1A — Hanover AB

AI and Machine Learning I

Session Chair: Nikolay Garabedian, Karlsruhe Institute of Technology, 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 the

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**

1B — Hanover C

Commercial Marketing Forum I

Session Chair: TBD

8:00 - 8:20 am - **Available**
8:20 - 8:40 am - **Kao Chemicals Europe**

8:40 - 9:00 am - **Chevron Phillips Chemical Company**
9:00 - 9:20 am - **Chevron Phillips Chemical Company**
9:20 - 9:40 am - **Colonial Chemical Company**
9:40 - 10:00 am - **Novel Reliable Technologies**

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

1C Hanover D

Wear I

Session Chair: Xue Han, Cummins, Inc., Columbus, IN
Session Vice Chair: Steven Thrush, Fuels & Lubricants, 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**

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

1E — Hanover F

Rolling Element Bearings I

Session Chair: Thomas Russell, Exponent, Natick, MA
Session Vice Chair: TBD

8:00 - 8:40 am
4184397: Numerical Modeling of Lubricant Levitation in High-Speed Bearings through a Soft-EHL Approach
Ujjawal Arya, Farshid Sadeghi, Purdue University, West Lafayette, IN

Lubricant flow in rolling element bearings can vary significantly during high-speed operation due to the potential for lubricant levitation. This study develops a numerical model based on soft-Elastohydrodynamic Lubrication (soft-EHL) to simulate lubricant droplet levitation near a high-

speed surface, demonstrating the Aerodynamic Leidenfrost Effect (ALE). The model treats the oil droplet as a deformable elastic body, supported by air-film lubrication pressure. The key factor is the Young's Modulus of the droplet, which was represented by its internal pressure. The model accurately captured ALE, analyzing air-film thickness and pressure profiles under different conditions. Comparisons with prior experimental and numerical studies validated the model and also revealed shortcomings in previous works. The model showed strong agreement with similar findings in existing literature, offering key insights into simulating ALE for a range of high-speed tribology applications.

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)
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**

1G — Regency V

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, Universität des Saarlandes, 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 am - 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 steels 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, Alpes Maritimes, 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 potentials 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**

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 - Available

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, State College, PA

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

Keynote Presentation **Centennial Ballroom**

10:30 am – 12:00 pm – STLE Annual Meeting Keynote Presentation

Watch for information on our Keynote Presenter coming soon.

2A **Hanover AB**

AI and Machine Learning II

Session Chair: Tianshi Fang, Shell Global Solutions, Houston, TX
Session Vice Chair: Max Marian, Pontificia Universidad Católica De Chile, Santiago, Chile

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 (CNN). 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
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.

2B — Hanover C

Commercial Marketing Forum II

Session Chair: TBD

1:40 - 2:00 pm - Advancion Corporation
2:00 - 2:20 pm - Evonik Oil Additives USA, Inc
2:20 - 2:40 pm - Functional Products, Inc.
2:40 - 3:00 pm - Optimal Instruments Pruftechnik GmbH

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

4:00 - 4:20 pm - VBASE Oil Company
4:20 - 4:40 pm - Zschimmer & Schwarz
4:40 - 5:00 pm - Available

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 behaviors 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 sources 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.

4:40 – 5:00 pm – Metalworking Fluids Business Meeting

2E — Hanover F

Rolling Element Bearings II

Session Chair: Ujjawal Arya, Purdue University, West Lafayette, IN
Session Vice Chair: TBD

1:40 - 2:20 pm
4182459: Advanced Stress-based Life Model for Hybrid Bearings Considering Surface and Subsurface Fatigue Risks
Nikhil Londhe, The 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
Wolfram Kruhoeffer, Joerg Loos, 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 - 4:40 pm
4205468: Mechanistic Study of White Etching Area Development in Butterflies Through 3D Investigations of Roller Bearings
Mostafa El Laithy, Ling Wang, Terry Harvey, University of Southampton, Southampton, Hampshire, United Kingdom; Wolfram Kruhoeffer, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany

The investigation of the development of butterflies (BFs) in bearings as a result of rolling contact fatigue has been a subject of intense research for decades, aimed at elucidating their underlying formation mechanisms. Notably, the majority of the studies have focused on two-dimensional analysis of the BF microstructure. In the present research, examination of butterflies at different stages of development, including their capsuled inclusions have been examined in three dimensions using laser-focused ion beam (FIB) serial sectioning method. Together with diverse electron microscopy techniques several butterflies have been fully captured. It has been revealed that the structural composition of fully developed butterflies, contradicting to the prevailing characterization in the existing literature, do not comprise two distinct/separated wings, rather that,

the white etching areas in a butterfly bear a closer resemblance to that of a single disc-shaped structure encapsuling an inclusion.

4:40 - 5:00 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: TBD
Session Vice Chair: TBD

1:40 - 2:00 pm
Introduction to Sustainability in Motion

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 economy 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 – Available

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, Diana Berman, University of North Texas, Burleson, TX; Satish Dixit, Plasma Technology Inc., Torrance, CA

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 behaviours.

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.

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 in the last years. It is well known that oil formulation plays a major role, when it comes to those requirements. But what is 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 for the oil. In this context on the one hand, new component tests shown are 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 nv, 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 bridge 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 damages 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.

Non-Ferrous Metals II

Session Chair: Thomas Oleksiak, Quaker Houghton, Oswego, IL
Session Vice Chair: TBD

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
4205310: Lubricant Selection for Enhancing Sustainability Profile in Copper Rod Mills
Randall Tyson, Gautier Burette, TotalEnergies, Nanterre, France; Steven Wheeler, TotalEnergies, Rockingham, NC

This paper will illustrate ways to improve the overall functioning of plant mechanicals through careful selection of lubricants that not only provide enhanced performance (ROI) but deliver on lowering CO2 footprint and improving overall plant sustainability profile. Of course biodegradables and renewables play a key role toward lowering the plants CO2 footprint but we will also discuss available condition monitoring and auditing schemes that will enhance the plants optimization process.

2:40 - 3:00 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.

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 sample 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**