially from those in bulk solutions. Two-dimensional materials, with their geometric periodicity and tunable polarity, influence the arrangement of liquid molecules at the liquid-solid interface. This study examines the structural ordering and nanotribological properties of non-polar solvent mixtures of hexadecane (HXD) and cyclohexane (CYC) on periodic few-layer graphene and an amorphous fused silica. Our results show friction forces on few-layer graphene remained constant across all HXD mole fractions, whereas amorphous silica exhibited a friction increase up to 0.8 HXD, followed by a decrease at 1.0 HXD. Using sum frequency generation vibrational spectroscopy and MD simulations, we investigated the effect of surface commensurateness on the organization of HXD at the interface when adsorbed from HXD-CYC mixtures, and their impact on friction behavior.

11:20 - 11:40 am
4200332: Shear as the Sculptor: Auto-Kirigami from Self-Folding, Self-Propagating Graphene
Li Yuan, Shuai Zhang, Cangyu Qu, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Graham Cross, Trinity College Dublin, Dublin, Ireland

Graphene, with its atomic-scale thickness, high out-of-plane flexibility, and strong self-adhesion, enables the self-assembly of stacked multilayer structures. Auto-kirigami (AK) exemplifies this, where graphene ribbons spontaneously tear and fold over an underlying host sheet. By scratching with a nanoscale atomic force microscopy tip, we induce AK in graphene along the scratch. Tip/graphene shear stress is crucial in AK formation, not only for fracturing graphene but also for releasing it from the substrate. In contrast, electrical current oxidation yields neat cuts in graphene but few AK structures. Using continuum and atomistic modeling, we further explore the relationship between AK tearing angles, scratching directions, and graphene's lattice orientation. We then

propose a method to fabricate stacked graphene with controlled interlayer twist angles via tip-induced shear, offering potential applications in semiconductors, twistronics, and beyond.

11:40 am - 12:00 pm
4200334: Tuning Interfacial Friction through Intercalated Surfactants in Graphene Confinement
Deepak Kumar, University at Buffalo, Amherst, NY; Prathima Nalam, SUNY at Buffalo, Buffalo, NY

The scalable exfoliation of layered materials has enabled 2D structures as novel additives for liquid lubrication. These 2D materials, often suspended with organic surfactants, lead to the intercalation of surfactants within the layers. Such structures, with sub-nanometer-thick confined liquid layers, show unique viscoelastic properties and the potential to tune interfacial friction. In this work, we use atomic force microscopy to study the time-dependent interactions of octylamine in the confinement generated by single- to few-layer graphene on a silica substrate. Preliminary results show that after a transition time of ~10h, octylamine molecules diffuse and intercalate at the confinement, reducing friction and adhesion. The friction reduction is layer-dependent, with intercalated thick-graphene (bilayer and few-layer) showing ~50% more friction reduction than intercalated single-layer graphene. The study highlights the importance of phase transitions to design low-shear interfaces.

7I The Learning Center

Grease I

Session Chair: Gareth Fish, The Lubrizol Corp., Wickliffe, OH
Session Vice Chair: Lu Fang, Tesla, Redwood City, CA

8:00 - 8:40 am
4199390: The Grease Meniscus in the Light of False Brinelling
Gernot Bayer, Sebastian Wandel, Ashkan Ayromlou, Gerhard Poll, Leibniz University Hannover, Hannover, Germany; Max Marian, Leibniz University Hanover, Garbsen, Germany

Oscillating greased rolling bearings, e.g. wind turbine blade bearings, are often prone to the wear mechanism false brinelling. Lack of base oil around the contact has already been identified as the root cause; its absence is called starvation similar to rotating EHL. The aim of this research is to better understand how the replenished oil acts around the contact and how the wear initiation is related to “conventional” starvation. Optical experiments with greases are carried out to observe the meniscus shape. Comparison with bearing experiments shows a correlation between the onset of false brinelling and the inlet length of the grease meniscus. This opens up a new perspective on the meniscus in boundary lubrication. The physical background for varying base oil viscosities and bleeding rates is discussed. This contribution aims to provide a better understanding of lubrication mechanisms under oscillating conditions, which can help to develop tailored greases and operating strategies.

8:40 - 9:00 am
4199354: The Effect of “Running-In” on Static Friction in Grease Lubricated and Unlubricated Hertzian Contacts
Benjamin Leonard, Quaker Houghton, Aurora, IL

Static friction in unlubricated and grease lubricated Hertzian contacts was investigated experimentally. A rheometer configured for the four-ball geometry with steel specimens was used

to study static friction; motion was initiated by both applying a rotational displacement and ramping-up the rotational torque. Both modes of testing had different static coefficients of friction but were similarly affected by running-in. As a contact experienced increased sliding distance the static friction initially decreased. In grease lubricated contacts that static friction remained low and approached the dynamic friction which experienced a slight rise. However, without lubrication the coefficient of friction decreased to a minimum and then rose again along with dynamic friction due to wear. Wear scar width correlated with the frictional response of the contact. Normalized friction (static friction divided by the dynamic friction) also described this behavior.

9:00 - 9:20 am
4200609: High Pressure Rheology of Fine Urea Greases
Bo Zhang, Toshifumi Mawatari, Saga Daigaku Riko Gakubu Daigakuin Kogakukei Kenkyuka, Saga-shi, Saga, Japan; So Nakajima, Yukitoshi Fujinami, Idemitsu Kosan Co.,Ltd., Ichihara-Si, Japan

A high-pressure viscometer has been developed, which is able to measure the high-pressure viscosity of the transparent liquid oils, and the opaque greases as well. The viscometer is based on the capillary action which does not need to observe the speed of the falling ball as in a falling ball viscometer commonly used. For the dependence of the density of greases on the pressure, a newly developed high pressure densimeter is used. In the densimeter, the differential principle is adopted, which improves the measurement accuracy by eliminating the uncontrolled change in the volume of the high-pressure container during increasing pressure. Some urea greases together with newly developed fine urea greases are investigated, and the experimental results of both the viscosity-pressure coefficient and the bulk modulus of the greases are given in the paper.

9:20 - 9:40 am
4205566: Evaluation of Rail Curve Grease Performance
Ezequiel Gallardo-Hernández, Instituto Politécnico Nacional, Mexico City, México

Commercial railway lines use greases with extreme pressure additives as thickener and, sometimes solid particles. This work assesses the sliding resistance value (SRVs) behaviour, pump-ability features and the distribution of the grease currently applied in gauge corners of rails in curves in tracks in Mexico. Initially, grease distribution was visually assessed by collecting adhesive tapes added to rail gauge corner. Besides, SRVs were measured at the rail gauge corner by using a British pendulum device with a modified slider pad. The tape results showed different amounts of grease depending on the position inside the curve, the number of axles, the number of trains passing along the day, and the train schedule. In general, the pendulum measurements showed some inconsistency of the grease distribution along the rail curves, low SRVs near the lubricator and random values in each position along the curve.

9:40 - 10:00 am
4204929: A New Numerical Method for Calculating the Oxidation Induction Time From TGA Measurements for Lubricating Greases
Piet Lugt, SKF Research and Technology Development, Houten, Netherlands; Andras Vernes, Maja Ilic, Christoph Schneidhofer, Michael Schandl, Nicole Dörr, AC2T research GmbH, Wiener Neustadt, Austria

In this contribution, a new numerical method is presented to calculate the oxidation induction time for lubricating greases from thermogravimetric data (TGA). This makes it possible to predict the oxidation induction time as a function of temperature via the application of Friedman's differential isoconversional method within which a conversion versus temperature obtained for various linear heating rates is translated into isotherms. Traditionally, oxidation induction times are measured in instruments where oxidation is accelerated by applying high pressure and pure oxygen, [1] and allow only to rank greases in performance. This new numerical method directly gives the oxidation

induction time for real life conditions and can therefore also be used in grease performance prediction models.

10:00 - 10:40 am - Break

10:40 - 11:00 am
4189925: Towards a Basic Understanding of Oil Separation from Lubricating Greases
Femke Hogenberk, Dirk Van Den Ende, Matthijn de Rooij, University of Twente, Enschede, Overijssel, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

The separation of base oil from a lubricating grease, also referred to as “bleed”, is an essential process for effective lubrication of grease lubricated bearings. Bleed is a complex process being influenced by multiple factors. Efforts have been made for a long time to improve the understanding of bleed, trying to overcome the challenges of studying the process in situ. This presentation will give a brief overview of the current knowledge of the bleed process and present a model that describes the relation between bleed rate and grease properties such as permeability, affinity and matrix elasticity. Different methods, models and other published works relevant to the understanding of bleed will be discussed. As well as identifying some of the current challenges and opportunities to further develop our understanding and the presented model.

11:00 - 11:20 am
4201520: Effect of Load on Temperature-induced Oxidation and Grease Life in Deep-Groove Ball Bearings
Varun Puthumana, Dirk Van Den Ende, University of Twente, Enschede, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

Grease life in ball bearings is reduced by increasing load. In this presentation, we show that this reduction can be explained by the increase in temperature at the bearing raceway, which accelerates the oxidative degradation of grease. This temperature is estimated by calculating the rise in temperature due to heat, generated by sliding friction with respect to the bulk temperature. By applying this surface temperature in the Arrhenius equation used in the bearing and lubricating grease community, a strong correlation between load and grease life is established. These calculations are consistent with the experimentally measured grease life versus bearing load.

11:20 - 11:40 am
4212013: Effect of Thermal Aging on the Grease Film Thickness in Ball Bearings
Piet Lugt, Nicola de Laurentis, SKF Research and Technology Development, Houten, Netherlands; Hui Cen, Xuchang University, Xuchang, Henan, China; Norbert Bader, University of Twente, Enschede, Overijssel, Netherlands

In this paper the effect of thermal aging of grease on the film thickness in a ball bearing is studied by aging two different types of greases in an oven for various duration and by measuring their film thicknesses in a sealed for life ball bearing and single contact. The results show that the bearing film thickness initially remains constant for a very long time. Thermal aging leads to evaporation and oxidation. Tests with thermally aged grease show that the film thickness will only change in the case oxidation has occurred. After this, the level of starvation decreases despite an increase of viscosity and decrease of bleed properties. Traction increases which would result in a loss of lubricity.

11:40 am - 12:00 pm
4199396: On Measuring the Oxidation Induction Time for Grease Lubricated Bearings
Piet Lugt, SKF Research and Technology Development, Houten, Netherlands; Yhan Williams, SKF B.V, Ede, Netherlands; Christoph Schneidhofer, Andras Vernes, AC2T research GmbH - Austrian Excellence Center for Tribology, Wiener Neustadt, Austria

It was earlier shown that grease life in deep groove ball bearings was closely related to the oxidation induction time. The induction time in industry is measured by placing samples in an oven under isothermal conditions or by using accelerated tests where the environment is pure oxygen and/or high pressure. We developed a fast test based on TGA where this time can be measured in minutes, in an air environment and ambient pressure, as in a real bearing, giving the induction time versus temperature. We have applied this method to actual grease life tests in ball bearings where we find a very good correlation with grease life but only under specific conditions. For other conditions this will not work. In this presentation we will show the details of that.

7J Dunwoody

Engine Oil, EV, and Driveline: Frontier

Session Chair: TBD
Session Vice Chair: TBD

8:00 - 8:40 am
4283256: In-situ Fluting Measurement in the MTM Electrified Contact
Monica Ratoi, Daniil Yurchenko, Harrison Ditch, Grigore Cernalevschi, University of Southampton, Southampton, United Kingdom

Electrical fields in EV motors damage bearings through a variety of wear mechanisms but fluting is the fastest one leading to failure. Weld craters generated by local high current electrical discharges and the ensuing vibrations act synergistically to build up fluting wear. The excessive vibrations and noise in the bearings will then rapidly lead to failure.
To develop fluting-preventing lubricants, tribometers with enhanced capabilities are required. These tribometers must generate, monitor and measure fluting in-situ as it develops. This study investigates the operating conditions for fluting formation using an MTM tribometer fitted with an electrical set-up. During the testing, the fluting features are monitored and characterized using a bespoke novel technology with in-situ real time measurement capabilities.

8:40 - 9:00 am
4200624: Additive-Additive Interaction in Advanced E-Drivetrain Fluids
Lakshmi Katta, Indian Oil Corporation, Faridabad, Haryana, India

Regulatory compliances on exhaust emissions and continuous strive for improved energy efficiency are the paramount drivers for transition to E-mobility. EVs require specialized lubricants differ from conventional lubricants due to the addition of new hardware technology including e-motor. The presence of e-motor in the gear box where motor is exposed to gear lubricant prompts new challenges. Bespoke e-fluid technology is required to deliver new performance attributes such as corrosion protection, heat management and insulate properties in addition to conventional requirements. The prime challenge here is that the components that provide extreme pressure and anti-wear performance are antagonistic to copper protection, likewise the chemistry that offers friction increases electrical properties.

