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TUESDAY

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Overview

Download the STLE Mobile App for the most up-to-date schedule (pg. 13).

Tuesday, May 21

Onsite Registration
6:30 am – 6:00 pm – Convention Center Foyer

Speakers Breakfast
7:00 am – 7:45 am – **Seasons**

Commercial Exhibits and Posters
9:30 am – 5:30 pm – **Exhibit Hall B**

Technical Sessions (8:00 am – 12:00 pm)

- 3A • Materials Tribology I: Tribute to Michael Dugger – **101 B**
- 3B • Tribotesting III – **101 C**
- 3C • Lubrication Fundamentals I: Additives – **101 D**
- 3D • Grease II – **101 E**
- 3E • Biotribology I – **101 F**
- 3F • Nanotribology III – **101 G**
- 3I • Commercial Marketing Forum III – **101 J**
- 3J • Electric Vehicles III – **200 DE**

Networking/Refreshment Break
10:00 am – 10:40 am – **Exhibit Hall B**

President's Luncheon/STLE Business Meeting
12:00 pm – 2:00 pm – **Grand Ballroom**

Technical Sessions (2:00 pm – 5:00 pm)

- 4A • Materials Tribology II: Tribute to Michael Dugger – **101 B**
- 4C • Lubrication Fundamentals II: Marine Lubrication – **101 D**
- 4D • Grease III – **101 E**
- 4E • Biotribology II – **101 F**
- 4F • Seals I – **101 G**
- 4I • Commercial Marketing Forum IV – **101 J**
- 4J • Electric Vehicles IV – **200 DE**

Exhibitor Appreciation Break
3:00 pm – 4:00 pm – **Exhibit Hall B**

Women in Tribology Panel
(Open to all attendees)
5:00 pm – 6:00pm – **Seasons**

Exhibition hours

- **Tuesday, May 21**
  (9:30 am – 12:00 pm & 2:00 pm – 5:30 pm)
- **Exhibitor Appreciation Hour** (3:00 pm – 4:00 pm)
  Evonik Raffle (3:30 pm) – Must be present to win.
  (Booth #303)

TIME	SESSION 3A Materials Tribology I Room 101 B	SESSION 3B Tribotesting III Room 101 C	SESSION 3C Lubrication Fundamentals I: Additives Room 101 D
8:00 am – 8:40 am	Tuning the Friction Evolution and Aging Behavior of PVD MoS_2 Films, M. Dugger, p. 58	Application of the Four-Ball EP Test as an FZG (A10/16.6R/90) Scuffing Screening Test with Reference Fluid Assessment, K. Cogen, p. 59	
8:40 am – 9:00 am	Advances in Solid Lubrication for Space and Vacuum Applications, C. DellaCorte, p. 58	Complete Mixing of Dilute – Highly Viscous Samples – for ICP Analysis, S. Twining, p. 59	Influence of Shear Stress and Pressure on the Mechanochemistry of ZDDP and ZDP, H. Spikes, p. 60
9:00 am – 9:20 am		Characterizing Tribofilms Formed on M50 and CR30 Bearing Steels, D. Isaac, p. 59	Understanding the In-Situ Formation and Evolution of Phosphorus Antiwear Tribofilms with FFM and NanoIR-AFM, K. Cogen, p. 60
9:20 am – 9:40 am	Mutual Interests in Metal Sulfide Solid Lubricants for Space and National Security Applications, J. Lince, p. 58	Enhancing the Spacer Layer Imaging Method by Error-Correcting Colorimetry, A. MacLaren, p. 59	Surface Competition of Lubricant Additives Impacting Antiwear Performance and Mitigation, A. Jha, p. 61
9:40 am – 10:00 am		Observation of Tribofilm Formation During Rolling Contact Fatigue Testing, M. Smeeth, p. 59	New Polymeric Organic Friction Modifiers, E. Amerio, p. 61
10:00 am – 10:40 am	**Break**	**Break**	**Break**
10:40 am – 11:00 am	In-Situ Tribology of Solid Interfaces, K. Wahl, p. 58	Analysis of Metals in Oils and Coolants with a Novel Nitrogen-Based Plasma Optical Emission Spectrometer, M. Plantz, p. 60	Synergy of Additives Improving Engine Cleanliness Performance of Lubricant Oils, A. Isenberg, p. 61
11:00 am – 11:20 am		Fretting Testing: Challenges and Statistical Considerations, M. Mushrush, p. 60	Impact of Alcohol Branching on Lubricant Performance, A. Satterfield, p. 61
11:20 am – 11:40 am	A MoS_2 Composite Mystery: Uncovering Hidden Performance Traits, T. Babuska, p. 58	What if Removing the Third Body Layer From a Dry Contact?, S. Ciprari, p. 60	How Polymeric Additives Affect Lubricant Film Thickness, J. Wong, p. 61
11:40 am – 12:00 pm	Effect of MoS_2 Coating Deposition Conditions on Water Sorption/Desorption, N. Molina Vergara, p. 58	Tribological Investigations Under Varying Pressure Atmospheres, F. Zak, p. 60	PPD Selection Criteria for Evolving Market and Regulatory Trends, D. Chalasani, p. 61
	SESSION 4A **Materials Tribology II** **Room 101 B**		**SESSION 4C** **Lubrication Fundamentals II** **Room 101 D**
2:00 pm – 2:40 pm	Frontiers Research on Solid Lubricants for Superlubricity, A. Erdemir, p. 72		Alternative Energy Carriers – Impact of Ammonia on Engine Oil Performance, N. Dörr, p. 74
2:40 pm – 3:00 pm	Friction and Wear of Composite MXene/MoS_2 Coating Under Dry and Hydrocarbon-Lubricated Conditions, A. Zayaan p. 72		Oil Film Thickness of Two-Stroke Marine Diesel Engines at Different Operating Conditions, O. Spenceley, p. 74
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:20 pm	Elucidating the Chemical and Structural Characteristics of Mechanocatalytically-Formed Carbonaceous Films on Platinum-Gold Surfaces, F. Mangolini, p. 72		Base Oil Properties Effect on Friction, Oil Film Thickness and Pressure Characteristics – Comparison to Multigrade Oils, P. Dellis, p. 74
4:20 pm – 4:40 pm			The Impacts of Biodiesel on Properties of Marine 4-Stroke Diesel Engine Oil, J. Zhang, p. 74
4:40 pm – 5:00 pm	Environment Dependence of MoS_2-Based Dry Film Lubricants, S. Leventini, p. 72		
5:00 pm – 5:20 pm	Investigation of MoS_2-Coated NITINOL60 for Tribo - elements in Extreme Environments, A. DeLong, p. 72		

SESSION 3D Grease II	SESSION 3E Biotribology I	SESSION 3F Nanotribology III	
Room 101 E	**Room 101 F**	**Room 101 G**	
Dynamic Thixotropic Recovery of Lubricating Greases Under Varied Recovery Conditions, J. Bonta, p. 62	Surface Texturing of Prosthetic Hip Implant Bearing Surfaces – A Review, Q. Allen, p. 64		**8:00 am – 8:40 am**
Characteristics of Hybrid Greases Blended with Nano Structure Urea Grease, A. Shishikura, p. 62	Rendering Contact Mechanical Stimuli for Texture Tactile Perception, F. Massi, p. 64	Clarifying Mechanism of Superlubricity of Solids, B. Zhang, p. 66	**8:40 am – 9:00 am**
Comparative Analysis of Lithium and Urea Thickener Morphology and Implication for Grease Performance, C. Liu, p. 62	Advancing Hemiarthroplasty – A Joint Motion-Simulating Biotribometer to Predict In Vivo Performance of Cartilage, M. Wimmer, p. 64	Nanotribological Study of MoS_2 Coatings Enhanced with Ti_3SiC_2 Nanoparticles, R. Fleming, p. 67	**9:00 am – 9:20 am**
A Novel Method for Assessing the Efficiency of Grease-lubricated Rolling Element Bearings, G.Calderon Salmeron, p. 62	2D Material-Enhanced Metal Matrix Composites – A Study on Their Mechanical and Tribological Properties for Bio-Tribological Applications, S. Ramteke, p. 64	Interlayer Friction Behavior of Molybdenum Ditelluride with Different Structures, L. Zhang, p. 67	**9:20 am – 9:40 am**
	MXene Nanosheets as Additives in Synovial Fluid, M. Marian, p. 66	Single-Step Metal-Catalyzed Synthesis of Graphene: An Exploration of Tribological Behavior, B. Sattari Baboukani, p. 67	**9:40 am – 10:00 am**
Break	**Break**	**Break**	**10:00 am – 10:40 am**
Sub-Zero Temperature Friction and Film Stability of Lubricating Greases, D. Patro, p. 62	Tribocorrosion Influence of PEEK in Metal on Polymer Joint Replacements: 3D Printed versus Conventional Manufacturing, D. Raj Shrestha, p. 66	Films for Friction Reduction – Key Characteristics and In-Situ Synthesis Investigated by Ab Initio and Machine Learning Molecular Dynamics, M. Clelia Righi, p. 67	**10:40 am – 11:00 am**
On Grease Lubrication of Oscillating Rolling Bearings – Probing the Potential of Ionic Liquid Additives, R. de la Presilla, p. 64	Superlubricious Double-Network Hydrogels with Excellent Mechanical Properties Based on the In-Suit Inhibition Strategy for Biomedical Application, J. Song, p. 66		**11:00 am – 11:20 am**
	Slide-Ring Hydrogel Friction, A. Pitenis, p. 66	Nanotribology and Nanomechanical Factors Governing the Formation of Graphene Auto-Kirigami, L. Yuan, p. 67	**11:20 am – 11:40 am**
		Effect of Silicon Nitride Balls and Rollers on Rolling Bearing Static Load Rating, I. Shareef, p. 67	**11:40 am – 12:00 pm**

