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 Cr_2O_3 (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-MoS_2, 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.