Our focus is to investigate diverse chemistries against corrosion, heat transfer properties, electrical properties of e-fluids and tribological performance.

9:00 - 9:20 am
4174073: Engine Oil Development for Hybrid Vehicles
Gösta Möller, Shell Global Solutions, Hamburg, Germany

Hybrid powertrains are seen as a necessity amongst slowing electric car sales and can be a viable solution in between ICE and electric vehicles. This begs the question whether there is a need for a hybrid-specific engine oil specification. Shell uses its various motorsport partnerships as an opportunity to test new ideas in the development of engine oil lubricants for hybrid vehicles. Racing offers the opportunity to test in extreme environments and under the harshest driving conditions, to ensure the product is up to the task of protecting the engine and providing maximum performance. Taking into account the learnings from the motorsport programs and current industry trends this presentation aims to give an outlook on what the future of engine oil lubricants for hybrid vehicles might look like and what the impact on the overall PCMO market might be.

9:20 - 9:40 am
4200702: Mitigating Electric Discharge Machining in Bearings Though Green Ionic Liquids.
Pieter Struelens, Oleon nv, Evergem, Belgium; Yen Yee Chong, Micky Lee, Oleon, Port Klang Selangor, Malaysia

Electric discharge machining (EDM) remains a common damage mode in electric motor bearings, despite advancements in electric vehicle powertrain architecture. EDM originates from capacitance build-up in the lubricant film, occurring when the film's dielectric strength is exceeded or during metal-to-metal contact. This study explores the potential of an easily soluble ionic liquid for EDM mitigation. Results identify optimal operating conditions (voltage, speed, temperature, and load) for minimizing EDM. Correlating lubricant properties with EDM frequency provides insights into the ionic liquid's effectiveness. The ionic liquid is applicable to both oil-based and grease lubrication systems, mitigating EDM through a different mechanism than conventional dielectric grease, which relies on conductive particles.

9:40 - 10:00 am
4221450: Suspension-ability and Tribological Performance of Functionalized Carbon Nanoparticles in PAO Oil
Mohammad Humaun Kabir, Texas A&M University, Bryan, TX; Darrius Dias, Hong Liang, Texas A&M University, College Station, TX; Evan Johnson, Joe Kosmoski, Nabors Energy Transition Solutions, Houston, TX

The functionalization of carbon nanoparticles (CNP) with dodecylamine (DDA) enhances their suspension stability in Polyalphaolefin (PAO) oil and improves tribological performance. Our experiments showed that DDA-CNP remained suspended for over 60 days, compared to 3-7 days for unmodified CNPs. The addition of DDA-CNP reduced the coefficient of friction (COF) by 15-26% in boundary, mixed, and hydrodynamic regimes. This presentation discusses the mechanisms behind the behavior and potential impacts of DDA-CNP as advanced additives for addressing lubrication challenges in automotive and industrial systems, including electric vehicles.

10:00 - 10:40 am - **Break**

10:40 - 11:00 am
4241034: Lower Viscosity Thermal Management Fluids for Electric Vehicle
David Du, Apalene Technology Co., Ltd., Shanghai, China

Electric vehicles are becoming more and more popular in the world for emission control. Higher electric motor speed is used to improve power density and efficiency, which bring challenges of thermal management fluids: how to keep enough lubrication for transmission and in the meantime to maximize heat dissipation of electric motor. Viscosity of a fluid is important to maintain enough oil film in lubrication, but on other hand, the lower the viscosity, the better for heat dissipation. In this paper, we will discuss lower viscosity PAO, its applications in EV motor's thermal management and its potential 3-in-1 application for battery immersion cooling, electric motor cooling and transmission lubrication.

8A Hanover AB

Lubrication Fundamentals IV

Session Chair: Mohammad Humaun Kabir, Texas A&M University, Bryan, TX
Session Vice Chair: Chanaka Kumara, Oak Ridge National Laboratory, Oak Ridge, TN

1:40 - 2:20 pm
4205427: Traction Modifier Alcohol Additives – Mechanisms and Applications
Tom Reddyhoff, James Ewen, Imperial College London, London, United Kingdom; Wren Montgomery, Natural History Museum, London, United Kingdom

We present research into the use of n-alcohols as “traction-modifier” additives that can be blended with oils in order to reduce elstohydrodynamic friction (traction) without impacting film thickness. This is based on a recent discovery that neat n-alcohols can self-assemble under pressure to form layered structures that provide liquid superlubricity. This occurs within the central, high-pressure region within a contact so that film thickness is unaffected. Furthermore, similar beneficial behaviour occurs even after n-alcohols have been diluted by a hydrocarbon base oil. These performance gains are supported by ball-on-disc tribometer friction and film thickness data, while insights into the mechanism are provided by FTIR measurements made on lubricants samples within a high-pressure diamond anvil cell. The link between molecular structure and friction reducing performance is explored and the implication of using such additives in practice are discussed.

2:20 - 2:40 pm
4203595: High-Performance Polymeric Friction Modifiers for Robust Lubrication Across a Wide Temperature, Load and Lifespan Range.
Pieter Struelens, Oleon nv, Evergem, Belgium; Micky Lee, Oleon, Port Klang Selangor, Malaysia

Organic friction modifiers (OFM) play a vital role in improving fuel economy, as well as enhancing the overall efficiency and longevity of lubricants. This study explores organic polymeric friction modifiers that can withstand harsh conditions such as high sliding-rolling ratio and high loads, while maintaining performance in aging lubricants. Our findings show that this polymeric friction modifier significantly reduces COF and wear through a distinct mechanism. Its versatility over a wide temperature range ensures robust functionality in ICE, hybrid, and EV conditions. Additionally, the polymeric friction modifier can reduce the conductivity of transmission fluids in electric vehicles, by lowering the dosage of conductive anti-wear, while ensuring sufficient surface protection. This innovation paves the way for low SAPS formulations and reduces the dosage of metal-based anti-wear, addressing stricter environmental regulations.

2:40 - 3:00 pm
4247437: Bench Friction Evolution of Lubricant Formulations to understand Engine Fuel Economy
Kuldeep Mistry, Devin Wall, Chevron Oronite Company, Richmond, CA; Felix Kha, Chevron, Richmond, CA

Automotive fuel efficiency remains a crucial focus for OEMs and lubricant suppliers. As lubricant viscosities continue to decrease for hydrodynamic gains in fuel economy, reducing surface friction will become increasingly important for fuel economy performance. This study examines and reports on the formulation of high-performance lubricants, emphasizing their effectiveness in improving engine fuel economy and overall performance. Utilizing various cutting-edge research methodology, we offer a comprehensive analysis of different additive systems and their impact on different lubrication regimes. These findings highlight the importance of optimizing lubricant formulations to achieve superior fuel economy and performance in engines. By leveraging advanced additive technologies and understanding their interactions, this study contributes to the development of next-generation lubricants that meet stringent performance and sustainability standards.

3:00 - 3:20 pm - **Break**

3:20 - 3:40 pm
4205216: Experimental Investigation of Performance Characteristics of Water-Lubricated Hydrostatic Journal Bearing Using Journal bearing test rig
Deeplaxmi Vaidya, Vikas Phalle, Vishwadeep Handikherkar, Veermata Jijabai Technological Institute (VJTI) Mumbai, Mumbai, Maharashtra, India

This paper presents an experimental study examining the performance of water lubricated hydrostatic journal bearings using custom-designed test rig under varying operating conditions. The fluid film thickness is maintained around 40 to 60 microns throughout the tests to ensure consistent hydrodynamic performance. The experiment evaluates the performance of bearing through start-stop cycles, to assess durability and operational stability. The data provide insights for WLB into the suitability for high-load, high-speed applications, emphasizing its potential for reliable operation in water-lubricated environments. The findings offer valuable insights into potential of water as a sustainable, cost-effective lubricant, aiding in the development of greener tribological solutions in industrial systems.

3:40 - 4:00 pm
4283047: The Behaviour of Tribofilms Under Realistic Gear Contact Conditions
Marc Ingram, Lauren McLean, Ingram Tribology Ltd, Carmarthen, United Kingdom; Thomas Baldwin, National Physical Laboratory, London, United Kingdom

Tribofilms are formed on steel surfaces under mixed, boundary or high shear EHD conditions. It is common to study the formation of the tribofilm under short (sub 3 hour) tests equating to a few thousand contact cycles. It is less common to study the effect of these tribofilms under realist conditions of lambda ratio, contact pressure and contact cycles, effectively stimulating the contact conditions of a gearbox. This is important to observe the tribofilm formation of oils under realistic conditions and the longevity of the film over an extended period of operation. Here we study the effect of commercial lubricants and common steels used in gear manufacture. We use a sliding/rolling contact of 2 GPa, and custom finished surfaces to achieve the require lambda ratios. We find the growth of the tribofilm to be rapid at lambda ratios of 0.4 and 0.05, and the morphology of the tribofilm effecting the friction in the contact.

4:00 - 4:20 pm
4242868: Structure-Property of Functionalized Sulfur-Containing Antiwear Additives for Driveline Applications
Jessica Tanuwidjaja, Travis Holbrook, Luke Stribling, Devin Wall, Michelle Curtis, Timi Singa, Chevron Oronite, LLC, Richmond, CA

In this presentation, tribological, corrosion, and oxidation properties of functionalized sulfur-containing antiwear additives will be discussed. This enables better componentry design to address various driveline wear needs.

4:20 - 4:40 pm
4199759: Impact of Surface Roughness on the Lubrication Performance of Low-Speed, Heavy-Duty Water-Lubricated Polymer Bearings
Zhenjiang Zhou, Xincong Zhou, Shaopeng Xing, Lun Wang, Wuhan University of Technology, Wuhan, Hubei, China; Konstantinos Gryllias, KU Leuven, Leuven, Belgium

With the growing use of water-lubricated stern bearings, asperity contact has become a key challenge in designing low-speed, heavy-duty bearings. To explore how surface roughness affects lubrication performance and state transitions in water-lubricated polymer bearings, a mixed lubrication analysis model was developed. This model incorporates elastic deformation, thermal effects, surface topography, and asperity contact. Experimental validation confirmed its accuracy. The analysis revealed that increased liner roughness slows water film formation, requiring higher speeds for hydrodynamic lubrication. In mixed lubrication, greater roughness slows friction reduction and temperature decrease, leading to higher contact pressure and flatter pressure distribution. In the hydrodynamic phase, surface roughness has less influence as speed increases.

8C — Hanover D

Fluid Film Bearings-Seals III

Session Chair: Bruce Fabijonas, Kingsbury, Inc., Philadelphia, PA
Session Vice Chair: Amruthkiran Hegde, Kingsbury, Inc, Philadelphia, PA

1:40 - 2:20 pm
4200214: Oil Varnish Along with the Morton Effect in Fluid Film Bearings
John Yu, Baker Hughes, Houston, TX

Vibration at both the drive end (DE) and non-drive end (NDE) bearings exceeded the trip limit of 85 µm pp. Although smooth 1X spiral vectors were observed well below the trip limit for some time, the unit eventually tripped after a slight drop in lube oil temperature, suggesting a possible Morton effect. Curiously, the Morton effect ultimately resulted in a vibration trip. However, raising the lube oil temperature by 5°C allowed the machine to run safely for three weeks with low vibration and no cyclic amplitude until a pre-scheduled overhaul, which did not disrupt plant operations. A thorough inspection, including bearing disassembly, revealed a 15 µm thick oil varnish buildup and signs of rubbing on the bearing pads. After repairing the bearings, the compressor operated smoothly, with no cyclic 1X vibration, while maintaining the lube oil temperature 5°C above the minimum threshold. The oil varnish issue was addressed by switching to a lower-viscosity lube oil.

2:20 - 2:40 pm
4205313: CFD Modeling of a Spiral Groove Seal in an Oil Mist
Sara Inezli, Mohamed Jarray, Aurelian Fatu, Institut Pprime, Angoulême, France; Mohamed Andasmas, Safran Aircraft Engines, Paris, France; Lassad Amami, CETIM, Nantes, France

Oil mist lubrication is a technology that offers enhanced reliability for many types of rotating equipment. It involves spraying oil in small droplets, then transporting and delivering sufficient quantities to bearings, seals and rotating surfaces. It improves the lubrication process, reduces friction losses and extends machine life. However, this technology requires a sealed medium containing the oil mist and one solution is to use an annular seal with a spiral groove. The study presented here involves CFD modeling of such a sealing device in a two-phase flow environment. In a main air flow treated as a continuous phase, oil droplets are modeled as a dispersed and discrete phase (using a Lagrangian approach) that can exchange momentum, mass and energy with the air phase. The simulations are aimed at understanding two-phase flow in this type of seal and will later be used for calibrating simplified bulk-flow models, allowing a significant reduction in calculation time.