SESSION 4D Grease III	SESSION 4E Biotribology II	SESSION 4F Seals I	
Room 101 E	**Room 101 F**	**Room 101 G**	
Influence of Processing on Polyurea Grease from Preformed Thickener, C. Liu, p. 76	Best Practices – Rheological and Tribological Testing of Soft Materials, K. Pondicherry, p. 76	Numerical Study of Textured Impulse Gas Seals, N. Brunetiere, p. 77	**2:00 pm – 2:40 pm**
Multiscale Approach for the Consideration of Limited Grease Availability in the Tribological Component Design, C. Pastor, p. 76	Sliding Induced Integration of Nanoparticles into Hydrogel Surfaces, M. Elinski, p. 77	Experimental Study of EHD Seals, A. Harcrow, p. 77	**2:40 pm – 3:00 pm**
Exhibitor Appreciation Break	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**3:00 pm – 4:00 pm**
Estimating Grease Degradation at the Inlet of a Cylindrical Roller Bearing Using CFD and Experimental Data From the Grease Worker, R. Meijer, p. 76	Polyglycerol-Functionalized Nanodiamonds for Improved Lubrication of Artificial Joints in Simulated Body Fluid, M. Eskandari, p. 77	Topology Optimization for Low-Leakage and Low-Friction Surface Textured Face Seal, I. Ou, p. 77	**4:00 pm – 4:20 pm**
A Simple and Novel Method Determining the Suitability of a Grease Related to the White Etching Crack Phenomenon, S. Mottaghi, p. 76	Biotribology Business Meeting	A Low-Leakage and Low-Drag Elastohydrodynamic Seal for Supercritical Carbon Dioxide Turbomachinery, M. Fuad Hassan, p. 78	**4:20 pm – 4:40 pm**
Grease Business Meeting until **5:40 pm**		Optimal Design of Sealing Unit for Multi-Stage ROT (Radial Outflow Turbine) Considering Ratio of Tip Clearance, Y. Lee, p. 78	**4:40 pm – 5:00 pm**
		5:00 pm – 6:00 pm – Seals Business Meeting	

TUESDAY >>

TIME		SESSION 3I Commercial Marketing Forum III Room 101 J	SESSION 3J Electric Vehicles III Room 200 DE
8:00 am – 8:20 am		ExxonMobil: High Performance Electric Vehicle (EV) Fluid Solutions Via Novel PAO Technology, M. Patel, p. 68	Development and Validation of Structure-Performance Ester Models for EV Fluids, J. Nelson, p. 69
8:20 am – 8:40 am		SI Group; Antioxidant & Antiwear Additives to Address Regulatory Challenges of Greases, T. Kuchta, p. 68	
8:40 am – 9:00 am		Nouryon: Achieving Future Performance Objectives with Better Labeling Components, A. Jose Ortiz, p. 68	SAPS-Free Bio-Based Additives for Lubrication in Next-Generation Vehicles, X. He, p. 69
9:00 am – 9:20 am		The Lubrizol Corporation – Mineral IGO: Additive Enabled Field Flexibility, J. Cornett, p. 68	Improving Electric Vehicle Energy Efficiency Using the High-Performance Base Oil and the Film Forming Friction Modifier, M. Okamura, p. 70
9:20 am – 9:40 am		Münzing – FOAM BAN® 204: Alternate to Fluorosilicone Based Antifoams for Electric Vehicle Driveline Fluids, S. Peerzada, p. 68	Ester Base Stocks for Electric Vehicle Drivetrains – Tailored Performance for Challenging Needs, P. Struelens, p. 70
9:40 am – 10:00 am		LANXESS – Naugalube® APAN S – Sustainable, Liquid Aminic Antioxidant for High-temperature Applications, T. Benanti, p. 69	Novel EV Fluid Technology Platforms, J. Carter, p. 70
10:00 am – 10:40 am	Break	Break	Break
10:40 am – 11:00 am		Sasol Chemicals – Surfactants Enhance Industrial Hard Surface Cleaning Capabilities, J. Villalta, p. 69	High Speed Air Entrainment Test Method Development for e-Fluids, M. Ishikawa, p. 70
11:00 am – 11:20 am		Falex – Four-Ball Applications, E. Kerr, p. 69	Low Foaming/Aeration and Low Traction Coefficient Sustainable Synthetic Lubricant Solutions for High-Speed Electric Drivetrain Fluids, P. Ma, p. 70
11:20 am – 11:40 am		Hanna Instruments – Improving Your Efficiency Through Lab Instrumentation, C. McAnespie, p. 69	Electric Vehicle Drive System Exceptional Fluids, A. Kolekar, p. 70

		SESSION 4I Commercial Marketing Forum IV Room 101 J	SESSION 4J Electric Vehicles IV Room 200 DE
2:00 pm – 2:20 pm		BASF – Emgard 7103 XFE 75W-85, a New Fuel Efficient, Shear Stable Axle Lubricant to Meet New US Green House Gas Emission Requirements, A. Goyal, p. 78	Probing the Effect of Electric Fields on Behaviors of Lubricant Additives Confined between Surfaces at the Molecular Level, Z. Zhu, p. 79
2:20 pm – 2:40 pm		VBASE® OIL Company – Secondary Polyol Ester™ Technology – Expanding the Portfolio of Novel Sustainable Base Oils, M. Greaves, p. 78	Viscosity Dependence of Oil Churning Losses in an Electric Vehicle Gearbox at High Speeds, A. MacLaren, p. 79
2:40 pm – 3:00 pm		The Lubrizol Corporation – Improved Performance for Open Gear Lubricant Systems, J. Clark, p. 78	Unraveling the Complex Tribochemistry of Lubricated Surfaces Under Electrified Sliding Conditions, A. Erdemir, p. 80
3:00 pm – 4:00 pm	Exhibitor Appreciation Break	Exhibitor Appreciation Break	Exhibitor Appreciation Break
4:00 pm – 4:20 pm		Evonik – High Performance, Energy Efficient Industrial Gear Oils Enabling Short-Timeline Cost Savings, M. Petit, p. 79	Optimization of EV Drivetrain Efficiency Through Lubricant Selection, A. Kadiric, p. 80
4:20 pm – 4:40 pm		ExxonMobil: Introducing Elevexx™ LAO and Exxal™ 1315 LE Alcohol, K. Lewis, p. 79	Simulation and Test-Based Methodologies for EDU Fluids Development, T. Wellmann, p. 80
4:40 pm – 5:00 pm		ExxonMobil – Alkylated Naphthalene: A Booster and a Base Stock, M. Patel, p. 79	Electrified Rheology and Elastohydrodynamic Lubrication (EHL) Behavior of Graphene-Based Low Viscosity Lubricants for EV Application, L. Farfan-Cabrera, p. 80

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Session 3A • 101 B

Materials Tribology I

Tribute to Michael Dugger

Session Chair: John Curry, Sandia National Laboratories, Albuquerque, NM

Session Vice Chair: Kylie Van Meter, Florida State University, Tallahassee, FL

8:00 am – 8:40 am

4024752: Tuning the Friction Evolution and Aging Behavior of PVD MoS_2 Films

Michael Dugger, Tomas Babuska, John Curry, Alexander Mings, Steven Larson, Sandia National Laboratories, Albuquerque, NM

The outstanding steady-state friction coefficient and wear behavior of physical vapor deposited (PVD) thin films of MoS_2 in inert atmospheres is well known. Steady-state friction coefficients below 0.01 and wear rates below 10-8 mm3/(N.m) have been achieved through doping with a variety of metals, ceramics, carbon, and other dichalcogenides. However, little attention has been given to film performance in low duty cycle applications or during startup after long periods of dormant storage. In these cases, the first few cycles of sliding are often all that matters for correct operation, and many films with low friction and wear at steady-state exhibit dismally high friction upon first operation or upon restart of a previously operated mechanism after a long period of storage. Fortunately, the start-up performance of PVD films can be tuned through modification of the near-surface structure without compromising steady-state performance. This presentation will highlight one such approach.

8:40 am – 9:20 am

4080358: Advances in Solid Lubrication for Space and Vacuum Applications

Christopher DellaCorte, The University of Akron, Akron, OH

Solid lubricant films have evolved to address the lubrication needs in space and vacuum applications. From simple monolithic, vapo deposited lead films to complex, multi-layer coating systems, the field of solid lubrication has advanced to meet ever more challenging lubrication requirements. This presentation will review advancements in thin metal film and multi-layer lamellar solid lubricants. Space experiments used to understand and improve the technology will be highlighted. Additionally, examples of their capabilities through vacuum bearing testing will show that long-term R&D has resulted in meaningful improvements in the technology enabling mission success here on earth as well as beyond.

9:20 am – 10:00 am

4071115: Mutual Interests in Metal Sulfide Solid Lubricants for Space and National Security Applications

Jeffrey Lince, Space Tribology Consulting, Inc., Culver City, CA

The space industry and Sandia National Laboratories (SNL) have historically had a mutual interest in metal sulfide-based solid lubricants like MoS2. Friction and endurance degradation during extended storage is an ongoing concern, either prior to launch or to ensure the reliability of electromechanical devices critical to nuclear weapons. Studying aging is complicated by the difficulty of quantitatively accelerating oxidation. We will present results on the effect of aging in real-time of sputter-deposited MoS2 based solid lubricants on their surface composition and tribology. We will also present results from a study conducted with SNL motivated by our mutual interest in sliding electrical contacts involving optimization of the friction and electrical conductivity of sputtered Au/MoS_2 coatings. Finally, new results will be presented on a novel cost-effective method we recently developed for producing metal sulfide-based solid lubricant coatings for space and other applications.