2:40 - 3:00 pm
4205617: Experimental and Modeling Analysis of Frictional Forces in Reciprocating Rod-Seals Under Varying Surface Profile Conditions
Pawan Panwar, Shubham Daler, Paul Michael, Milwaukee School of Engineering, Milwaukee, WI

Stick-slip friction, characterized by sawtooth force oscillations due to pre-sliding adhesion and elastohydrodynamic slip, negatively impacts machine control and operator safety in applications such as cranes, telescopic lifts, and utility bucket trucks. Optimizing lubricated sealing systems to mitigate stick-slip requires an accurate friction model for the contact area. This study explores frictional forces and stick-slip in reciprocating rod-seal interfaces, focusing on fluid chemistry and hydraulic rod surface characteristics. Three hydraulic fluids with varying viscosities were tested under different conditions with a U-cup seal. A rod section was modified to analyze surface effects. Results showed that increased roughness suppressed stick-slip but raised friction, while higher sliding speeds reduced both. Increased pressure raised friction without impacting stick-slip. A modified LuGre model effectively predicted frictional behavior, aiding hydraulic system optimization.

3:00 - 3:20 pm - **Break**

3:20 - 3:40 pm
4204904: Numerical Analysis of Cylindrical Multi-Hole Hydrostatic Journal Bearing
Meiraj Shaikh, Vishwadeep Handikherkar, Vikas Phalle, Veermata Jijabai Technological Institute (VJTI), Mumbai, Maharashtra, India

The Numerical analysis performed for Water Lubricated Cylindrical Hydrostatic Journal Bearing using ANSYS Fluent. To provides detailed insights into fluid flow and pressure distribution, allowing designers to predict and improve bearing performance under dynamic conditions. This helps in optimizing designs for greater reliability, efficiency, and lifespan in high-precision and demanding applications. A three-dimensional k-epsilon turbulence model solved with water as the working medium. The analysis highlights maximum pressure formation within the Bearing fluid-film region for three distinct hole entry location. Through analysis significant variation has been observed for multi hole entry location.

3:40 - 4:00 pm
4205224: Performance Evaluation of Water-Lubricated Hydrostatic Cylindrical Journal Bearings using CFD
Deeplaxmi Vaidya, Meiraj Shaikh, Vishwadeep Handikherkar, Vikas Phalle, Veermata Jijabai Technological Institute (VJTI) Mumbai, Mumbai, Maharashtra, India

The CFD analysis present a comprehensive study of water-lubricated hybrid cylindrical journal bearings, aiming to enhance the performance and evaluate critical operational parameters of the bearing. By employing ANSYS Fluent for simulations, the research explored the pressure distribution and thermal properties of the bearing under different eccentricities. The study assesses the impact of eccentricity on the load-carrying capacity, stability, and thermal characteristics of the water-lubricated hybrid bearing. The results reveal significant influences on maximum pressure and maximum temperature, which are crucial for bearing design and material selection. These insights contribute to a better understanding of the dynamic behaviour of hybrid bearings, enabling more efficient, sustainable and reliable design optimizations thereby reducing the carbon footprints aiding in the development of greener tribological solutions in industrial systems.

8D — Hanover E

Tribology of Biomaterials I

Session Chair: Quentin Allen, Brigham Young University, Provo, UT
Session Vice Chair: Tomas Grejtak, Oak Ridge National Laboratory, Oak Ridge, TN

1:40 - 2:20 pm
4204407: Tribology of Charged Hydrogels
Rosa Espinosa-Marzal, University of Illinois at Urbana-Champaign, Urbana, IL

Hydrogels have garnered significant attention across various scientific disciplines including tissue engineering and wearable technologies, due to their unique properties and versatile applications. Our research is focused on the design of stimuli-responsive hydrogel interfaces that enable control of interfacial forces like friction and adhesion. Obtaining insight into the interfacial structure and dynamics of hydrogels is challenging due to the large amounts of water. Recently, my lab has developed a technique to image hydrogel surfaces in a liquid environment at the nanoscale using Atomic Force Microscopy while spatially resolving interfacial properties like adhesion, friction, and surface compliance in situ. I will show how this method can help to determine the mechanisms underlying lubrication. I will also discuss how intrinsic and extrinsic parameters influence the interfacial structure, contact mechanics and frictional characteristics of different types of charged hydrogels.

2:20 - 2:40 pm
4189513: Influence of Adding Cellulose Nanocrystals (CNC) to Hyaluronic Acid (HA) Suspensions on Tribology and Tribochemistry
Akshai Bose, Behzad Zakani, Dana Grecov, University of British Columbia, Vancouver, British Columbia, Canada

Hyaluronic acid (HA) is a biopolymer widely used as a lubricant for biomedical applications. However, HA can be corrosive and has a limited tribological performance. Cellulose nanocrystals (CNC) are rod-shaped particles known for their antioxidant and lubrication properties. This study examines the effect of CNC concentration on friction, wear, and tribo-corrosion properties of HA-

CNC suspensions. The addition of CNCs up to 2 wt.% reduced friction and wear characteristics due to its mending effect. A tribo-corrosion study (using an electrochemical workstation with a tribometer) showed that CNCs help in reducing corrosion, likely due to their antioxidant capability. By increasing CNC concentration beyond 2 wt.%, the corrosion attained a minimum state, possibly due to network formation and gelation, thus restricting oxygen diffusion. EDX mapping of friction pairs further validated these observations. This study could aid the development of HA-CNC lubricants for biomedical applications.

2:40 - 3:00 pm
4204724: Improvement of Lubricity and Wear Resistance Due to the Bilayer Structure of a Hydrated Polymer Brush Film and a Free Polymer Adsorption Layer
Shintaro Itoh, Nagoya University, Nagoya, Aichi, Japan

2-Methacryloyloxyethyl phosphorylcholine (MPC) polymer is a coating material that improves the biocompatibility and lubricity of implantable medical devices (T. Moro et al., Nat. Mater. 3, 2004, 829–836). The lubricity of MPC polymer coatings is due to the hydrated lubrication caused by the polymer containing water (F. Lin et al., J. Colloid Interface Sci., 655, 2024, 253-261). In particular, it has been shown that brush-like polymer films are superior to randomly adsorbed polymer films. Lin et al. showed that the lubricity of a brush film can be improved by using it with an aqueous polymer solution as a lubricant (F. Lin et al., Tribol. Int., 191, 2024, 109189.). It is thought that the bilayer structure of the brush film and adsorbed polymer film contributes to improved lubricity. This study experimentally verified the dependence of the friction coefficient of the brush film on the molecular weight of the polymer in solution and found optimum conditions.

3:00 - 3:20 pm - **Break**

3:20 - 3:40 pm
4205236: Indentation Behavior of Slide-Ring Gels
Andrew Rhode, Christopher Bates, Angela Pitenis, University of California Santa Barbara, Santa Barbara, CA

Hydrogels are interconnected networks of polymer chains swollen in water. Hydrogel-like structures are utilized in the body for their ability to maintain lubricious interfaces, such as in articular cartilage. Polymer chains in hydrogels are traditionally bonded together with immobile covalent crosslinks. However, hydrogels with figure-eight sliding crosslinks were introduced by Okomura and Ito in 2001. The synthesis and bulk mechanical properties of these materials have been studied, and it has been shown that slide-ring hydrogels exhibit impressive toughness and extensibility due to their mobile crosslinks. Despite this progress, the interfacial behaviors of slide-ring gels are still not well understood. We used micro-indentation measurements to investigate the surfaces of slide-ring gels and showed that material properties depended on testing parameters and chemical formulation of the gel.

3:40 - 4:00 pm
4204966: Mechanical and Tribological Properties of Cross-Linked Polymer Networks
Manoj Maurya, University of Freiburg, Freiburg im Breisgau, Baden-Württemberg, Germany

Mechanical and tribological properties are critical when designing soft materials such as polymers, as they significantly influence performance and functionality across various applications. Key mechanical properties include stiffness and elastic modulus, while tribological properties, such as the friction coefficient, are vital for material behavior under load. Crosslinking is an essential mechanism for tuning polymer properties. In this study, we present a computational investigation of indentation using explicit indenters in weakly crosslinked polymer (WCP) networks through

molecular dynamics simulations. The indentation technique is commonly employed to measure elastic modulus and stiffness via force-distance curves. Additionally, we explore the structural characteristics and evaluate the coefficient of friction as a function of crosslinking bond density in polymer networks. We establish a relationship between force-depth response and local bond-breaking in WCP networks.

4:00 - 4:20 pm
4205674: Tribology of Physically Entangled Hydrogels
Conor Pugsley, Andrew Rhode,Angela Pitenis, University of California, Santa Barbara, Santa Barbara, CA

Biological hydrogels are tribologically fascinating materials due to their ability to maintain highly lubricious surfaces in aqueous environments. Synthetic hydrogels have reached high levels of lubricity but are often held back by their lack of mechanical robustness. Recent studies have shown that the toughness of polyacrylamide hydrogels can be increased by using extremely high monomer concentration and low initiator and crosslinker concentration in synthesis. This is thought to result in the polymerization of long acrylamide chains which form many physical entanglements with each other, resulting in tougher gels. Studies of these physically entangled hydrogels suggest that low friction may result from long dangling chains at the surface. We synthesized a range of physically entangled polyacrylamide hydrogels and measured them using a microtribometer. Our results show that friction coefficient and elastic modulus of these materials can be tuned by altering their chemical formulation.

4:20 - 4:40 pm
4254220: Relationship Between Fractography and Sliding Friction on Soft Materials
Alison Dunn, Abrar Mohammed, University of Florida, Gainesville, FL; Srividhya Sridhar, Shelby Hutchens, University of Illinois Urbana-Champaign, Urbana, IL

Surface features and structures are used to tailor the contacting and friction response of soft materials like silicones and hydrogels through the feature dimensions and composition. However, these features are usually manufactured specifically for such purpose rather than created by an upstream process. Toward understanding the combined mechanics of cutting and sliding of the tool through a soft material, we have used planar cutting with a tunable energy release rate to create relatively rough, smooth, and periodic surfaces in silicones and hydrogels. Then, each sample was characterized by both optical profilometry for its topography, and by microtribometry for its friction behavior. Preliminary results suggest that there is a correlation between the tearing contribution to the energy release rate, and the resulting sliding friction. In this talk, data sets will be shown and discussed.

4:40 - 5:00 pm
4279672: Optimizing Tribological Properties of Metal on Polymer Bio Implants with Multiscale Textures
Fitsum Tewelde, Beijing Institute of Technology, Beijing, China

Total joint replacements are widely performed surgeries, offering solutions for damaged hip and knee joints; however, the limited longevity, particularly of metal-on-polyethylene implants, remains a major challenge. This study explores the use of bio-inspired multiscale textures fabricated on CoCrMo alloy surfaces using an Nd:YAG laser. The friction and wear performance of the textured surfaces were tested against Ultra High Molecular Weight Polyethylene (UHMWPE) pin under lubricated sliding conditions using a pin-on-disc tribometer. Results show a significant reduction in friction coefficient and wear of UHMWPE compared to those of untextured and single-scale textured surfaces. To optimize the multiscale texture parameters for maximizing lubricant film thickness, hydrodynamic lubrication simulations were conducted. This study demonstrates the

potential of bio-inspired multiscale textures to enhance the tribological performance of bio-implants.

8G Regency V

Materials Tribology VIII

Session Chair: Tomas Babuska, Sandia National Laboratories, Albuquerque, NM
Session Vice Chair: Mark Sidebottom, Miami University, Oxford, OH

1:40 - 2:20 pm
4186626: Transfer and Wear Asymmetry Within a Tribological Contact
Farida Ahmed Koly, David Burris, University of Delaware, Newark, DE; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Nikhil Murthy, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD; Oyelayo Ajayi, Cinta Lorenzo Martin, Scott Walck, Argonne National Laboratory, Argonne, IL

Previous scuffing studies revealed distinct roles for migratory (m) and stationary (s) components. The contact location changes with sliding on the migratory part but remains in one location on the stationary part. Damage often starts on the migratory component, but plastic deformation and material transfer occur on the stationary side. We studied how varying hardness and surface energy affect damage and transfer direction. Alumina, aluminum, and steel were tested under lubricated conditions on a custom ball-on-flat tribometer. For porous alumina (s) on steel (m), a stable tribo-film formed, but steel debris led to a steel-on-steel interaction, increasing friction and causing scuffing. Non-porous alumina (s) on steel (m) showed similar behavior. In contrast, no scuffing occurred with steel (s) on alumina (m). Steel (s) on aluminum (m) maintained low friction with a stable tribo-film, while aluminum (s) on steel (m) showed minimal material transfer, and with neither scuffing.

2:20 - 2:40 pm
4218571: Aging-Related Coating Failure of MoS_2 Nanocomposites: Understanding the Role of Dopants on Coating Toughness
Tomas Babuska, Michael Dugger, Frank DelRio, Steven Larson, Alexander Mings, John Curry, Sandia National Laboratories, Albuquerque, NM

Molybdenum disulfide (MoS_2) nanocomposite coatings doped with Sb_2O_3 and Au are used in aerospace and defense applications to reduce friction and improve wear resistance. Often, these coatings are used in mechanisms (such as deployment latches) that experience periods of dormancy where exposure to terrestrial environments leads to oxidation (i.e., aging). While post-aging performance of MoS_2/Sb_2O_3/Au coatings is usually characterized by high initial friction and prolonged run-in behavior, less common phenomenon such as severe cracking has been observed with no explanation. In this work, we investigate the importance of toughness measured via nanoindentation cracking experiments on the pre and post aging performance of PVD deposited MoS_2/Sb_2O_3/Au coatings. The Sb_2O_3 and Au content are varied to understand the role of dopants on toughness, hardness, adhesion and aging-induced tribological performance changes. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

2:40 - 3:00 pm
4192189: Investigation of the Friction and Wear Characteristics of Novel NBR/UHMWPE Double-Lined Rubber-Plastic Water-Lubricated Bearings
Shaopeng Xing, Qipeng Huang, Zhenjiang Zhou, Xueshen Liu, Wuhan University of Technology, Wuhan, Hubei, China; Lun Wang, Xincong Zhou, School of Transportation and Logistics Engineering, Wuhan University of Technology, Wuhan, Hubei Province, China

Our team has innovatively developed a double-lined water-lubricated rubber-plastic tail bearing with UHMWPE as the inner liner substrate and a mixture of UHMWPE and graphite blended into Nitrile Rubber (NBR) for modification and as the surface layer material. The friction and wear test and vibration performance test were carried out by using a ZY-1 ring block friction and wear tester, the friction coefficient and wear amount were measured and compared, and the surface morphology of the test block was examined by using a laser interference profiler, laser confocal microscope, and scanning electron microscope. The results show that the mechanical properties of this double-lined rubber-plastic water-lubricated tail-bearing material have reached the requirements of the Chinese marine standard CB/T769-2008, and the material has good tribological properties by the U.S. military standard (MIL-DTL-17901C(SH)).

3:00 - 3:20 pm
4203156: Simulation Study on the Mixed Lubrication Performance of Ship Stern Bearings Based on Oil-Water Mixtures
Zhenjiang Zhou, Xincong Zhou, Shaopeng Xing, Wuhan University of Technology, Wuhan, China; Konstantinos Gryllias, KU Leuven, Leuven, Belgium; Lun Wang, School of Transportation and Logistics Engineering, Wuhan University of Technology, Wuhan, Hubei Province, China

To maximize the clean, energy-efficient, high-specific-heat benefits of water-lubricated bearings while enhancing performance under low-speed, heavy-load conditions, this study explores oil-water mixtures as lubricants. PTFE, Thordon, and NBR were selected as typical stern bearing materials. A mixed lubrication model based on viscosity, lubrication, and energy equations was established to analyze performance at various oil-water ratios. Results show that, under the same oil content, Thordon had the thinnest film and highest pressure, while NBR had the thickest film and lowest pressure. The friction coefficients of the three materials initially dropped to their minimum values at oil contents of 15%, 30%, and 35% for Thordon, PTFE, and NBR, respectively, then rose gradually. Temperature rise trends differed: NBR showed an increase-decrease-then-slow-rise pattern, while Thordon and PTFE showed an initial decrease followed by a gradual increase.

3:20 - 3:40 pm – Break

8H Regency VI

Nanotribology II

Session Chair: Cangyu Qu, University of Pennsylvania, Philadelphia, PA
Session Vice Chair: TBD

1:40 - 2:20 pm - Invited Talk

2:20 - 2:40 pm
4200564: Ultrafast Dynamics of Electronic Friction Energy Dissipation in Defective Semiconductors Monolayer
Rui Han, Dameng Liu, Huan Liu, Tsinghua University, Beijing, China

Friction is the central cause for about 1/3 of the primary energy dissipation, severely impacting the performance limits of micro and nanoscale mechanical devices. Especially in two-dimensional semiconductor devices, electronic friction energy dissipation becomes particularly pronounced. However, the dynamic mechanisms underlying electronic friction energy dissipation remain unclear due to the ultrafast timescales of electronic behavior. Here, the ultrafast dynamic of electronic friction in monolayer WS_2 is observed using femtosecond transient absorption spectroscopy. We find that friction exhibits a significant enhancement as the rate of electronic dissipation increases. It is experimentally found to be closely related to the generation of atomic defects at the sliding interfaces. These defects capture electrons in picoseconds and provide a new dissipation channel, resulting in increased friction. This study is vital to understand the origin of friction and reduce energy dissipation.

2:40 - 3:00 pm
4202475: Controlling Friction Energy Dissipation by Ultrafast Interlayer Electron-Photon Coupling in WS_2/Graphene Heterostructures
Chong Wang, Huan Liu, Dameng Liu, Jianbin Luo, Tsinghua University, Beijing, China

Electrons and phonons are regarded as the microscopic carriers of friction energy dissipation and their coupling is a typical dissipation mode. However, due to the lack of ultrafast detection technic, the friction mechanism about electron-phonon coupling remains unexplained. Here, using high resolution non-contact atomic force microscopy and ultrafast pump-probe spectroscopy, we find that interlayer electron-phonon coupling dissipation channel in WS_2/graphene heterostructures can be enhanced by defects and the electron-phonon scattering time is accelerated from 0.62 ps to 0.27 ps . The enhanced electron-phonon coupling leads to significant energy dissipation. We further quantitatively model the friction with dissipation rate to control the friction energy dissipation by ultrafast interlayer electron-phonon coupling. This work provides a new way to understand the mechanism of electron-phonon coupling in friction.

3:00 - 3:20 pm - **Break**

3:20 - 3:40 pm
4203384: Impact of Binary Solvent Mixtures on the Nanotribology of Graphene Interfaces: An MD Approach
Judith Harrison, Sophia Yun, Brian Morrow, United States Naval Academy, Annapolis, MD; James Schall, North Carolina Agricultural and Technical State University, Greensboro, NC; Prathima Nalam, Bhadrakalya Pathirannehelage, Luis Velarde, SUNY at Buffalo, Buffalo, NY

Graphene is added to oil-based lubricants to enhance the load-bearing capacity of the contact. Molecular dynamics (MD), AFM and Sum Frequency Generation (SFG) were used to provide a molecular-level understanding of the role of interfacial solvent mixtures on the friction behavior of graphene additives and to understand interfacial molecular ordering. MD utilized DLC tips with both DLC and silica surfaces, with and without a few layers of graphene (FLG), with interfacial mixtures of cylcohexane and n-hexadecane . Friction & adhesion were examined as a function of solvent mole fraction and load. FLG surfaces exhibit lower friction in non-polar solvent mixtures than amorphous substrates and little change with changes in solver mole fraction. Higher friction forces were measured on silica compared to FLG at all mole fractions and normal loads. MD results using DLC tips and with DLC and silica substrates will be contrasted and will be used to help elucidate the experimental behavior.

3:40 - 4:00 pm
4203891: Performance Comparison of Nano Graphene-Enhanced Lithium and Complex Lithium Greases
Ethan Stefan-Henningsen, Amirkianoosh Kiani, Ontario Tech University, Thornhill, Ontario, Canada

This study provides a comparative analysis of two different types of lithium-based greases, each enhanced with 0.5 wt% graphene. The research explores the effects of graphene on the tribological and thermal properties of both greases through a series of tests, including the Four Ball Wear Test, thermogravimetric analysis (TGA), water washout and thermal imaging. Although both greases demonstrated improved performance in friction reduction, wear resistance, and thermal stability, notable differences were observed in their behavior, particularly due to their base grease composition. The study aims to determine the advantages of graphene enhancement in each grease type, identifying the most suitable formulation for industrial applications that demand high-performance lubrication under extreme conditions.

4:00 - 4:20 pm
4205269: Revealing Orientation-Dependent Deformation Mechanisms at Nanoscale Asperities
Amit Prasad, Ruikang Ding, Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA; Claire Zhang, Ting Liu, Ashlie Martini, University of California Merced, Merced, CA

Nanoscale asperities represent the fundamental unit of contact. Using in situ transmission electron microscopy, 10-50-nm noble-metal nanoparticles were compressed to reveal how dislocations initiate and interact. Our observations show that plasticity consistently initiates with the nucleation of dislocations at the free surface. However, crystal orientation significantly influences subsequent microstructural evolution. Highest-symmetry orientations like [111] exhibit slip, where dislocations can interact and “lock”, strengthening the particle. By contrast, lower-symmetry orientations predominantly deform through twinning. These differences in the interaction and propagation of dislocations, lead to distinct deformation behavior as a function of crystal orientation. Understanding these mechanisms at the nanoscale opens the door to designing more resilient nanostructured materials for applications ranging from wear-resistant coatings to next-generation electronic devices.

4:20 - 4:40 pm
4205300: Metal Oxide Nanocrystals for Enhancing the Performance of Gear Oils
Robert Wiacek, Lei Zheng, Z. Serpil Gonen-Williams, Pixelligent Technologies LLC, Baltimore, MD; Robert Carpick, Andrew Jackson, University of Pennsylvania, Philadelphia, PA; Meagan Elinski, Hope College, Holland, MI; Nicholaos Demas, Aaron Greco, Argonne National Laboratory, Argonne, IL

Improving vehicle fuel efficiency by using lower viscosity lubricants is a common method for reducing operating costs. This comes at a cost as lower viscosity oils lack the ability to form an elastrohydrodynamic film as gear wear rate is inversely proportional to the gear oil viscosity. To benefit from low viscosity lubricants, these oils need to utilize enhanced wear protection. We have demonstrated that when metal oxide nanocrystals are used as an additive in oils, they form thick solid tribofilms in boundary lubrication and provides superior durability and resilience to wear, meeting industrial standards for scoring, gear distress, and scuffing. This allows us to utilize lower viscosity gear oils, providing up to 2% fuel efficiency improvement, as the metal oxide coating protects the gears while operating under a mixed EHD/boundary condition. Other tribological properties of these metal oxide coatings will also be discussed.

4:40 - 5:00 pm
4205448: Molecular Dynamics Simulations of Blocked Channel Flows: Modelling Boundary Conditions Near Asperity Contacts
Nicole Dorcy, Shuangbiao Liu, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL

Micro- and nano- fluidics continue to increase in applications from biomedical, to microcomputing, to nano-tribology. Molecular Dynamics has emerged as a powerful tool to better understand these flows and has been applied to accurately model such channel flows. Existing computational methods have failed to capture what happens when a channel is constricted and blocked completely such as in the presence of an asperity contact. This work uses an atomistic simulation of a 3D shear driven channel flow of fluid Argon confined by solid walls with one surface translating at a constant velocity approaching a fixed incline converging to a total blockage of the channel. Focus is placed on the boundary layer behavior approaching the wedge tip and the point at which the 'no-slip' condition fails. Simulations are run to explore the effects of incline steepness, wall velocity and intermolecular properties to produce an equation representing the point of transition of the boundary condition.

8I The Learning Center

Grease II

Session Chair: Femke Hogenberk, University of Twente, Enschede, Overijssel, Netherlands
Session Vice Chair: William Tuszynski, Unamigroup, Quakertown, PA

1:40 - 2:20 pm
4180147: A Comparison of Bearing Manufacturers Recommendations on Lubrication of Bearings
Michael Holloway, 5th Order Industry, Highland Village, TX

In the world of bearing lubrication and reliability, there are certain concepts that are universally agreed upon and others that are application or OEM centric. This presentation compares how major bearing manufacturers address common concepts such as grease volume fill application.

2:20 - 2:40 pm
4188540: Film Thickness in Grease-lubricated Deep Groove Ball Bearings–a Master Curve
Piet Lugt, SKF Research and Technology Development, Houten, Netherlands; Pramod Shetty, SKF, Houten, Netherlands

Most rolling element bearings use grease as a lubricant, and their service life depends on both bearing fatigue life and grease life, influenced by the film thickness. Currently, there is no specific equation for predicting the film thickness in grease-lubricated bearings, so oil lubrication equations are used. In this study, the film thicknesses immediately after the churning phase under various conditions on different bearings and greases were studied. It is shown that the film thickness after churning is determined by the dynamics of the lubricant flow in and around the contacts and not by oil released by the grease (bleed). In addition, it is shown that the film thickness in a grease-lubricated bearing is almost independent of speed at higher speeds. Finally, a semi-empirical equation is proposed to calculate the film thickness in grease-lubricated ball bearings under radial, axial, and combined loads.