10:00 am – 10:40 am – Break

10:40 am – 11:20 am

4071046: In-Situ Tribology of Solid Interfaces

Kathryn Wahl, US Naval Research Laboratory, Washington, DC

Tribology problems by nature involve the examination of contacts within "buried" interfaces. Rubbing surfaces may be separated by protective (or corrosive) fluids or solids and operate in environments ranging from vacuum to high pressure or temperature. Determining the mechanisms behind friction changes, wear or failure involves either separating the contacts or devising a way to determine what is happening in real time, while the tribocontact is loaded and active. These in-situ or in operando approaches increase the technical challenge to engineer the test apparatus and interpret the data, but also bring great rewards in providing insight into what physical and chemical processes are occurring during sliding and wear. In this presentation, we will describe and highlight the ways we have approached developing in-situ tribometry and tribology science along with the 'behind the scenes' connections and inspiration we took from others in the field.

11:20 am – 11:40 am

4024754: A MoS_2 Composite Mystery: Uncovering Hidden Performance Traits

Tomas Babuska, Michael Dugger, Steven Larson, Alexander Mings, John Curry, Sandia National Laboratories, Albuquerque, NM

Molybdenum disulfide (MoS_2) based coatings doped with materials such as Sb_2O_3, Au, Ti and Ni have been accepted as the industrial standard because of their touted environmental agnostic ultra-low friction ($\mu<0.05$) and wear behavior (10^{-7}–10^{-9} mm^3/Nm) in both humid and dry environments. Their performance in humid environments is due to the mitigating interactions of dopants with environmental species allowing MoS_2 to be expressed at the sliding interface. There exists an unreported phenomenon that can occur at high relative humidities where the friction coefficient of MoS_2/Sb_2O_3/Au becomes extremely high ($\mu\sim1$), yet the coating does not fail. This ultra-high friction behavior has never been shown in published literature yet has far reaching consequences for real-world applications. This work looks at the fundamental causes of ultra-high friction instabilities for MoS_2/Sb_2O_3/Au composites in humid environments. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

11:40 am – 12:00 pm

3999448: Effect of MoS_2 Coating Deposition Conditions on Water Sorption/Desorption via ToF-SIMS

Nicolas Molina Vergara, Filippo Mangolini, Andrei Dolocan, The University of Texas at Austin, Austin, TX; John Curry, Michael Dugger, Tomas Babuska, Sandia National Laboratories, Albuquerque, NM

Molybdenum disulfide (MoS_2) coatings find extensive use in applications demanding low friction response in inert or vacuum environments. Nonetheless, the reversible and irreversible water sorption within the coating during handling or periods of dormancy leads to a pronounced increase in friction with potential catastrophic reliability issues of sliding components. Despite the number of studies that quantitatively evaluated the water uptake in MoS_2, a quantification of the water diffusivity in

MoS_2 and its dependency on the material microstructure is still lacking. To address this knowledge gap, we conducted ToF-SIMS depth-profile analysis after dosing MoS_2 films with a water isotopic tracer (D2O). The resulting depth profiles are then modelled using a classical Fickian diffusion model that allows for the quantification of the dependence of the diffusion coefficient on coating morphology. This work was funded by SNL, managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

Session 3B • 101 C

Tribotesting III

Session Chair: Kerry Cogen, Infineum USA LP, Linden, NJ

Session Vice Chair: Steven Twining, Elemental Scientific, Inc., Navasota, TX

8:00 am – 8:40 am

4004801: Application of the Four-Ball EP Test as an FZG (A10/16.6R/90) Scuffing Screening Test with Reference Fluid Assessment

Kerry Cogen, Yanzhao Wang, Jannat Ahmed, Infineum USA LP, Linden, NJ

Scuffing performance is a key metric in assessing electrified vehicle fluid performance. The FZG (A10/16.6R/90) gear scuffing test is typically used but is resource intensive. A bench screener test, based on the 4 Ball EP Test Method (ASTM 2783), has been developed to facilitate prioritizing oils to be run in the more resource-intensive gear test. Previously, the screener test development was discussed in detail. However, the screener test also makes it possible to study the formation of tribofilm as a function of load. This systematic approach to analyzing film formation with load offers the opportunity to better understand tribofilm formation in the presence of other surface-active components typically found in electrified vehicle lubricants and how these interactions might impact scuffing performance.

8:40 am – 9:00 am

4005000: Complete Mixing of Dilute – Highly Viscous Samples – for ICP Analysis

Steven Twining, Elemental Scientific, Inc., Navasota, TX

Most new lubricant manufacturers measure elemental content using Inductively Coupled Plasma. More often than not, lubricant samples are diluted 1:10 with kerosene, xylene, or a similar solvent. This works for most samples having viscosities lower than 600 cSt. One of the challenges with ICP is that even if they sit for a short time, diluted samples containing more viscous oil tends to settle. This talk highlights a novel technique using a non-mechanical homogenization capability to fully mix samples ranging from 600 cSt to 4000 cSt that have been diluted 1:10 with solvent, to present fully homogenized samples to the ICP for analysis immediately after mixing. Both the ICP analytical technique and results from complete homogenization for all lubricant analysis sample types in this study will be highlighted. This includes sample preparation by weight, and automated sample introduction across the stated viscosity range for ICP analysis.

9:00 am – 9:20 am

4005068: Characterizing Tribofilms Formed on M50 and CR30 Bearing Steels

Daulton Isaac, Mathew Kirsch, Alexander Fletcher, Air Force Research Laboratory, Wright-Patterson Air Force Base, OH; Justin Schuh, Elizabeth Craft, Ronald Zeszut, University of Dayton Research Institute, Dayton, OH

Bearing steels exhibit varying resistance to scuffing, and it is thought that this is influenced by a steel's ability to form a tribofilm to protect the underlying material in low specific film thickness conditions. Thus far, only a limited amount of work has been done to characterize the tribofilms formed on these steels. This work uses X-Ray Photoelectron Spectroscopy (XPS) and Scanning Electron Microscopy (SEM) to chemically and morphological characterize the tribofilms formed on various bearing steels tested in the same MIL-PRF-23699 lubricant. The growth characteristics and the composition of the film are seen to depend on the substrate on which it is generated.

9:20 am – 9:40 am

4005119: Enhancing the Spacer Layer Imaging Method by Error-Correcting Colorimetry

Alexander MacLaren, Imperial College London, London, United Kingdom; Parker LaMascus, Robert Carpick, University of Pennsylvania, Philadelphia, PA

The Spacer Layer Imaging Method (SLIM) is widely used to measure the thickness of additive and lubricant films, in lubricant development and testing, and for research on mechanochemistry and elastohydrodynamic lubrication. The measurement is extremely sensitive to experimental procedure and image analysis, in some cases reporting completely unphysical film thickness trends. The prevailing image analysis techniques make it challenging to interrogate these errors, which are routinely obscured by spatial averaging. This talk presents a robust suite of novel a priori and a posteriori method to improve the accuracy of the SLIM measurement. Several common 'silent errors', including aliasing to adjacent fringe orders, and color drift due to the optical properties of the system, are discussed, with examples. In combination, these methods allow reliable mapping of films up to 700 nm in thickness, representing a significant milestone for SLIM applied to elastohydrodynamic contact.

9:40 am – 10:00 am

4005128: Observation of Tribofilm Formation During Rolling Contact Fatigue Testing

Matthew Smeeth, PCS Instruments, London, United Kingdom; Marc Ingram, Ingram Tribology Ltd., Carmarthen, United Kingdom

The spacer layer image mapping technique has been a very useful tool in Tribology research for many years. It has been widely used on mixed sliding /rolling tribometers to view the Tribofilms being formed under relatively short (<3 hours) tests. With the need for greater longevity of machine components it would be beneficial to observe the behavior of these tribofilms over much longer and higher contact cycle tests. Carrying out these tests using a standard sliding rolling tribometer would mean very long tests, typically many days long. In this work the SLIM technique was modified to allow measurements to be made on the central roller from an MPR test rig. This rig simulates the line contact of gears and provides the high rates of contact cycles desired for rapid tribofilm longevity studies. This new technique was investigated using a range of fully formulated oils and simple blends.

10:00 am – 10:40 am – Break

3B

10:40 am – 11:00 am

4005581: Analysis of Metals in Oils and Coolants with a Novel Nitrogen-Based Plasma Optical Emission Spectrometer

Mike Plantz, Eric Moen, Radom Corporation, Pewaukee, WI

Performing elemental tribology without argon and large ICP platforms is possible with the novel Radom MICAP-OES 1000 nitrogen plasma system. This microwave inductively coupled plasma instrument relies on a patented Cerawave™ ceramic disk which replaces the water-cooled coil and high-power RF generator required in traditional ICP systems. The use of nitrogen gas, a simultaneous spectrometer, and a water chiller-free design presents significant cost-of-operation savings over Ar-based ICP systems. Unique features of the system will be discussed, followed by analysis results and sample throughput performance for both engine oil and coolant samples.

11:00 am – 11:20 am

4014032: Fretting Testing: Challenges and Statistical Considerations

Melissa Mushrush, DuPont de Nemours Inc., Wilmington, DE

Wear and degradation of surfaces due to fretting leads to many issues across many industries, from automotive applications to electrical connections to osteosynthetic implant plates and screws. This work takes a closer look at the various test methods and equipment, as well as statistical considerations for the measurement of lubricant effectiveness against fretting damage.

11:20 am – 11:40 am

3998708: What if Removing the Third Body Layer From a Dry Contact?