2:40 - 3:00 pm
4200436: Design of Plant-Based Bio-Greases with High Temperature Stability and Reliable Lubrication Under Large Contact Stresses
Mohammad Eskandari, Asghar Shirani, Ali Zayaan Macknojia, Diana Berman, University of North Texas, Denton, TX

Biolubricants are gaining significant attention due to their environmental friendliness and potential to replace traditional petroleum-based lubrication formulations. This study investigates the performance of bio-greases composed of crop-seed oils and functionalized nanoclays evaluating their rheological and tribological characteristics across a range of temperatures. Viscosity, shear stability and dynamic recovery were analyzed to understand the performance of the bio-greases under heat and cold. Additionally, oxidation resistance, friction and wear tests performed to simulate the performance of the bio-greases in real-world applications. The results suggest that these greases maintain consistent performance across a broad range of temperatures, velocities, and contact loads, making them suitable for diverse industrial applications. The findings highlight the potential of bio-greases as sustainable alternatives and emphasize the need for further formulation optimization.

3:00 - 3:20 pm - **Break**

3:20 - 3:40 pm
4306218: Enhancing Grease Lubricity with Ionic Liquids: Insights from Multinuclear NMR Spectroscopy
Sergei Glavatskih, Roman de la Presilla, KTH Royal Institute of Tribology, Stockholm, Sweden; Johan Leckner, Axel Christiernsson Int. AB, Nol, Sweden; Andrei Filippov, Oleg Antzutkin, Lulea University, Lulea, Sweden

Grease lubricity plays a crucial role in the performance of machine components. The thickener retains the base oil, acting as a reservoir, while additives are used to fine-tune its properties for specific applications. Composed of cations and anions, ionic liquids (ILs) represent a novel class of functional additives and introduce unique grease properties such as enhanced lubricity and electrical conductivity. However, the underlying ionic mechanisms responsible for these enhanced functionalities remain unexplored.
We employ multinuclear NMR to study molecular and ionic mobilities in a grease system and its base oil. Nuclear magnetic resonance (NMR) provides critical insights into the mobility of individual components, shedding light on their interactions within the lubricant matrix. The findings help elucidate how the molecular architecture of ionic liquids influences grease lubricity and offer a framework for optimizing grease formulations through IL-based additives.

3:40 - 4:30 pm - **Grease Committee Meeting**

9A Grand Hall - Exhibit Hall

Graduate Student Posters

4206558: Wear Resistance of a Thermochemical Diffusion Treatment on AISI 304 Stainless Steel
Andrea Mandujano-Rodríguez, Instituto Politecnico Nacional, Azcapotzalco, Ciudad De MexicoO, Mexico; A. Márquez-Herrera, Universidad de Guanajuato, Irapuato, Guanajuato, Mexico; Ezequiel Gallardo-Hernández, Instituto Politécnico Nacional, Mexico City, México

Boron Treatment is a common thermochemical treatment used to increase wear resistance on engineering materials. This work aims to evaluate the friction coefficient and the wear behavior of 304 steel and boride Steel in a Pin-on-Disk Tribometer the results show a steady friction coefficients on the Steel samples, and slaily variation on the samples with thermochemical treatment. However, the wear resistance was improved on the treat examples compared to on treated Steel samples, according to the wear rate and wear coefficients.

4301953: Adhesion of Diamond Like Carbon Transfer Films to Intermetallic Shape Memory Alloys

Craig Barbour, Florida Agricultural and Mechanical University, Tallahassee, FL; Adam DeLong, Catherine Fidd, Santiago Lazarte, Brandon Krick, Florida State University, Tallahassee, FL; Tomas Babuska, John Curry, Sandia National Laboratories, Albuquerque, NM; Christopher DellaCorte, University of Akron, Akron, OH; William Scott, Samuel Howard, NASA, Huntsville, AL

Dry film lubricants rely on transfer film formation to reduce wear and friction, but adherence varies by material. This study examines the transfer film adherence of Diamond-Like Carbon (DLC) coatings on counter surfaces including Silicon Nitride, 440C stainless steel, and NiTi60, using ball-on-flat testing, with experiments conducted in an inert nitrogen environment. NiTi60's elastic properties are ideal as a long duration bearing material. While some materials are known to promote better transfer film formation, the adherence of transfer films on NiTi60 remains largely unexplored. This research provides insights into DLC performance on NiTi60, with implications for aerospace applications where stable lubrication under extreme conditions is critical. Findings will enhance material selection and coating strategies for advanced tribological systems.

4302771: Effect of Oil Viscosity and Nanoparticle Additives on Electrically Induced Pitting in Rolling Element Contacts

Sudip Saha, Jack Janik, Robert Jackson, Auburn University, Auburn, AL

Electrically induced pitting remains a significant challenge in rolling element bearings of electric vehicle (EV) drivetrains and other tribological systems exposed to electrical discharge. This study examines the effects of oil viscosity and nanoparticle additives on electro-pitting performance in rolling contacts. Ball-on-flat rolling contact tribological experiments were conducted to assess the influence of different viscosity oils, with and without nanoparticle additives, on surface pitting morphology under applied external electrical loads. Preliminary findings indicate that viscosity plays a crucial role in film formation and electrical insulation, while the effectiveness of nanoparticle-enhanced lubrication depends heavily on the dispersibility of nanoparticles within the contact zone. This research provides valuable insights into optimizing lubricant formulations to enhance bearing durability in EVs and other electrically stressed mechanical systems.

4301890: Grease Tribological Performance in Electrified Conditions Evaluated Using Four-Ball Tests

Alex Hartzler, Amani Byron, Ashlie Martini, University of California Merced, Merced, CA; Christina Cheung, Anoop Kumar, Chevron, Richmond, CA

Electrified conditions can affect the interactions between mechanical components and lubricants. To better understand these effects, we conducted four-ball tribotests with grease under both electrified and unelectrified conditions. We observed and recorded trends in electrical contact resistance, friction, wear scar diameter, and wear volume. Scanning electron microscopy was used to identify potential wear mechanisms. Results revealed differences in grease performance based on the presence of applied current or voltage and grease formulation. These findings contribute to optimizing grease formulations for use in electrified environments, offering insights into improved lubrication strategies for electric vehicles and other machinery exposed to electrical conditions.

4301490: Design Optimization Of Oil Rings: A Time Dependent Numerical Solver
Alistair McLane, Mark Wilson, Liuquan Yang, University Of Leeds, Leeds, United Kingdom

Loose ring oil lift is a passive method for lubricating self-contained bearings, used for over a century. Despite its longevity, little progress has been made in identifying optimal ring designs. The design space is highly multidimensional, with complex interdependencies, making holistic experimental optimization infeasible. To date, no computational studies have systematically optimized oil ring performance.
This poster presents a numerical framework for simulating oil ring behavior, providing a crucial first step toward computational optimization. The framework is designed to evaluate a ring's ability to deliver the minimum required lubricant to the target area. The underlying theory and implementation are detailed, followed by example results that showcase its capability to capture key mechanisms. This work lays the foundation for large-scale, multidimensional design optimization studies, advancing the scientific understanding and engineering design of oil ring lubrication systems.

4299978: Nanoscale Mechanisms of Catalytically-induced Tribofilm Growth on NiCoCr Alloy: An In-situ Atomic Force Microscopy Study
Bunty Tomar, Vikas Paduri, Ritesh Sachan, Pranjal Nautiyal, Oklahoma State University, Stillwater, OK

Catalytic alloys reduce wear at sliding contacts by forming carbon-based tribofilms from ambient hydrocarbons. However, existing catalytic alloys rely on expensive noble metals, limiting their applications. This study explores the catalytic properties of NiCoCr, a multi-principal element alloy, to form tribofilms in a lubricant-free environment. Using in-situ atomic force microscopy, we investigated tribofilm growth mechanisms at single asperity sliding contacts. The tribofilm growth rate constant and yield increased exponentially with stress, consistent with stress-assisted reaction rate theory. Tribofilm growth was self-limiting, reaching saturation as catalytic sites were exhausted. At elevated stresses, mechanochemical wear countered catalytic tribofilm growth, with the final film thickness determined by the equilibrium between the two processes. These tribofilms prevented wear of alloy under stresses up to 20 GPa, demonstrating NiCoCr's potential as a self-lubricating material.

4301432: In-situ Probing of Lubrication Mechanism in Phosphonium Phosphate Ionic Liquid Under Electric Field
Foyez Ahmad, Pranjal Nautiyal, Oklahoma State University, Stillwater, OK; Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Tribochemical reaction mechanisms under electric fields remain largely unexplored, limiting the development of advanced lubricants for electrified mechanical systems. This study investigates the effect of electrical current on tribofilm formation by a phosphonium phosphate ionic liquid. Using in-situ optical interferometry, we measured tribofilm growth kinetics at a sliding/rolling steel contact under varying direct current. We discovered that tribofilm growth follows zero-order reaction kinetics, with electrical current accelerating the formation of a phosphorus- and oxygen-rich tribofilm. However, beyond a critical current, micropitting counteracts tribofilm deposition. Scanning electron microscopy revealed a direct correlation between the current magnitude and the extent of micropitting. Based on these results, we propose a model that integrates electrical current into the widely used stress-augmented, thermal activation model for tribofilm growth.

4301609: Study of the Tribology and Physiochemical Properties of Newly-synthesized Bio-lubricants via Trans(esterification), Epoxidation, and Friedel Crafts Acylation
Noor Fatima, Hossein Jahromi, Robert Jackson, Sudip Saha, Sushil Adhikari, Auburn University, Auburn, AL

Bio-lubricants produced through advanced methods can address key limitations of traditional vegetable oil-based lubricants, such as limited VI, delivering sustainable solutions. This study builds on a previously developed four-step process to convert vegetable oils into a new generation of FC-based bio-lubricants (FC-HT). A novel low-temperature (LT) process has been developed that could significantly reduce the energy requirements compared to the previous method. The new pathway includes fatty acid chloride synthesis, followed by fatty acid anhydride formation, before the FC acylation step at 80°C to synthesize the new bio-lubricant (FC-LT). Bio-lubricants synthesized using techniques such as transesterification and epoxidation were evaluated as benchmarks. The ball-on-flat Stribeck curve test revealed that FC-LT exhibited the best lubricating performance. The FC-LT had a kinematic viscosity of 41.6 cSt, pour point of 6°C, VI 151.9, Noack volatility of 5%, and a much higher yield.

4301829: High Performance Hydraulic Components Extend Battery Life in Mobile Hydraulic Equipment
Brandon Janes, Pawan Panwar, Paul Michael, Milwaukee School of Engineering, Milwaukee, WI; Jim Kaas, IFP Motion Solution, Cedar Rapids, IA

The electrification of machines prompts designers to balance machine runtime and battery costs. Enhancing hydraulic system efficiency can prolong operating time on existing battery capacity or reduce battery size for cost savings. An investigation on advanced counterbalance valve energy-saving potential was conducted using a battery-driven power unit. Various load levels were tested to examine duty cycle impacts. Factors such as cylinder load, position, pressure, and fluid temperature were monitored. Results showed a 10% increase in cycle counts and operating times with high-efficiency valves, enabling the elimination of an entire battery, with a cost/benefit analysis provided.

4301736: Tribofilm Formation and Tribological Performance of Additive-Enhanced Water-Based Drilling Fluids
Kevin Moreno-Ruiz, Ashlie Martini, University of California Merced, Merced, CA; Mario Ramirez, Troy Griff, Chevron Phillips, Woodlands, TX

This study explores the tribofilm formation and tribological performance of water-based drilling fluids enhanced with a specialized additive at different concentrations on 52100 steel surfaces. Tests were conducted under elevated temperatures to investigate the additive’s impact under simulated drilling conditions. Coefficient of Friction (CoF) data and wear rates were analyzed to assess the fluid's tribological behavior. Surface characterization using interferometry, SEM, EDS, and XPS provided detailed insights into the chemical characteristics of the tribofilms. Preliminary findings indicate that the additive influences tribofilm formation, stabilizes friction, and potentially mitigates wear.

4301832: Experimental and Modeling Analysis of Frictional Forces in Reciprocating Rod-Seals Under Varying Surface Profile Conditions
Omer Mohamed, Shubham Daler, Pawan Panwar, Paul Michael, Milwaukee School of Engineering, Milwaukee, WI

Stick-slip friction, characterized by sawtooth force oscillations due to presliding adhesion andelastohydrodynamic slip, negatively impacts machine control and operator safety in applications such as cranes, telescopic lifts, and utility bucket trucks. Optimizing lubricated

sealing systems to mitigate stick-slip requires an accurate friction model for the contact area. This study explores frictional forces and stick-slip in reciprocating rod-seal interfaces, focusing on fluid chemistry and hydraulic rod surface characteristics. Three hydraulic fluids with varying viscosities were tested under different conditions with a U-cup seal. A rod section was modified to analyze surface effects. Results showed that increased roughness suppressed stick-slip but raised friction, while higher sliding speeds reduced both. Increased pressure raised friction without impacting stick-slip. A modified LuGre model effectively predicted frictional behavior, aiding hydraulic system optimization.