Simone Ciprari, Sapienza University of Rome and Safran Landing Systems, Roma, Italy; Valentin Ripard, Safran Landing Systems, Villeurbanne, France; Aurélien Saulot, Univ. of Lyon, INSA Lyon, Villeurbanne, France; Francesco Massi, Sapienza University of Rome, Roma, Italy

An experimental approach to evaluate the role of third body in dry contacts is proposed. Ultrasonic cleaning technique is applied on a contact pair to remove the third body layer. The comparison of the frictional tests performed on the same first bodies, with and without the interface layer, evidenced a strong influence of the third body on the overall frictional behavior. Moreover, an external third body has been reintroduced on the cleaned samples to test its effect on the frictional response of the contact pair. A predominant role of the interface layer on the overall frictional behavior, rather than the one of the substrate, has been pointed out. The third body layer almost fully control the frictional response of the material. The developed procedure allows to test artificially produced third bodies, to investigate the role of different features (morphology, composition) on the overall frictional response of the system.

11:40 am – 12:00 pm

4004549: Tribological Investigations Under Varying Pressure Atmospheres

Felix Zak, Gregor Patzer, Optimol Instruments Prüftechnik GmbH, Munich, Bavaria, Germany; Ameneh Schneider, Optimol Instruments, München, Germany

This paper presents a novel tribotest option specifically designed to operate under various pressurized atmospheres. The development of this test option addresses the need to simulate real-world conditions encountered in numerous industrial applications where components and materials are subjected to mechanical friction and wear under specific gas environments. By exposing test samples to controlled gas atmospheres at different pressure levels (up to 100 bar), the tribotest option provides a valuable tool for evaluating the tribosystem for performance and durability of materials under different operating conditions. In some series of tests, the behavior of a common material pairing (100Cr6) with different lubricants under varying pressure environment in a nitrogen atmosphere has been investigated. The aim of the investigation is to verify the response of the tribosystem expressed by the variation of the Coefficient of Friction (COF) as a function of the ambient pressure.

Session 3C • 101 D

Lubrication Fundamentals I: Additives

Session Chair: Kuldeep Mistry, Chevron Lubricants, Richmond, CA

Session Vice Chair: Ramoun Mourhatch, Chevron Oronite, Richmond, CA

Session Starts at 8:40 am

8:40 am – 9:00 am

4000333: Influence of Shear Stress and Pressure on the Mechanochemistry of ZDDP and ZDP

Hugh Spikes, Chuan Wang, Jie Zhang, Janet Wong, Imperial College, London, United Kingdom

Zinc dialkyldithiophosphates (ZDDPs) are crucial lubricant additives in almost all engine oils and in many hydraulic and industrial gear oils. They limit wear by reacting to form protective phosphate-based films on rubbing metal surfaces. Several previous studies have shown that the rate of this phosphate tribofilm formation increases exponentially with both temperature and shear stress, indicative of a mechanochemical reaction mechanism. Recently, it has also been suggested that the reaction rate decreases slightly with applied hydrostatic pressure. This presentation describes a study of the influence of both shear stress and pressure on tribofilm formation of ZDDPs and their sulphur-free analogues the zinc dialkylphosphates (ZDPs). The results are interpreted in terms the underlying molecular mechanism of ZDDP tribofilm formation.

9:00 am – 9:20 am

4004698: Understanding the In-Situ Formation and Evolution of Phosphorus Antiwear Tribofilms with FFM and NanoIR-AFM

Kerry Cogen, Jannat Ahmed, Infineum USA LP, Linden, NJ; Matthew Flynn-Hepford, Arya Ahmadi, Mahshid Ahmadi, Olga Ovchinnikova, The University of Tennessee, Knoxville, TN

In electrified vehicles, the lubricating fluids deliver the chemistry needed to form the antiwear tribofilms in rolling/sliding contacting surfaces and serve to control friction and protect surfaces from wear and fatigue. Understanding the mechanism of antiwear film formation and how to tune surface chemistry to control functionality is essential for development of next generation driveline fluids. In this work, we utilize multimodal atomic force microscopy to understand initial film formation from different phosphorus-containing lubricants in-situ. We combine Friction Force Microscopy to capture the spatial details of friction on the surface as the tribofilm forms and evolves and Nano Infrared

Spectroscopy AFM (NanoIR-AFM) to understand the chemistry of the film. We investigate the different rates of film formation for different phosphorus-containing additives on steel surfaces as a function of pressure and how other components typically found in EV fluids can impact that formation.

9:20 am – 9:40 am

4002804: Surface Competition of Lubricant Additives Impacting Antiwear Performance and Mitigation

Ashish Jha, Christophe Le Deore, Marco Mata Mendoza, Brendan Miller, Chevron Oronite, Richmond, CA

Wear control is one of the key performance areas for lubricant oils. Antiwear additives in the oil require unhindered access to metal surfaces to be able to form tribofilms and minimize wear. However, antiwear additives often compete with other additive components for these metal surfaces compromising their surface antiwear activity to varying extents. This presentation will show how such detrimental surface competitions can be overcome (minimized) through knowing the structure-activity correlations of specific additives posing such risks.

9:40 am – 10:00 am

3988349: New Polymeric Organic Friction Modifiers

Ezio Amerio, Alina Filin, John Dixon, Nouryon, Deventer, Netherlands

CO2 emissions limits are getting stricter worldwide, increasing the demand for low viscosity lubricants. However, these lubricants are extremely thin at high temperatures, which poses a potential threat of boundary friction. Multifunctional polymeric organic friction modifiers provide a solution to this problem by reducing friction and wear, leading to improved energy efficiency and extended equipment lifetime. What differentiates these products from conventional organic FMs is that they contain multiple functional groups within a single oligomeric molecule. This allows them to adsorb onto the metal surface at various points, forming a specific film that significantly reduces the coefficient of friction across all lubrication regimes, even at very low treat rates, without negatively impacting traction properties. These FMs outperform metal-containing ones across a wide temperature range and demonstrate a highly advantageous synergistic effect when used in combination with MoDTC.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4002795: Synergy of Additives Improving Engine Cleanliness Performance of Lubricant Oils

Allan Isenberg, Ashish Jha, Devin Wall, Matthieu Decuupere, Sandy Lemesle, Priyank Shah, Andrew Suen, Chevron Oronite, Richmond, CA

Modern internal combustion engines are designed by OEMs to be increasingly more fuel and power efficient. These design improvements, however, set a much higher performance standard for lubricating oils to maintain engine cleanliness. This presentation will showcase novel components and some synergies between these lubricant components providing ways to meet these stringent cleanliness requirements. Mechanistic insights underlying those synergies will be discussed.

11:00 am – 11:20 am

4004620: Impact of Alcohol Branching on Lubricant Performance

Andrew Satterfield, ExxonMobil Technology & Engineering, Clinton, NJ

Alkyl carbon chains derived from long-chain alcohols are ubiquitous in lubricants, whether as integral components of synthetic ester base stocks, or as side chains to improve the additive solubility, friction control, or wear protection of lubricant additives. Long-chain alcohols are derived either from natural sources or from various synthetic processes, each yielding a unique molecular structure. The unique structures of these long-chain alcohols can have a profound impact on lubricant performance. However, such differences in performance are not always well understood, particularly for commercially available alcohols that are complex mixtures. This presentation will review the characteristics of some commercially available long-chain alcohols, particularly the nature of their molecular branching. Test data for model lubricant components prepared from these alcohols will be presented, and the impact of alkyl chain structure on lubricant performance will be discussed.

11:20 am – 11:40 am

4001276: How Polymeric Additives Affect Lubricant Film Thickness

Janet Wong, Bastien Bolle, Imperial College London, London, United Kingdom; Mao Ueda, Shell Lubricants Japan, Kanagawa, Japan

Polymeric additives are frequently used as viscosity modifiers (VMs) in lubricants. They modulate the viscosity of a lubricant and hence impact on lubricant film thickness in a rubbing contact. Usually, higher viscosity lubricants give higher film lubricant. For VM-doped lubricants, however, this is not always the case. Literature has shown that they can generate films thicker or thinner than predictions. This may be due to induced changes in inlet conditions or lubrication flow. In this work, laser spectroscopy will be used in operando to examine the behavior of polymeric additives in lubricants. Specifically, the distribution of VMs in and around a contact and how that relates to film thickness will be explored.

11:40 am – 12:00 pm

3994940: PPD Selection Criteria for Evolving Market and Regulatory Trends

DurgaPrasad Chalasani, Evonik Oil Additives USA, Inc., Horsham, PA

Several market trends and increasingly stringent regulations are influencing PPD selection and treat rates. Some of these trends a.) continued concern about low temperature performance of aged engine oils, b.) the drive toward fuel efficiency and corresponding shift toward low viscosity engine oil grades, c.) increasing interest in and use of re-refined base oils (RRBO's), and d.) more stringent low temperature performance specifications in industrial applications, particularly Tractor Hydraulic Fluids- are demanding a renewed interest in studying PPD selection and performance. Polyalkyl Methacrylate chemistry based PPD's can adapt to a variety of lubricant formulations and can be tailored to meet the latest formulation requirements. This presentation will provide an overview of the PPD mechanism and will demonstrate how proper PPD selection and fine tuning of treat rates for each of the above four trends allows formulations to meet stringent low temperature performance requirements.

Session 3D • 101 E

Grease II

Session Chair: Gareth Fish, The Lubrizol Corporation, Wickliffe, OH

Session Vice Chair: Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

8:00 am – 8:40 am

4001958: Dynamic Thixotropic Recovery of Lubricating Greases Under Varied Recovery Conditions

Jacob Bonta, Valvoline Global Operations, Lexington, KY

In this study, the thixotropic recovery of lubricating greases under varied strain and temperature is examined using a parallel plate rheometer. Degradation and subsequent modulus recovery are properties associated with the grease microstructures when exposed to cycles of shear and rest. The conditions of the rest cycle have impacts on the rate and extent of recovery. Three grease thickeners are considered: lithium 12-hydroxystearate, fumed silica, and polyurea. Small amplitude oscillatory (SAOS) testing is first used to evaluate the moduli in an undisturbed state. A 1-hour shear program is applied to each material, after which the storage modulus is tracked over time in SAOS evaluation. Varied conditions of recovery are explored by varying the % strain and temperature applied during the recovery phase. The recovery profiles compare the differences microstructural recovery. These results show that rheological analysis may provide insights not observed in standard industrial testing.

8:40 am – 9:00 am

4004325: Characteristics of Hybrid Greases Blended with Nano Structure Urea Grease

Akihiro Shishikura, Idemitsu Kosan Co., Ltd., Ichihara, Chiba, Japan

The characteristics and performances of nano structure urea grease (INS-UG), which has thickener fibers down to nano-sized, have already been reported. On the other hand, by mixing separately manufactured greases with different types of thickeners, a hybrid grease that has the characteristics of each type can be manufactured. In this presentation, we mixed INS-UG to lithium and lithium complex greases and tried to add the characteristics of INS-UG, such as low fretting wear, to the performance of those greases. As a result, by adding 5 to 10 wt% of INS-UG to lithium and lithium complex greases, heat resistance (dropping point) was improved, and fretting wear was reduced by 1/3 to 1/5. In addition, the results of oiliness tests and rheology analysis showed that mixing INS-UG with different thickener type greases was effective in controlling friction and wear as well as the transport properties of the grease.

9:00 am – 9:20 am

4004129: Comparative Analysis of Lithium and Urea Thickener Morphology and Implication for Grease Performance

Cindy Liu, Matthew Thorseth, Lauren Huffman, Pete Rozowski, Dow Chemical Company, Midland, MI; Jocelyn Zhao, Shell, Shanghai, China; Edward Worthington, Shell, Hamburg, Germany

Lithium thickeners are the most widely used in grease, but they are challenged by raw material increased price, competitive supply, and EH&S concerns in recent years. Urea-based thickeners are one of the alternatives of lithium thickeners, especially for high temperature application. This study investigates morphology of lithium and urea thickeners, aiming to elucidate the microstructure characteristics in relation to their grease properties. Through advanced microscopic techniques, we will show the morphological attributes of lithium complex soap, in-situ formed diurea and preformed diurea thickeners as in the grease within the base oil matrices. We also analyze the thickeners by removal of the oil phase similar to the previous literature and show the effect of sample preparation conditions on microstructure. We will highlight the commonalities and distinctions between these thickeners and discuss the interplay between the morphology and grease properties in rheology and tribology.

9:20 am – 9:40 am

4027391: A Novel Method for Assessing the Efficiency of Grease-lubricated Rolling Element Bearings

Gabriel Calderon Salmeron, Sergei Glavatskih, KTH Royal Institute of Tribology, Stockholm, Sweden; Johan Leckner, Axel Christiernsson Int. AB, Nol, Sweden

One component in achieving a more sustainable society is improved grease lubrication, which can potentially reduce global CO2 emissions by up to one percent in the short-term perspective. However, achieving such a challenging goal demands a transformative shift in how grease lubricants are selected and formulated. Additionally, the current absence of methodologies to assess grease efficiency adds further complexity to this challenge. In this work, the authors present a new methodology for measuring grease efficiency in a bespoke high-speed bearing test rig. The friction torque response of different grease compositions is presented in experiments with long duration (up to one-month experiments). A wide range of operating speed conditions, covering from zero to very high speeds, was evaluated to tackle several challenges of emerging technologies, such as electric vehicles. A discussion of the impact of the energy-saving potential of different grease candidates is presented.

9:40 am – 10:00 am

Open Slot

10:00 – 10:40 am – Break

10:40 am – 11:00 am

4003024: Sub-Zero Temperature Friction and Film Stability of Lubricating Greases

Debdutt Patro, Amar Sheelwant, Sravan Josyula, Anshuman Dube, Ducom, Bangalore, India

Sub-zero temperatures cause cold-induced stiffness, making grease impede and retard the motion of rolling elements in several applications. Existing standards ASTM D1478, ASTM D4693 provide guidelines to evaluate the starting and running torque but suffer from poor precision. In this work, we have developed a novel low-temperature module on the multi-capability pin/ball on disc tribometer with electrical contact resistance technique to simultaneously record friction and film stability at -50°C. Several greases were tested at different sub-zero temperatures both on the tribometer as well as the standard ASTM D1478 tester. The ball on disc tribometer tests show strong correlations between friction and % film thickness. Furthermore, long duration tests were used to evaluate and differentiate durability of low temperature greases. The results highlight the suitability of standard and non-standard test methods for analyzing the sub-zero temperature behavior of lubricating grease.

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3D

11:00 am – 11:20 am

4027387: On Grease Lubrication of Oscillating Rolling Bearings – Probing the Potential of Ionic Liquid Additives

Roman de la Presilla, Sergei Glavatskih, KTH Royal Institute of Tribology, Stockholm, Sweden; Johan Leckner, Axel Christiernsson Int. AB, Nol, Sweden

Oscillating rolling element bearings are found in a wide range of applications. From the large pitch bearings that allow wind turbine blades to be turned into and out of the wind, to the bearings found in pointing or gimbaling mechanisms used in space applications. When bearings are subjected to oscillating motions, they do not achieve full film lubrication. Instead, mixed or boundary lubrication prevails. A complex wear process ensues, compromising the life of the component and leading to excessive bearing torques. Current research indicates that no single grease formulation can prevent bearing wear in such conditions. A test rig has been developed to evaluate lubricating bearing grease performance in a wide range of oscillating frequencies and amplitudes. Results for greases loaded with ionic liquid additives are presented and discussed. Grease formulation is shown to have a profound influence on the emergence and severity of the resulting surface damage.

Session 3E • 101 F

Biotribology I

Session Chair: Meagan Elinski, Hope College, Holland, MI

Session Vice Chairs: Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile and Quentin Allen, Brigham Young University, Provo, UT

8:00 am – 8:40 am

4113339: Surface Texturing of Prosthetic Hip Implant Bearing Surfaces – A Review

Quentin Allen, Brigham Young University, Provo, UT; Bart Raeymaekers, Virginia Tech, Blacksburg, VA

More than 300,000 total hip replacement surgeries are performed in the United States each year to treat degenerative joint diseases that cause pain and disability. The statistical survivorship of these implants declines significantly after 15–25 years of use. This limited longevity has unacceptable consequences, such as revision surgery to replace a worn implant, or surgery postponement which leaves patients in pain. One method to reduce wear is to add a pattern of texture features to the bearing surfaces. We critically review the literature on textured orthopedic biomaterial surfaces in the context of prosthetic hip implants. We discuss the different functions of texture features by highlighting experimental and simulated results. We also discuss and compare manufacturing techniques to create texture features on orthopedic biomaterial surfaces and emphasize the key difficulties that must be overcome to produce textured prosthetic hip implants.

8:40 am – 9:00 am

3976511: Rendering Contact Mechanical Stimuli for Texture Tactile Perception

Francesco Massi, Livia Felicetti, Sapienza University, Rome, Italy; Eric Chatelet, INSA Lyon, Villeurbanne, France

In the past decades, notable efforts have been placed in the investigation and understanding of tactile perception. Nevertheless, while acoustic or visual stimuli are well mastered and simulated by screens or loudspeakers, it is still a challenge to simulate tactile stimuli, leading to the reproduction of tactile perception and discrimination. Recent works allowed to identify the friction-induced vibrations as one of the main signals at the origin of touch. Originated by the transient contact interaction between skin and surface textures, the key features of such vibrations have been related to the textures of the explored surfaces. In this work, the rendering of such mechanical stimuli by a vibrotactile device is presented. While the reproduced signals demonstrated to be effective in discriminating the different simulated textures, playing with the identified signal features allows to guide perception of virtual textures.

9:00 am – 9:20 am

4005538: Advancing Hemiarthroplasty – A Joint Motion-Simulating Biotribometer to Predict In Vivo Performance of Cartilage

Markus Wimmer, Amandine Impergre, Francesca De Vecchi, Rush University Medical Center, Chicago, IL; Olga Antipova, Argonne National Laboratory, Lemont, IL

Hemiarthroplasty involves replacement of one of the articular joint surfaces with an artificial bearing surface. It offers a clear benefit in patients with localized cartilage damage, preserving the healthy bone and cartilage in the joint to maximize future treatment options. And hemiarthroplasty is inherent in the replacement of individually diseased wrist or foot bones, which have multiple articulations with neighboring bones. Currently, failure most often occurs by degeneration of the opposing articular surface. A critical challenge in advancing hemiarthroplasty performance is the ability to identify bearing surfaces that will maintain healthy cartilage. Here, we report about the performance of candidate biomaterials by wear testing them against bovine cartilage plugs in a joint motion-simulating biotribometer, using PG/GAG and hydroxyproline as measures of cartilage matrix degradation and live/dead assays as a measure of cell damage.

9:20 am – 9:40 am

4001963: 2D Material-Enhanced Metal Matrix Composites – A Study on Their Mechanical and Tribological Properties for Bio-Tribological Applications

Sangharatna Ramteke, Pontificia Universidad Catolica De Chile, Santiago, Santiago, Chile; Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile

This study focuses on the development of CoCr matrix composites with improved tribological performance using additive manufacturing and 2D materials. The composites were produced using SLM and reinforced with graphite, graphene, graphene oxide, reduced graphene oxide, and Ti3C2 MXenes. The structural and chemical alterations that occurred during SLM were analyzed to confirm the presence of 2D materials in the manufactured samples. The mechanical characteristics, including surface roughness and hardness, as well as the tribological performance were assessed using steel and ceramic ball-on-disk tribometer tests under both dry and lubricated conditions. The results showed that the fusion of additive manufacturing with MMCs based on 2D materials offers significant potential for the development of custom-made implants and prosthetic devices with exceptional durability against wear.