4283863: Lubricant Levitation in High-Speed Bearings: A Combined Experimental and Numerical Approach

Ujjawal Arya, Farshid Sadeghi, Purdue University, West Lafayette, IN

This study investigates the phenomenon of lubricant levitation on bearing surfaces during high-speed operation, where flow can be significantly affected by lubricant levitation. Experiments were conducted using high-speed rotating setups involving the ball, inner race, and outer race, with a high-speed camera capturing the lubricant film levitation under various operating conditions. The results revealed the occurrence of Aerodynamic Leidenfrost Effect, which causes the lubricant film to levitate over the surface, reducing adhesion at elevated speeds. A numerical model based on compressible Reynolds Equation for air was also developed to simulate this effect, treating the lubricant droplet as a deformable soft elastic body supported by the air-film lubrication pressure. The model's predictions closely aligned with experimental trends and existing literature, offering valuable insights into the critical parameters influencing lubricant adhesion and effectiveness in high-speed tribology.

4201737: Thermal Transport and Tribological Performance of Tungsten Dissulfide Vegetable-Based Nanolubricants

Jose Taha, Dyana De Leon-Elizondo, Gerardo Lopez, University of Texas Rio Grande Valley, Edinburg, TX

Novel ecofriendly alternatives are search to counterattack the petroleum-based fluids and lubricants in diverse . Thermal conductivity and Tribological characteristics (Coefficient of Friction and Wear) are evaluated and analyzed on vegetable lubricants reinforced with tungsten dissulfide (WS_2) nanostructures.

4191568: Influence of Oil-Water Mixing Conditions on the Friction and Wear Performance of Ship Tail-Bearing Materials

Lun Wang, Qipeng Huang, Zhenjiang Zhou, Xincong Zhou, Shaopeng Xing, Wuhan University of Technology, Wuhan, Hubei, China

The study addresses lubrication failures in ship tail bearings under extreme conditions, such as collisions, reefing, grounding, and attacks during navigation. Three composite materials—Polymer, Thordon, and Feroform—were tested with varying oil-water mixtures using a rotational rheometer (MCR102) and a ring-block friction tester. The results indicate that the friction coefficients of all three materials decrease with increasing load and velocity. Wear initially increases with oil content before decreasing, and higher oil content leads to less wear. Under poor conditions, the materials exhibit abrasive and adhesive wear. This research provides insights for designing sub-bearings for oil-water mixed lubrication in particular conditions.

4195866: Tailoring Tribo-Mechanical Behavior of Direct Energy Deposited Austenitic Stainless Steels via Interlayer Ultrasonic Impact Treatment
Uday Venkat Kiran Kommineni, Sougata Roy, Iowa State University, Ames, IA

This study explores the potential of combining laser powder blown-directed energy deposition (L-DED) with ultrasonic impact treatment (UIT) to fabricate nitrogen-strengthened austenitic stainless steel (nitronic-60) components with enhanced surface quality and performance. UIT was introduced to mitigate the inherent crystallographic texture associated with L-DED by inducing dynamic recrystallization, refining grain size, and reducing anisotropy. A multi-layer deposition process was employed, consisting of a base layer of nitronic-60 followed by alternating L-DED and UIT layers. Materials characterization, including 3D surface topography, optical microscopy, electron backscatter diffraction, and microhardness, was conducted to evaluate the effects of the hybrid process on the microstructure and mechanical properties. Further, the fretting wear behavior of fabricated samples was assessed to understand the suitability of the material for nuclear energy applications.

4199735: Molecular Dynamics Simulation Analysis of Self-Assembled Monolayer of Organic Additives
Takehiro Kobayashi, Ryuichi Okamoto, Hitoshi Washizu, University of Hyogo, Kobe-shi, Hyogo-ken, Japan

Chain matching in a boundary lubrication film by organic friction modifier is one of the most important concept to obtain low friction. If the chain length of the organic additives (such as a carboxylic acid with a linear alkyl chain like stearic acid) is same as the chain length of the linear base oil, the system shows lower friction. Although this idea is supported by experiments, the mechanism of low friction on the molecular level is not well-understood. In this study, we investigate how the chain lengths of the base oils and organic additives affect the physical properties of boundary films using reactive molecular dynamics simulations. Interestingly, The high orientation factor and low coefficient of friction observed in the case of stearic acid indicate a strong boundary film, which has been anticipated by the experimental results for a long time.

4201613: Tissue Properties Independently Influence Articular Cartilage Superlubricity
Emily Lambeth, Tanmayee Joshi, Kayla Siciliano, Elise Corbin, David Burris, Christopher Price, University of Delaware, Newark, DE

In vivo, articular cartilage exhibits remarkable superlubricity ($\mu<0.01$), which has, historically, been attributed to the tissue's material properties. However, recent works, using our cSCA testing approach, suggest that key (naïve) cartilage lubrication behaviors may be insensitive to material properties. Whether such independence extends to non-naïve tissue properties or to the sustenance of superlubricity is unclear. Thus, osteochondral explants underwent mechanical and tribomechanical characterization (under physiological sliding speeds) in PBS and HA of varying tonicity—to alter tissue stiffness. PBS-lubricated cSCA cartilage exhibited tonicity-dependent μ (including superlubricity in hypertonically "softened" tissues) while HA-mediated superlubricity was independent of tonicity. In uncovering this dependence between cartilage superlubricity and tissue properties (i.e. softening), the present work should help reconcile disputes over certain cartilage lubrication mechanisms.

4302077: Developing and Characterizing a Low-COF Graphite Coating from Recycled Graphite
Zachary Frank, Sujan Ghosh, University of Arkansas - Little Rock, Little Rock, IL

This study aims to develop and characterize a low-coefficient-of-friction (COF) graphite-based coating using recycled graphite as the primary material. Using recycled graphite offers an eco-friendly alternative to traditional coatings while maintaining excellent tribological properties. The

recycled graphite undergoes purification and particle size optimization before combining with a suitable binder system to enhance adhesion, durability, and mechanical integrity. The coating is applied to stainless-steel substrates and analyzed through surface morphology analysis (SEM), tribological testing (pin-on-disc and scratch testing), and thermal stability evaluations. The results indicate that the recycled graphite-based coating displays comparable or superior friction and wear performance to conventional graphite coatings, positioning it as a promising option for sustainable lubrication solutions in high-performance applications.

4302067: Lubrication Performance of Chemically Synthesized WDTC Using Lubricant Additives
Sota Seki, Graduate School of Tokyo University of Science, Tokyo, Japan; Shinya Sasaki, Kaisei Sato, Leonardo Hayato Foianesi-Takeshige, Akiharu Satake, Tokyo University of Science, Tokyo, Japan; Takuya Kuwahara, Noriyoshi Tanaka, Offie Tanaka, Saitama, Japan

To achieve a carbon-neutral society, developing new lubricant additives that reduce friction is essential. Molybdenum dithiocarbamate (MoDTC) is a well-known friction modifier that improves fuel efficiency when added to engine oil. However, its friction-reducing effect diminishes with increasing driving distance.
In this study, we explored tungsten as an alternative friction modifier by synthesizing tungsten dithiocarbamate (WDTC) and evaluating its lubrication performance. We hypothesized that WDTC would undergo a chemical reaction similar to MoDTC, forming WS_2 at the friction interface and reducing friction.
This presentation covers the synthesis of WDTC, chemical analysis—including mass spectrometry—and its friction and wear performance assessed using a reciprocating tester. We also discuss the composition of tribochemical reaction films analyzed by Raman spectroscopy and XPS, highlighting WDTC's potential as a durable friction modifier.

4302053: Effects of Shear/Compression Stresses on Tribofilm Growth Distribution in Tritolyl Phosphate
Kensuke Anegawa, Tokyo University of Science, Katsusika, Tokyo, Japan; Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Tokyo, Japan; Robert Carpick, University of Pennsylvania, Philadelphia, PA

With the aim of improving fuel and power transmission efficiency, reduction of lubricant viscosity is promoted and concerns about wear and seizure in sliding parts raises due to thinner oil films. To address this, establishing formulation guidelines for lubricant additives that enhance wear resistance is essential. Phosphorus ester-based additives adsorb onto metal surfaces and form tribo-films by generated high temperatures and high stress at single asperities to suppress wear. Previous research reports that tribofilm growth rates are dominated by shear/compression stresses, but growth remains uneven under similar stress values, and their effects on growth distribution are unclear. This study used in situ Atomic Force Microscopy (AFM) to observe nanoscale tribofilm growth in tritolyl phosphate and examined the influence of shear/compression stresses. Additionally, contact analysis was conducted to investigate the relationship between compressive/shear stresses and tribofilm growth.

4302127: Experimental Method for In-Situ Real-Time Scuffing Observation in Self-Mated Steel Using Synchrotron XRD
Farida Ahmed Koly, David Burris, Arnab Bhattacharjee, University of Delaware, Newark, DE; Cinta Lorenzo Martin, Oyelayo Ajayi, Argonne National Laboratory, Argonne, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Nikhil Murthy, Scott Walck, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

Scuffing is a tribological failure with rapid friction rise and plastic deformation. Studying it is challenging as it occurs unpredictably at buried interfaces. This poster presents a method for real-

time scuffing analysis in self-mated steel contacts using high-energy X-rays from the synchrotron at the Advanced Photon Source, Argonne National Laboratory. An X-ray-compatible tribometry system was developed for in-situ and real-time investigation. The method employs a crossed-cylinders configuration with a thin (500 μm) stationary component and a small (~200 μm) contact width, maximizing X-ray interaction within the stress field. Despite the small contact area and loads, the setup reliably induces scuffing. In-situ XRD reveals an increase in peak width (FWHM) during frictional rise, persisting after the test, indicating grain refinement and strain accumulation. Post-scuffing analysis confirms grain refinement and grain elongation, which correlate with in-situ diffraction data.

4302032: Comparative Tribological Study of Ni-Cr Coatings with Ti and Cr Modifications via DC Magnetron Sputtering

Mohammad Ashikul Alam, Sujan Ghosh, University of Arkansas - Little Rock, Little Rock, IL

Ni-Cr coatings are used in aerospace and industrial applications for their thermal stability and oxidation resistance. However, Ni-Cr coatings suffer from high friction and suboptimal wear resistance in tribological applications. This study enhances Ni-Cr coatings by incorporating a Titanium (Ti) and Chromium (Cr) underlayer. A comparative analysis was conducted on three coatings: Ni-Cr alone, Ni-Cr with a Ti underlayer (Ti/Ni-Cr), and Ni-Cr with a Cr underlayer and Ti interlayer (Cr/Ti/Ni-Cr). Coatings were deposited on AISI 304 stainless steel using DC Magnetron Sputtering and evaluated for microstructure, adhesion, wear resistance, and friction. SEM and EDS characterized morphology and composition, while Ball-on-Disk testing measured CoF and wear rates. Results showed Ni-Cr alone had the highest friction and material loss, Ti/Ni-Cr improved wear resistance but had adhesion issues, while Cr/Ti/Ni-Cr exhibited the lowest CoF, highest wear resistance, and longest wear life.

4301932: Tribology Within Hydrogen Environments

Christian Micko, Adam DeLong, Brandon Krick, Florida State University, Tallahassee, FL; Craig Barbour, Florida Agricultural and Mechanical University, Tallahassee, FL; Nicolas Argibay, Aero-Propulsion, Mechatronics and Energy Lab, Tallahassee, FL

Developing hydrogen power systems requires materials that mitigate wear and friction. This study presents a tribometer situated in a hydrogen environment, designed to evaluate the ability of dry lubrication coatings. By using tests in extreme hydrogen environments, specific material properties and wear mechanics can be determined. The technical evaluation uses standard ball-on-flat wear test in a pressurized hydrogen system that enables controlled pressure variations to replicate specific conditions. Within this study, this tribometer should support the optimizations of coating performances within other hydrogen surrounded systems. This research will contribute to advancing material selection and durability strategies essential for hydrogen-based technologies.

4301911: Abrasive Behavior of Pristine vs. Environmentally Degraded Additively Manufactured and Molded Polymers

Zachary Rehg, Alex Patrick, Ronald White, Jin Choi, Caleb Luo-Gardner, Michael Norenberg, Arash Afshar, Stephen Hill, Dorina Mihut, Mercer University, Macon, GA

This study explores tribological performance of polymers subjected to environmental degradation, focusing on similar polymers fabricated through additive manufacturing and molding. The reciprocating abrasion tester (ISO1518) is used to investigate the Acrylonitrile Butadiene Styrene and Polyethylene Terephthalate Glycol. The research also evaluates hardness, flexural strength, and surface roughness of the polymers. The harsh environmental conditions are simulated by exposing materials to UV radiation and moisture for up to 1200 hours, according to ASTMG154 standard. Materials are evaluated before and after environmental exposure. Mechanical properties are investigated using ASTMD790 for flexural strength and ASTMD785 for hardness, while abrasion

resistance and surface roughness are assessed using digital optical microscopy. The results provide insights into polymers behavior, supporting material selection for applications demanding resistance to abrasion and environmental aging.