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9:40 am – 10:00 am

4002174: MXene Nanosheets as Additives in Synovial Fluid

Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile; Cotty Quiroz Esteban, Andreas Rosenkranz, Universidad de Chile, Santiago, Chile

There's a pressing need to enhance wear resistance in load-bearing joint implant materials. Traditional metals like CoCr alloys, while widely used, can generate harmful wear debris. Additive manufacturing (AM) offers potential for personalized implants, but achieving sufficient wear resistance remains challenging. Current research focuses on low-friction, minimal-wear materials, including 2D materials. However, integrating 2D materials into joint implants, especially in synovial fluid (SF), remains poorly understood. This study aims to bridge these gaps by adding 2D MXene nanomaterials to SF and reduce wear in additively manufactured metal implants. Ti_3C_2Tx and Mo_2TiC_2Tx MXenes were synthesized, and their dispersibility in SF at varying concentrations, contact angle, and surface tension were studied. Additionally, the interaction with CoCr alloy samples from selective laser melting (SLM) AM and the effect on friction and wear in reciprocating ball-on-disk experiments were investigated.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4004290: Tribocorrosion Influence of PEEK in Metal on Polymer Joint Replacements: 3D Printed versus Conventional Manufacturing

Dilesh Raj Shrestha, Nazanin Emami, Lulea University of Technology, Lulea, Sweden; Rob Beadling, Richard Hall, Michael Bryant, University of Leeds, Leeds, United Kingdom

This study explores tribocorrosion in MOP contacts with implication in joint implant applications, with a specific focus on polyetheretherketone (PEEK). FDM 3D-printed and extruded PEEK against CoCr alloy was studied, along with VIT E-UHMWPE as a reference material. Potentiostatic tests were conducted in-situ by integrating an electrochemical cell into a tribometer, followed by post tribology surface analysis. Surface roughness, attributed to manufacturing methods, emerged as a critical determinant for tribocorrosion. Using Serum as a lubricant reduced CoCr electrochemical loss compared to PBS, possibly due to faster re-passivation. Notably, after polishing PEEKs, the manufacturing method had no significant effect on the total electrochemical loss of CoCr. CoCr exhibited significantly higher electrochemical loss when in contact with PEEK than with VIT E-UHMWPE. This study highlights the pivotal role of material selection and lubricants in influencing wear and corrosion properties.

11:00 am – 11:20 am

4023547: Superlubricious Double-Network Hydrogels with Excellent Mechanical Properties Based on the In-Suit Inhibition Strategy for Biomedical Application

Jian Song, Sun Yat-sen University, Shenzhen, Guangdong, China; Yuhong Liu, Tsinghua University, Beijing, China

Osteoarthritis (OA) is the most common joint disorders and hydrogels could be an effective tool to solve this problem. In this work, we explore the mechanism of tribology properties of double-network hydrogel (DN hydrogel) under effect of free radical polymerization inhibitors. Fe3+ is added to the DN hydrogel as highly efficient and easily adjustable inhibitor, and the friction coefficient can be reduced to 0.0038 by adjusting the concentration. Even after 6 hours of continuous tribological testing, the DN hydrogel remains a surprising sustained superlubricity. Furthermore, the strength of the hydrogel can be 20 times higher than that of the SN hydrogel. The optimum concentration of Fe3+ is explored to achieve the synergetic improvement of lubricative and mechanical properties. This work opens innovative technology routes for developing superlubricious and tough hydrogels, which is a brighter future for artificial cartilage applications.

11:20 am – 11:40 am

4042223: Slide-Ring Hydrogel Friction

Angela Pitenis, Andrew Rhode, Juan Manuel Uruena, Christopher Bates, University of California, Santa Barbara, Santa Barbara, CA

Hydrogels are highly hydrated three-dimensional networks of crosslinked polymer chains. Conventional crosslinking strategies have used covalent linkages, which create permanent and rigid attachment points between polymer chains. Alternative routes include dynamic bonds, or "flickering" linkages, that allow greater network rearrangements at the cost of strength. Another involves mobile rings of crossslinker constrained along linear polymer chains that together form slide-ring gels, first described in 2001 by Okumura and Ito. In this work, we incorporated pseudorotaxanes into hydrogel networks to create tough yet soft slide-ring gels. In this study, we investigated the tribological, rheological, and mechanical properties of slide-ring gels in an effort to characterize their structure-property relationships. Our results suggest that the chemical formulation of slide-ring gels can be tuned to control friction coefficient and the elastic modulus.

Session 3F • 101 G

Nanotribology III

Session Chair: Arnab Neogi, University of Illinois Chicago, Chicago, IL

Session Vice Chair: Pranjal Nautiyal, Oklahoma State University, Stillwater, OK

Session Starts at 8:40 am

8:40 am – 9:00 am

4001110: Clarifying Mechanism of Superlubricity of Solids

Bo Zhang, Saga Daigaku Riko Gakubu Daigakuin Kogakukei Kenkyuka, Saga-shi, Saga, Japan

Friction process is an energy dissipation process. It is found that MoS_2 and graphite have zero-friction, a superlubricity. It is proposed that incommensurate contact surfaces are associated with the super lubricity. However, engineering surfaces in contact are almost incommensurate because there are always exist misalignment in crystal orientation between two contact surfaces and crystal defects within the surfaces, while the superlubricity belongs to very limited special cases. Friction-induced low energy basal plane and hydrogenation of carbon-contained materials are also considered as possible mechanisms of superlubricity. Both give a good explanation of low friction, but they are definitely not sufficient to explain the superlubricity. Structural superlubricity (SSL) is proposed but the physical mechanism is not clear. A clarifying mechanism of superlubricity of solids is proposed and potential materials of superlubricity are listed.

9:00 am – 9:20 am

4002638: Nanotribological Study of MoS_2 Coatings Enhanced with Ti_3SiC_2 Nanoparticles

Robert Fleming, Morgan Diamond, Arkansas State University, Jonesboro, AR; Sujan Ghosh, Nihal Ahmed, University of Arkansas-Little Rock, Little Rock, AR

Molybdenum disulfide (MoS_2) is a widely used solid lubricant owing to its low coefficient of friction (COF) and high chemical and thermal stability. Bulk MoS_2 is composed of layered sheets, and weak van der Waals interactions between adjacent layers impart lubricity, but also a relatively high wear rate. To address this, Ti_3SiC_2 nanoparticle additives have been used to improve the wear resistance and mechanical cohesion of MoS_2 coatings. Ti_3SiC_2 is a layered hexagonal carbide in the family of MAX phase materials, which is noted for its mechanical fatigue resistance. In this study, laser sintering was used to prepare both pure MoS2 coatings and MoS_2 coatings doped with 5-10% Ti_3SiC_2 nanoparticles by weight. The coatings were characterized with nanoscratch testing, scanning wear, and nanoscale dynamic mechanical analysis (nanoDMA) to assess frictional performance, wear rate, and fatigue performance, respectively.

9:20 am – 9:40 am

4004339: Interlayer Friction Behavior of Molybdenum Ditelluride with Different Structures

Lina Zhang, Tsinghua University, Beijing, China

The interlayer friction behavior of two-dimensional transition metal dichalcogenides as crucial solid lubricants has attracted extensive attention in the field of tribology. In this study, the interlayer friction is measured by laterally pushing the $MoTe_2$ powder on the $MoTe_2$ substrate with the atomic force microscope tip. The lower interfacial friction of 1T′-$MoTe_2$/1T′-$MoTe_2$(2.025 × 10-4) compared to 2H-$MoTe_2$/2H-$MoTe_2$ interface(3.086 × 10-4) can be explained by the relative magnitudes of the ideal average shear strengths and maximum shear strengths obtained based on the interlayer potential energy, while the smallest interlayer friction of the 1T′-$MoTe_2$/2H-$MoTe_2$ heterojunction(6.875 × 10-5) is related to the weak interlayer electrostatic interaction and the weakening of the potential energy corrugation caused by the incommensurate contact. This work suggests that $MoTe_2$ is expected to reduce interlayer friction in the future by inducing the 2H-1T′ phase transition.

9:40 am – 10:00 am

4006096: Single-Step Metal-Catalyzed Synthesis of Graphene: An Exploration of Tribological Behavior

Behnoosh Sattari Baboukani, Kyriakos Komvopoulos, University of California, Berkely, Berkely, CA; Zhijiang Ye, Miami University, Oxford, OH

Graphene is renowned for its exceptional thermal, mechanical, and tribological properties. This study focuses on a one-step catalyzed synthesis of graphene involving an ultrathin amorphous carbon (a-C) film precursor deposited on an ultrathin catalyst sublayer. The process utilizes radio-frequency sputtering and filtered cathodic vacuum arc deposition to create a stack of Si/ultrathin alloy catalyst sublayer (NiFe, CoFe, and Co) /ultrathin a-C film. Controlled annealing results in a thin layer characterized by a hybrid a-C-continuum graphene structure. To understand the transformation from amorphous carbon to graphitic structures, the study employs Raman spectroscopy, X-ray photoelectron spectroscopy (XPS), and transmission electron microscopy (TEM). The tribological behavior of the a-C films is assessed using a nanoindenter. Molecular Dynamics (MD) simulations of the Si/alloy catalyst/a-C film stack provide insights into the graphitic transformation during thermal annealing.

10:00 am – 10:40 am – Break

10:40 am – 11:20 am

Invited Talk

4072234: 2D Films for Friction Reduction – Key Characteristics and In-Situ Synthesis Investigated by Ab Initio and Machine Learning Molecular Dynamics

M. Clelia Righi, University of Bologna, Bologna, Italy

Thanks to their inert nature, bidimensional materials can efficiently reduce the reactivity of the surface areas they adsorb onto, thus reducing the interfacial adhesion and shear strength. I will compare these functions for MXenes and phosphorene with well-established solid lubricants [1,2]. I will also show that slippery layered materials can be synthesized in situ thanks to tribochemical reactions. In particular, I will show that selenide layers can be formed by sprinkling Se nanopowders onto sliding contacts [3] and graphene can be obtained by the tribologically induced polymerization of aromatic molecules [4]. Finally, I will discuss the potentiality of machine-learning molecular dynamics in describing tribochemistry processes by considering the case of self-assembled monolayers as friction modifiers [5].

[1] Advanced Materials 35, 2207757 (2023).

[2] Journal of Nanostructure in Chemistry 13, 497 (2023).

[3] Advanced Materials 35, 2302076 (2023). [4,5] To be published.

11:20 am – 11:40 am

4004960: Nanotribology and Nanomechanical Factors Governing the Formation of Graphene Auto-Kirigami

Li Yuan, Jacob Goell, Cangyu Qu, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Graham Cross, Trinity College Dublin, The University of Dublin, Dublin, Ireland

2D materials such as graphene have remarkable mechanical and tribological properties. Recently, it was shown that graphene can spontaneously assemble into out-of-plane structures through self-folding followed by self-tearing and self-propagating, which involve overcoming the sliding friction over a graphene sheet below. We call these structures graphene auto-kirigami (gr-AK). To evaluate the nanomechanics and nanotribology of gr-AK, we cut graphene with atomic force microscope (AFM) tips. This produces structures with asymmetric self-tearing orientations, attributed to in-plane fracture anisotropy. Combining Raman spectroscopy, electron backscatter diffraction, and lattice-resolved lateral force imaging, we reveal how the cutting direction with respect to the graphene lattice affects the tearing and propagation and assess the role of interfacial incommensurability on interlayer friction. This gives insights into applications of 2D materials involving out-of-plane structures.

11:40 am – 12:00 pm

4095074: Effect of Silicon Nitride Balls and Rollers on Rolling Bearing Static Load Rating

Iqbal Shareef, Bradley University, Peoria, IL; Erwin Zaretsky, NASA, Cleveland, OH; Jacob Pitman, Caterpillar Inc., Peoria, IL

This paper investigates hybrid rolling-element bearings with silicon nitride balls and AISI 52100 bearing steel races. Objectives include determining the load and maximum Hertz stress for plastic deformation onset, as well as the Static Load Capacity. Tests involve applying 15 different loads ranging from 2,229 N to 22,290 N on discs of Rockwell C hardness from 54 to 68. Results include measurements of indentation depth, diameter, perimeter, horizontal surface area, cavity area, and

volume. Based on Yhland, the Static Load Capacity for steel-on-steel, at a ball-race conformity of 52%, was found to be 3.71 GPa, and for roller bearings 3.34 GPa. For hybrid ball and roller bearings, the Static Load Rating is reduced by 29% and 15%, respectively, compared to that of all-steel ball bearings of the same size and geometry. Thus, the static Load Rating for a hybrid ball and roller bearing listed in the manufacturer's catalog can be adjusted using correction factors of 0.71 and 0.85, respectively.

Session 3I • 101 J

Commercial Marketing Forum III

Session Chair: TBD

Session Vice Chair: TBD

8:00 am – 8:20 am

4094297: ExxonMobil: High Performance Electric Vehicle (EV) Fluid Solutions Via Novel PAO Technology

Manish Patel, ExxonMobil Chemical Company, Spring, TX

Evolving regulations and consumer trends will continue to drive the automotive industry to reduce CO2 emissions. This in turn will drive growth in the adoption of alternate powertrain vehicles such as BEVs, FCEVs, HEVs and PHEVs. Next-generation EV hardware designs aimed at maximizing energy efficiency are likely to require new, optimized, high performance, low viscosity fluids. Integrated electric drive units which combine an electric motor, power electronics and a gearbox will challenge lubricant formulators to deliver low viscosity fluids that balance traditional lubrication with electro-performance, material compatibility and thermal management (cooling). Therefore, base oil selection is a critical consideration when developing next-generation EV fluids. This presentation summarizes recent evaluations documenting benefits in energy efficiency, and other key EV fluid performance areas, made possible via a new low-viscosity/low-volatility PAO technology platform.

8:20 am – 8:40 am

4079428: SI Group; Antioxidant and Antiwear Additives to Address Regulatory Challenges of Greases

Tyler Kuchta, Timothy Chipuk, SI Group, Painesville, OH

The lubricants and greases industries are facing regulatory challenges. Several critical chemistries may be impacted by these pressures including common antioxidants that are already, or may be in the near future, labeled as reprotoxic or environmentally hazardous and antiwear additives containing heavy metals are under continuous scrutiny by regulatory bodies who want to minimize environmental impact. New additive options are under development to address these regulatory challenges while maintaining the performance of traditional technologies. This study explores a new combined antiwear and antioxidant technology that can provide equivalent performance to traditional additive technologies found in automotive and industrial greases. The data generated in this study indicates that this new additive technology can replace traditional antiwear and antioxidant technologies and minimizes environmental impact by removing the need for heavy metal-containing antiwear additives in greases.

8:40 am – 9:00 am

4093574: Nouryon: Achieving Future Performance Objectives with Better Labeling Components

Alvaro Jose Ortiz, Nouryon, Houston, TX

Additives and lubricants contribute to sustainability in many ways. Formulators are constantly seeking to improve fuel efficiency, reduce emissions and increase durability. New regulations are progressively limiting the usage of current chemistry that are deemed hazardous. The industry will require to move to safer chemistries as replacement for traditional chemistry, while delivering the same or better performance. Future lubricants must enable engine technology to meet new emissions standards with friendlier components, requiring some fundamental shifts in formulation and additive chemistry to meet this challenge. Nouryon has being exploring components with improved labelling that meet or surpass performance vs mainstream chemistries across different functionalities like antiwear, friction modifiers and emulsifiers, enabling additive and lubricant companies to have more flexibility when formulating their products to meet regulatory requirements and achieve performance specifications.

9:00 am – 9:20 am

4093069: The Lubrizol Corporation – Mineral IGO: Additive Enabled Field Flexibility

Jared Cornett, The Lubrizol Corporation, Wickliffe, OH

Industrial gear oil is used in a variety of modern equipment on a job site. The need for different oil solutions for each OEM represented leads to higher inventory levels and increased complexity while compounding the risk of misapplication, resulting in potential equipment failure in the field. A top tier performing fluid that can meet the demands of multiple OEMs will lower carrying costs, simplify job sites and reduce the potential for costly application errors. In this talk, we will discuss how Lubrizol balances performance with enabling field flexibility to meet the demands of even the most challenging applications. Lubrizol has kept the end users' needs at the center our of next generation Industrial Gear Oil additive development, leading to better outcomes for oil marketers, distributors, and end users alike.

9:20 am – 9:40 am

4089034: Münzing – FOAM BAN® 204: Alternate to Fluorosilicone Based Antifoams for Electric Vehicle Driveline Fluids

Safia Peerzada, Münzing North America, LP, Bloomfield, NJ

Perfluoro and polyalkylfluoro substances (PFAS) have become of high concern due to health concerns and their nature of low degradation/decomposition. Regulatory agencies all over the world, such as ECHA and US EPA, have initiated regulatory programs to limit the use of these substances. The upcoming PFAS regulations may limit the use of fluorosilicone-based antifoams causing lubricant formulators to search for alternate chemistries. This has become an important issue for non-aqueous Electric Vehicle (EV) driveline fluids as fluorosilicone based antifoams consistently provide strong foam control under high stress conditions. Münzing will present a comprehensive study to show the effective foam control performance of FOAM BAN® 204 against fluorosilicone antifoam in EV driveline fluids based on different base oil groups. The testing will be conducted using Münzing's High Shear-Air Sparge Test that is designed to simulate the high stress environment that EV fluids are exposed too.

9:40 am – 10:00 am

4093130: LANXESS – Naugalube® APAN S – Sustainable, Liquid Aminic Antioxidant for High-temperature Applications

Travis Benanti, LANXESS Corporation, Naugatuck, CT; Su Mi Beack, LANXESS, Toronto, Ontario, Canada

Naugalube® APAN S, from LANXESS, is an innovative, alkylated PANA antioxidant with sustainability in mind. After several years of development, LANXESS experts have optimized the process chemistry to produce a premium liquid antioxidant with very low residual PANA content. The liquid form provides easy handling and ensures good solubility in group I to V base oils. The composition is designed to protect high temperature lubricants such as turbine engine oils, oven chain conveyor oils, and other essential industrial lubricants. LANXESS is a backward integrated, leading aminic antioxidant producer with a global footprint, serving local markets with a just-in-time model. LANXESS continues to leverage its technical expertise to bring innovative products to meet ever-changing market demands. In this presentation, LANXESS is pleased to share an overview of its comprehensive aminic antioxidant portfolio and the latest encouraging test results for Naugalube® APAN S.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4089550: Sasol Chemicals – Surfactants Enhance Industrial Hard Surface Cleaning Capabilities

Jonathan Villalta, Sasol Chemicals, Houston, TX

Contaminants and residue cause increased downtime, shorter machine life, and a multitude of safety, heath, environmental, regulatory and quality concerns to manufacturers. For over 40 years, Sasol Chemicals has been providing surfactant solutions that meet your cleaning requirements. Ethoxylates and alkoxylates, nonionic surfactants, can be used in a variety of hard surface industrial cleaning applications. These unique surfactants will maximize your cleaning formulations with their fast-cleaning kinetics and high-performance characteristics. Sasol's product range is characterized by high detergency and surface activity, hard water stability, foam control, excellent wetting properties, favorable environmental characteristics, emulsifying power, chemical stability over a wide pH range, and user-friendly viscosity and storage behavior. These products are an ideal building block for cleaning metal surfaces from industrial deposits, oils, greases, and soils.