4301613: Resolving Local Sliding and Stress to Study Tribofilm Growth In Situ
Anthony Kholoshenko, Parker LaMascus, University of Pennsylvania, Philadelphia, PA; Meagan Elinski, Hope College, Holland, MI; Andrew Jackson, University of Pennsylvania, Philadelphia, PA; Marjeta Fusha, Robert Wiacek, Pixelligent Technologies LLC, Baltimore, MD; Robert Carpick, University of Pennsylvania, Philadelphia, PA
Poster abstract pending approval

4277928: Friction and Wear of PTFE Composites on DLC Counter Sample
Catherine Fidd, William Nester, Brandon Krick, Florida State University, Tallahassee, FL; Kylie Van Meter, Sandia National Laboratories, Albuquerque, NM

Ultralow wear PTFE based composites, such as PTFE-Alumina and PTFE-PEEK, have wear rates on the order of 10^{-8}-10^{-7} mm^3/Nm. This has been attributed to tribochemical interactions leading to the development of tribofilms on the surface of the substrate. A majority of this work has been using stainless steel as the countersample slid against the polymer composite. Diamond like carbon (DLC) coatings are another ultralow wear, low friction solid lubricant material. In this project, PTFE composites were slid against thin film diamond-like carbon (DLC) counter samples in humid air and nitrogen using a 6-stage linear reciprocating tribometer. The composites were found to have lower wear rates when slid against DLC compared to sliding against stainless steel counter samples. IR spectroscopy was used to examine the tribochemistry of the sample surfaces. SEM was used to look at tribofilm morphology on the DLC counter samples.

4205505: Study of the Influence of a Sour Media on Erosion-Corrosion of an API 5L-X52 Section Pipeline.
Javier Frias-Flores, Ezequiel Gallardo, Jesus Godinez-Salcedo, Manuel Vite-Torres, Instituto Politecnico Nacional, México, Iztapalapa, Mexico

Corrosion is one of the principal sources of expense in many industries, mainly in the extractive oil and gas industries. Different parameters affect this phenomenon like pH and the amount of sulfides contained in the media. Besides, the phenomenon of erosion by solid particles could enhance the corrosion by erosion or vice versa. The aim of this work is to study the effect of a sour media on a pipeline section of a carbon steel (API 5L) to obtain corrosion rate and corrosion velocity. On the other hand, solid particle erosion wear resistance tests were carried out at impact angles of 30° and 90° on the samples with corrosion. The media was prepared based on the NACE 1D182 standard and the solid particles were aluminum oxide with an average size of 90 microns. All the specimens were physically and chemically characterized. The results show the influence of corrosion on the wear rate by solid particles.

4203381: Evaluating the Impact of Corroded Brake Rotors and Pads on Braking Performance and Particle Wear Emissions
Ishmaeel Ghouri, University of Leeds, Rochdale, United Kingdom

The upcoming Euro 7 standard, scheduled for implementation in 2026, represents the first set of regulations aimed at controlling emissions stemming from brake systems. This development has prompted brake manufacturers to explore alternative approaches for curbing emissions. With the growing prevalence of electric vehicles, their regenerative braking systems are diminishing the reliance on friction brakes and lead to the accumulation of corrosion on brake rotors.
Testing involved the evaluation of a new GCI brake rotor and brake pads. The brake rotors and pads were subjected to a corrosive environment in a salt spray chamber for 96 hours, following ASTM

B117-11 standards. The corroded brake rotor and pads were paired with new counter friction surface and underwent the same drag braking duty cycles at each pressure level. The braking performance and particle emissions results were compared to determine the extent of impact on the corroded brake rotor or corroded brake pad due to corrosion

4203568: The Potential Lubricating Role of Alginate Acid and Carrageen in Cleaning Solution for Orthokeratology Lenses
Hsu-Wei Fang, You-Cheng Chang, Chen-Ying Su, National Taipei University of Technology, Taipei, Taiwan

Wearing orthokeratology (ortho-k) lenses has been commonly used among myopia schoolchildren. Corneal damage is one of major clinical complications, that is mainly caused by friction between the cornea and the lens when adsorbed tear components are not removed completely from the lens. By using in vitro ortho-k lens friction testing method, the result showed the friction coefficient of ortho-k lenses was greatly increased in the presence of tear proteins but could be reduced when alginate acid and carrageen cleaning solution was added. By analyzing with quartz crystal microbalance, the adsorbed proteins would be removed if the solution of alginate acid and carrageen was passed through the chip. The potential mechanism was then proposed that alginate acid and carrageen could remove adsorbed proteins from the ortho-k lenses and increase the viscosity of the liquid, resulting in providing lubrication between two sliding surfaces and decreasing friction coefficient of ortho-k lenses.

4205160: Investigating The Tribological Performance of Additively Manufactured Al-6061 Alloy for Space Application
Pial Das, Sougata Roy, Iowa State University, Ames, IA; Annette Gray, Matthew Mazurkivich, William Scott, NASA, Huntsville, AL

In space exploration, managing energy loss due to friction is critical, especially for long-duration missions where lubrication options are limited. Aluminum 6061 (Al6061) is a favored material for spacecraft components due to its corrosion resistance, strength-to-weight ratio, formability, and durability in space conditions. Its compatibility with additive manufacturing methods like Wire Arc Additive Manufacturing (WAAM) and Laser-Powered Direct Energy Deposition (LP-DED) offers great flexibility in part production. However, the tribological behavior of Al6061 parts made using these methods has been less-explored. We explored manufacturability and tribological properties of Al6061 and its Metal Matrix Composite (MMC) version, reinforced with Titanium Carbide (TiC), under simulated lunar conditions. We found that the Al6061 MMC exhibits a significantly lower coefficient of friction than its wrought counterpart, highlighting its potential for space applications under extreme conditions.

4205347: Enhancing Scratch Resistance of Graphite Coatings through a Polydopamine Adhesive Layer
Adedoyin Abe, Min Zou, University of Arkansas, Fayetteville, AR

Polydopamine (PDA) exhibits strong adhesion to various substrates, making it valuable for enhancing the durability and wear resistance of solid lubricant coatings. Graphite, valued for its low friction, is often used as a filler rather than a standalone coating because of its high wear rate and poor adhesion. This study presents a solution: incorporating a PDA adhesive layer beneath graphite to create a more wear-resistant coating. We applied 7-micron graphite coatings with and without PDA underlayers and tested their scratch resistance using a steel ball under linearly increasing loads, with loading rates of 0.1, 0.2, and 0.44 N/s over a 0.5–18 N range. Results showed that graphite coatings alone failed at an average critical load of 2 N, while PDA/graphite coatings withstood up to 18 N without failure. These findings demonstrate that PDA significantly enhances

the scratch resistance of graphite coatings, offering promise for applications requiring durable, low-friction surfaces.

4205458: Interactions Between Surface Texture Lubricant Additives
Tom Reddyhoff, Mohd Syafiq Abd Aziz, Imperial College London, London, England, United Kingdom

The application of surface texturing to sliding components can significantly enhance friction and wear performance. Consequently, extensive research has been conducted on textured surfaces, primarily focusing on the geometric parameters of the textures. However, few studies have examined the influence of lubricant composition on the performance of textured surfaces. Here, we present recent research comparing the friction-reducing performance of surface-textured components with non-textured references across various commercial and model lubricant formulations. The findings demonstrate how lubricants can be optimized for textured contacts and reveal the interactions (synergist and antagonist) between specific additives (e.g., antiwear and friction modifiers) and texture features, thereby elucidating the underlying mechanisms.

4304189: Tribological Performance of a Cold Spray Ti/TiOx Composite Coating Optimized for Boundary Lubrication Conditions
Adam Nassif, Sarah Sadoudi, Frédéric Georgi, Francesco Delloro, Pierre Montmitonnet, Imène Lahouij, MINES Paris | PSL Research University, Sophia Antipolis, France; Mustapha Yahiaoui, Abdelwahed Elghizlani, Abdel Tazibt, CRITT-TJFU, Bar-le-Duc, France

In tribological applications involving boundary lubrication conditions, the development of advanced coatings is essential for reducing friction and enhancing wear resistance. This study investigates a Ti/TiOx composite coating deposited via cold spray. The composite features hard TiOx ceramic particles embedded in a ductile titanium matrix, combining structural reinforcement with robust bonding properties.
Key parameters such as powder morphology, deposition conditions, substrate surface preparation (fluid jet), and reinforcement ratios were optimized to achieve high coating density, strong adhesion, and improved mechanical performance. The friction and wear behavior of the Ti/TiOx composite coating were evaluated under boundary lubrication conditions and compared with a pure titanium coating reference to assess the effect of reinforcement.
The relationship between deposition parameters, coating microstructure, and tribological performances are discussed based on the results.

4307896: Frictional Behavior of Soft Solids
Abrar Mohammed, Alison Dunn, University of Florida, Gainesville, FL; Srividhya Sridhar, Shelby Hutchens, University of Illinois Urbana-Champaign, Urbana, IL

Understanding the frictional behavior of soft solids can support predictive knowledge in soft robotics and needle-insertion procedures. This study investigates the frictional behavior of soft solids through a series of experiments and its response by varying surface topography (smooth, periodic, and rough). Characteristic silicone and hydrogels were slid against a steel probe under varying normal loads (5 to 70 mN), sliding speeds (0.1 to 5 mm/s) and probe sizes (2 to 4 mm diameter) on a custom micro tribometer. Results indicate that friction is highly dependent on surface topography, with rough surfaces exhibiting 43% higher surface friction than smooth surfaces when compared at similar matrix. However, friction barely changes for hydrogel surfaces. The study highlights the dominant role of material properties and surfaces in dictating friction. Future work aims to develop mathematical validations to establish predictive frameworks for this relationship.

4287141: Thin Film Lubrication for Extreme Environments
Leon Burky, Juan Bosch Giner, Christopher DellaCorte, University of Akron, Akron, OH

With a heightened interest in greater service lifetimes for applications in space an increased interest in lubrication for space mechanisms has surfaced. Conventional oil-based lubricants are chemically and thermally unstable in space environments and therefore paved the way towards thin film coatings to extend the service frequency of space mechanisms. There have been few advancements for extended life coatings and a restricted understanding of performance in high temperature conditions. This study aims to assess thin film coating in high vacuum at room and high temperatures. Preliminary tests analyzing greases and implemented solid lubricants (MoS_2 and Ag) display stable and repeatable yields.

4303472: Experimental Considerations for Measuring the Forces of Fracture and Friction During Needle Insertion into Soft Materials
Gabriela Whitmer, Sebastian Herrero Casteigts, Abrar Mohammed, Alison Dunn, University of Florida, Gainesville, FL

Needle steering technology has recently achieved various methods for directional control through needle designs and fast feedback mechanisms, but predictive control is hampered by the lack of knowledge of the integrated cutting and sliding forces at the boundary of the needle and soft material. Further, many synthetic soft materials are used for research in this area, including silicones, hydrogels, and plasticenes, which does not allow validation of findings between setups. In this work we demonstrate the design of a needle insertion tester in situ over a fluorescence microscope with specific focus on the fabrication of appropriate hydrogel samples and guiding the needle to translate without significant parasitic motion. Hydrogels with specific toughness and swelling properties were created in specific shapes for testing. A custom needle translation and guide system was designed and fabricated. Such research will lead to visualizing the needle/sample boundary for the first time.

4307914: Open-Source, Multi-component Control of Wear Tribometer
Adam Hamdan, Ta'myah Byars, Alison Dunn, University of Florida, Gainesville, FL

Wear of materials is a gradual process requiring precise measurements of forces, motions, and material loss. Further, tribological phenomena are often strongly affected by environmental conditions such as humidity and temperature. Modern experiments require simultaneous control and acquisition of multiple properties and conditions, including a reciprocating stage, a load cell, and data acquisition system. The development of a standardized mechanical, electrical, and software infrastructure is critical for consistent and meaningful scientific findings. This research focuses on the development of this infrastructure, utilizing Python with relevant packages for reading and controlling analog voltages, pneumatic controllers, and a linear screw-driven stage with the goal of creating precise measurements. The establishment of this infrastructure allows for proper and consistent experimentation, enabling understanding of tribological wear for advanced polymer materials.

4307907: Interfacial Stiffness and Contact Mechanics of Coated Aluminum Surfaces
Thomas Eggers, Alexander Gordillo Jimenez, Alison Dunn, University of Florida, Gainesville, FL

Interfacial stiffness between mechanical components, for example in sliding bearings, is important to their operation, especially when used as part of larger dynamic systems of distributed stiffness. This stiffness can change over various timescales due to startup, run-in, or even creep, which complicates operational and life prediction. In this work we seek to connect surface evolution to interfacial stiffness using the hypothesis that elastic-plastic asperity properties control them both. Toward this goal we will present a proof-of-concept correlating theoretical elastic-plastic asperity

deformation to real measurements of metallic coated surfaces under high pressure. Samples of grades 2011 and 6061 aluminums were polished to roughness values ranging from 3-387 μm, then anodized to thicknesses from 0.4-1 mil. Large normal loads were applied to the sample surfaces, and statistical parameters were used to quantify deformation and interfacial stiffness as a function of the load.

4307918: Frictional Control of Bio-inspired Latches
Nabin Bastola, Kaylei Rodriguez, Rajshibhu Pandey, Jadon Reuben, Alison Dunn, University of Florida, Gainesville, FL

Certain small arthropods exhibit precise control over explosive maneuvers through spring-latch mechanisms, overcoming the physical trade-off between force and velocity that limits mechanical power in larger systems. These animals store energy in exoskeletal tissues and rapidly release it via slip-contact latch systems. The Click Beetle is of particular interest due to its externally visible latch mechanism, where friction and contact properties influence power output and acceleration. Understanding the latch's kinematic interfacial mechanic and geometry-contact interaction is key to scaling small-scale kinematics, enhancing motion control, and improving system durability through optimized stiffness and contact properties. In this study, a contact latch system has been developed to examine how its stiffness, contact geometry, and friction influence power output, acceleration, release velocity, and angle, offering insights for efficient and durable mechanical designs inspired by biology.

4310894: Surface Topography Analysis of As-built Parts in Binder Jetting Additive Manufacturing Process
Ertiza Hossain Shopnil, Christopher Williams, Bart Raeymaekers, Virginia Tech, Blacksburg, VA

Binder jetting (BJT) is an additive manufacturing process that uses selective deposition of liquid binder on a powder bed to fabricate green parts by chemically bonding the powders. However, the surface topography of as-built parts is coarse and often necessitates post-processing for most engineering applications. This study investigates the influence of key BJT process parameters, including binder saturation, layer thickness, drying time, roller rotational speed, and roller traverse speed on the surface topography and green density of SS 316L parts. We measure the surface topography parameters that characterize the as-built surfaces and identify binder saturation, layer thickness, and drying time as the most influential process parameters governing surface topography and green density. The study reveals the parameter settings corresponding to minimum surface roughness and maximum green density. Additionally, the green density shows an inverse relationship with the surface roughness.

4310874: The Effect of Build Plate Location on As-built Surface Topography of Laser Powder Bed Fusion Parts
Piash Bhowmik, Bart Raeymaekers, Virginia Polytechnic Institute and State University, Blacksburg, VA

Laser powder bed fusion (PBF-LB) is an additive manufacturing process that enables fabrication of structural parts with complex geometry. Yet, parts manufactured with PBF-LB require post-processing to improve mechanical properties and modify the as-built surface topography. Researchers have characterized the relationship between PBF-LB process parameters and the as-built surface topography, yet the effect of the build plate location on surface roughness remains unclear. Thus, we print 121 cylindrical stainless steel 316 specimens on a single build plate and measure the surface roughness of their top surface. The surface roughness varies along both coordinate directions on the build plate. Specifically, the surface roughness decreases with increasing distance from the edges of the build plate, and the highest surface roughness appears near the corners of the build plate, driven by energy density variations of the laser beam across the

build plate.

4309949: Ultra-low Wear of Boride Layers Formed on WRe Alloys
Merve Uysal Komurlu, Ali Erdemir, Texas A& M University, College Station, TX

Using an ultrafast boriding technique, we synthesized a composite of WB4 and ReB2 layers on a W+25 wt.% Re alloy in a borax-based molten salt electrolyte at 1000°C for 10 min. The resultant boride layers were approximately 10 µm thick and with nano-hardness values exceeding 40 GPa. Sliding friction and wear tests against a sapphire ball revealed significantly reduced friction coefficients of 0.15 for the top boride layer. In contrast, the control or unborided W+25 wt.%Re alloy exhibited friction coefficients of approximately 0.25 against the same ball sample. Post-test characterization using microscopic and spectroscopic tools revealed essentially zero wear on the borided surface, whereas the wear of the unborided WRe alloy was rather significant. Overall, our experimental and surface analytical studies confirmed that superhard boride phases formed on WRe alloy are essentially wearless and, hence, hold great promise for applications involving harsh tribological conditions.

9B Grand Hall - Exhibit Hall

Early Career Posters

4200641: Stretching and Sliding Capillary Bridges
Lennard Holschuh, Lars Pastewka, University of Freiburg, Freiburg, Germany

Capillary forces play a critical role in the adhesion between two contacting bodies. However, existing theories of macroscopic adhesion on rough surfaces often assume dry conditions, attributing adhesive interactions solely to dispersion forces and overlooking the effects of capillary bridge formation. This study employs molecular dynamics simulations to directly examine the interactions of nanoscale probes with nominally flat surfaces in the presence of liquid bridges, which form due to condensation in humid environments. The objective is to link the thermodynamic understanding of capillary bridges with molecular simulations and atomic-force microscopy experiments. The focus lies on investigating energy dissipation during adhesion (normal separation of the probe from the surface) and friction (lateral motion of the probe). By quantifying the interplay between humidity, adhesion, and friction, this work aims to improve the understanding of macroscopic adhesion in humid conditions.

4300120: The Influence of Heat Treatment on Tribofilm Formation of Pyrowear 675
Justin Schuh, Elizabeth Craft, Ronald Zeszut, University of Dayton Research Institute, Dayton, OH; Daulton Isaac, AFRI Turbine Engine Division, Wright Patterson Air Force Base, OH

The performance of a bearing steel can be attributed to its wear resistance and its ability to form a tribofilm on its surface, and both of these factors can be impacted by heat treatments. This study investigates how the tribological performance of Pyrowear 675 is affected by different heat treatments, such as low-temperature tempering (LTT), high temperature tempering (HTT), and carbonitriding (CN). Scanning Electron Microscopy (SEM) and X-Ray Photoelectron Spectroscopy (XPS) will be used to assess the formation of tribofilms using the same MIL-PRF-23699 lubricant for each variant.

4294441: CO_2 Emission Reduction Through Targeted Grease Analysis
Julie Solis, MRG Labs, York, PA

With the growing environmental consciousness of waste generated by rotating mechanical equipment, sustainable lubrication practices have continued to evolve and become more pertinent in maintaining the longevity and integrity of equipment but also contribute to the reduction of carbon emissions. For instance, wear is a type of waste that can be generated by insufficient or excessive lubricant, contamination, or incompatibility with the equipment of operation. Through targeted grease analysis, lubricant conditions can be assessed and monitored through a series of tests, such as analytical ferrography, water content, or FTIR spectroscopy. By implementing the right lubrication practices, there may be an opportunity to reduce CO_2 emissions without sacrificing total functionality.

4298899: Investigation into actual asperity pressures in elastic-plastic rough surface contacts
Keita Inose, Amir Kadiric, Imperial College London, London, United Kingdom

The actual asperity pressures in metallic rough surface contacts were ascertained by combining direct experimental observations and numerical simulations. The investigation covering a range of roughness and contacting material properties confirmed that the maximum contact pressure of asperities was much higher than the bulk hardness, and the mean asperity pressure was strongly affected by the roughness levels: it increased linearly with the plasticity index ψ and then levelled off at approximately 1.5 times the bulk hardness. Furthermore, numerical contact simulations using the elastic-perfect plastic model showed that limiting the maximum contact pressure to 1.5 times the bulk hardness was a good approximation for predicting the actual contact. These results provide new insights into the level of plasticity of asperities and can aid the modelling for better prediction of rough surface contact with plastic deformation of asperities.

4242539: The Best Way of Preventing and Anticipating the Oxidation Residues and Varnish Formation
Marie Roucan, Jérémy Pallas, ANTARA GROUPE, Chateaudun, France, France

Lubricants have attracted a lot of consideration to understand the complexity behind the oxidation process which is a key asset to increase the oil lifetime. Usual strategies employed consist of physical and macro-chemical analysis of lubricants, however, oxidation also involves the rapid formation of free radicals in “in-service” oil. EPR is a well-established technique to identify and quantify free radicals. Coupled with the spin trapping method, it allows us to see highly reactive oxygen species such as peroxides as well as the decomposition of additives such as antioxidants. We are using these EPR-spin trapping techniques in our industry as a tool to have a better comprehension of the degradation process of lubricants. Coupled with our newly synthetized nanomaterials for filtration, this will allow an appreciation of the synergy between the oil, additives and the radical species formed in order to define key performance indicators seen during the oil degradation process.

4201772: The Influence of Boron-Containing Ionic Liquid on the Colloidal Stability and Tribological Property of Lubricating Grease
Enhui Zhang, Yunxin Wang, Weimin Li, Rui Ma, Junyang Dong, Wenwen Ma, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Qingdao, China

The Lewis acid-base interaction between boron atoms and lithium soap fibers on the microstructure control of grease can be employed as the basis for the development of novel boron-containing grease additives. In this study, boron-containing ionic liquid additives have been designed to both control the grease microstructure and reduce friction and wear. The addition of these additives to lithium grease has been shown to increase the dropping point by more than 30 °C

and greatly improve the colloidal stability of grease. The tribological tests demonstrate that the additives significantly enhances the high-temperature tribological performance of the grease. This improvement is primarily attributed to the additive's capacity to elevate the high-temperature colloidal stability and thermal stability of the grease, thereby augmenting its film-forming performance on the friction surface. This study provides novel ideas for developing multifunctional lubricating additives for greases.

4295764: Tribochemical Reactions of Si-DLC/Si_3N_4 by Reactive Molecular Dynamics Simulation

Tomoya Hasegawa, Iwa Ou, Masayuki Kawaura, Eagle Industry Co., Ltd., Sakado, Saitama, Japan; Momoji Kubo, Tohoku University, Sendai, Miyagi, Japan

Diamond-like carbon (DLC) coating is widely applied in sliding components due to their high hardness, low friction and excellent wear resistance, where continuous tribo-film formation is expected to play an important role.
A recent study on the sliding between silicon-doped DLC (Si-DLC) and silicon nitride (Si_3N_4) in humid air has reported that the amount of Si content and the surrounding environment affect the tribological film formation. However, the underlying mechanism is not clear.
In order to investigate the effect of Si doping on the formation of tribo-film and its composition, we performed a reactive molecular dynamics simulation of Si-DLC/ Si_3N_4 in water environment.
In the initial stage of sliding, Si atoms reacted with water molecules to form Si-OH terminations. As the sliding distance increased, the reaction with water molecules stopped and the number of Si-OH terminations decreased. As a result, Si-O-Si and Si-O-C increased, which may lead to tribo-film formation.

4299877: The Influence of Lubricant Composition on Tribofilm Formation on P675

Elizabeth Craft, Justin Schuh, Ronald Zeszut, University of Dayton Research Institute, Dayton, OH; Daulton Isaac, AFRI Turbine Engine Division, Wright Patterson Air Force Base, OH

Bearing surface fatigue life is known to be influenced both by lubricant physical and chemical properties. The chemical composition and additive content of a lubricant have an effect on fatigue life, particularly for applications operating in low specific film thickness. This work explores how lubricant physical properties, specifically viscosity, and chemical composition affect tribofilm formation both for changes over time and exposure level in a particular lubricant as well as differences across lubricants of various manufacturers or grades. This study also investigates the impact that additive content has on tribofilm formation and how additive content changes with time and temperature for different grade and class oils, utilizing SEM and XPS to monitor tribofilm growth.

4301233: New Insights into the Interactions Between Phosphorus and Sulfur-containing Lubricating Additives

Yunlong Chen, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Qingdao, Shandong, China

This study investigates the interaction mechanisms between a phosphorus-based anti-wear additive (AP) and sulfur-based extreme pressure additives (SIB and PS) using reciprocating friction tests. Results revealed opposing effects: AP+SIB significantly reduced friction and wear, while AP+PS impaired anti-wear performance. SIB's low active sulfur content minimally competed with AP in tribofilm formation, enabling phosphate-dominated films that enhance durability. In contrast, PS's high active sulfur content suppressed AP-derived phosphate film growth, favoring less protective sulfides. Notably, SIB contributed to tribofilm formation only under high load/temperature conditions, synergistically enhancing AP's performance. The study highlights the critical role of sulfur reactivity in additive compatibility, demonstrating that phosphate-rich

tribofilms outperform sulfide-based ones in wear resistance.

4192999: A Century of Lubrication Modeling Techniques: A Journey from Reynolds Equation to Contemporary AI-based Simulation

Abderrachid Hamrani, Fuad Hasan, Florida International University (FIU), Miami, FL

Lubrication modeling has undergone significant evolution since the formulation of the Reynolds equation in the late 19th century, which laid the foundation for understanding fluid film lubrication in engineering applications. Over the past century, advancements in computational techniques, tribological understanding, and material science have driven the development of increasingly sophisticated models. This systematic review explores the historical progression of lubrication modeling, tracing its journey from analytical approaches based on the Reynolds equation to modern-day computational techniques that leverage artificial intelligence (AI) and machine learning. We highlight key milestones, examine the strengths and limitations of various modeling approaches, and provide an in-depth analysis of AI-based simulations that are shaping the future of lubrication research.

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