11:00 am – 11:20 am

4080066: Falex – Four-Ball Applications

Erin Kerr, Falex Corporation, Sugar Grove, IL

This presentation will focus on the application of electricity through wheel bearings specific with the newest generation of Four-Ball testers offered by Falex, the Model 89, in conjunction with the team at Flucon.

11:20 am – 11:40 am

4092535: Hanna Instruments – Improving Your Efficiency Through Lab Instrumentation

Conor McAnespie, Hanna Instruments, Smithfield, RI

To ensure quality, lubricant manufacturers must maintain appropriate levels of acidity and moisture in their products. Effective management is crucial for this to occur. However, the power of management in manufacturing Quality Control labs is only as strong as the procedures in place. The effectiveness of any procedure relies on its data. Typically, data for these two parameters is collected from wet chemistry instrumentation. However, some may have outdated instrumentation in their labs, hindering their ability to establish a solid foundation that can withstand external business factors, such as new ventures requiring increased production of lubricants. Through my time at Hanna Instruments, I have had the opportunity to gain knowledge on wet chemistry instrumentation and the industries that need this instrumentation. I would like to share the information have amassed during this time that can aid lubricant manufacturers in establishing the solid foundation I described earlier.

Session 3J • 200 DE

Electric Vehicles III

Session Chair: Christopher Cleveland, Afton Chemical Corporation, Richmond, VA

Session Vice Chair: Hyeok Hahn, Chevron Lubricants, Richmond, CA

8:00 am – 8:40 am

4004284: Development and Validation of Structure-Performance Ester Models for EV Fluids

Jared Nelson, Emery Oleochemicals LLC, Cincinnati, OH; Kevin Manouchehri, The Lubrizol Corporation, Wickliffe, OH

Lubrication and thermal management are key challenges in the development of next generation fluids for electric vehicles (EV). A Design-of-Experiment (DoE) approach was used to systematically explore a variety of molecular structures. An array of 23 esters was synthesized and statistical models were developed to understand correlations between structure of an ester and its performance properties. These models will be validated in their ability to predict thermal properties (specific heat, viscosity, density) and tribological behavior (frictional/tractional). The results of this study will be essential to optimizing the product development cycle for EV applications.

8:40 am – 9:00 am

3981183: SAPS-Free Bio-Based Additives for Lubrication in Next-Generation Vehicles

Xin He, Christelle Chretien, Solvay, Bristol, PA

Commercial vehicle OEMs rely heavily on engine oil containing sulfated ash, phosphorus, and sulfur (SAPS) to achieve superior lubrication performance, while these elements are detrimental to the environment and sustainability. To overcome this issue, Solvay has developed an advanced synthesis technology enabling the production of SAPS-free bio-based twin-tail amine derivatives that exhibit similar lubrication properties. Experiments have been conducted in Group III base oils for various aspects. The top candidates outperformed the benchmark additives in terms of wear resistance and friction coefficients. The copper

corrosion is negligible for the newly developed additives. Additional analysis suggested that the recently invented additives possess significant possibilities for use in the realm of electric vehicles (EVs).

9:00 am – 9:20 am

4001106: Improving Electric Vehicle Energy Efficiency Using the High-Performance Base Oil and the Film Forming Friction Modifier

Moeka Okamura, Toshitaka Nakamura, Mari Iino, Akira Tada, Shingo Matsuki, ENEOS Corporation, Yokohama, Kanagawa, Japan

Improving the efficiency and cooling performance of electric vehicles is an essential technology for EV drivetrains. Low viscosity lubricants contribute to improving efficiency by reducing stirring resistance under mild conditions. However, there are concerns about a deterioration of durability performance under severe conditions. To develop technologies specially designed for EV drivetrains, we optimized base oils and other additives. First, a high-performance base oil with low viscosity and low traction coefficient was investigated, which led to achieve high efficiency and reduce heat generation on sliding surfaces. This base oil also improved fatigue life effectively. Then, effect of a newly developed friction modifier was compared to that of conventional friction modifiers. The novel friction modifier enables to reduce friction coefficient in mixed lubrication area by forming thick adsorption films, and it indicated higher gear efficiency and better cooling performance.

9:20 am – 9:40 am

4000942: Ester Base Stocks for Electric Vehicle Drivetrains – Tailored Performance for Challenging Needs

Pieter Struelens, Oleon NV, Evergem, Belgium

As the rise of the electric vehicles (EVs) is taking massive leaps, the development dedicated EV fluids cannot lack behind. Especially the fluid design for integrated electrical drivetrains is challenging since these require properties that go beyond traditional specs. These fluids will need to provide wear and friction reduction at very high rpm, they must be di-electric, conduct heat, be copper compatible and show outstanding cold flow properties. Furthermore, since a mayor driver for EV introduction is sustainability, these fluids should display a low environmental impact. In this work novel esters will be presented that can take up this challenge and meet all above requirements. Specific focus will be on thermal management, cold flow, dielectric properties, safety and material compatibility of these newly designed synthetic esters. Moreover, it will be discussed how ester technology can fit this bill at the lowest environmental footprint possible.

9:40 am – 10:00 am

4086935: Novel EV Fluid Technology Platforms

Jason Carter, SK enmove, Clarkston, MI

Every electric vehicle system on the market has its own unique set of demands for the EV fluids: load carrying, anti-corrosion and traction boosting. How do these technologies work together or against one another in finished fluid applications? What combinations can be made to bring out the best performance in your hardware? Data and example fluids from in-house blending and testing of mock finished EV fluids.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4005324: High Speed Air Entrainment Test Method Development for e-Fluids

Masahiro Ishikawa, Scott Campbell, Infineum USA LP, Linden, NJ

In automotive electrification, motors and gear boxes run at extremely high speeds >20,000 rpm, for which fluid foam and air entrainment issues may arise, e.g., leakage, churning and hydraulic losses. E-fluids must have good aeration performance under extremely high-speed operations. Commonly used foam tests (ASTM Seq. I-IV) use airflow to generate foam and may not represent the air entrainment running at high speeds under shear in spinning parts. To simulate this, we have developed a High-Speed Air Entrainment Test, utilizing a homogenizing aggregator that generates extremely high speeds under shear up to 27,000 rpm. Foam and air entrainment volume are measured at oil temperatures between 40°C and 140°C. This paper addresses the test method development and learning summary based on Infineum e-fluid technology (including correlation to ASTM foam, effects of viscosity, base oil, additive and oil aging).

11:00 am – 11:20 am

3981837: Low Foaming/Aeration and Low Traction Coefficient Sustainable Synthetic Lubricant Solutions for High-Speed Electric Drivetrain Fluids

Philip Ma, Donna Mosher, Chad Steele, BASF, Tarrytown, NY

Internal combustion engines (ICE) are being replaced by electric motors as power sources for both passenger cars and heavy-duty trucks. OEMs are using off-the-shelf lubricant fluids, such as automatic transmission fluids (ATF), manual transmission fluids (MTF), etc., as electric drivetrain fluids (EDF). EDFs are driving toward lower viscosity for better heat transfer capacity and better energy efficiency. In this paper, we will highlight the importance of low foaming/aeration, low traction coefficient which are critical for the performance of low viscosity EDF during the high rotation-per-minute (rpm) speed applications. Sustainable EDFs with ultra-low foaming/aeration can potentially reduce electric induced bearing damage (EIBD), thus provide better bearing protection and life, and in the meantime provide better heat transfer capacity. Low traction coefficient fluids will also contribute to better lubricant energy efficiency in comparison to other fluids with the same viscosity.

11:20 am – 11:40 am

3997228: Electric Vehicle Drive System Exceptional Fluids

Anant Kolekar, Valvoline Global Operations, Lexington, KY

The recent growth in the electric vehicle (EV) market has significantly affected the automotive industry along with the lubricant industry. For the lubricant industry, EV requirements are unique compared to internal combustion engine vehicles (ICEVs) where electrical, thermal, extreme pressure and foam performances are becoming more critical. In EVs, gears and bearings experience significant fluctuations in power, torque and speed which demand for more precise testing work. This motivated us to develop new tests and worked with OEMs to formulate exceptional fluids. Tribological, analytical, benchtop and vehicle testing for EV DSFs were conducted to evaluate the performance and further understand the effect of fundamental properties of these specialty lubricants. There were significant improvements in the overall vehicle efficiency (3+%), driving range (15+ miles) and reductions in operating temperatures (13+°C) as tested by OEMs and third-party labs.

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Session 4A • 101 B

Materials Tribology II

Tribute to Michael Dugger

Session Chair: John Curry, Sandia National Laboratories, Albuquerque, NM

Session Vice Chair: Kylie Van Meter, Florida State University, Tallahassee, FL

2:00 pm – 2:40 pm

4077153: Frontiers Research on Solid Lubricants for Superlubricity

Ali Erdemir, Texas A&M University, College Station, TX

Solid lubricants have been around for so long and are the most desired options for applications involving extreme conditions. In recent years, interest in solid lubricants increased noticeably, especially for the design and development of 2D materials (i.e., graphene, MoS_2, MXene, black phosphorous, etc.) and other carbon nanostructures providing friction coefficients as low as 0.001 [1]. In this presentation, a comprehensive overview of recent progress in solid lubricants will be provided together with many intrinsic and extrinsic factors that can affect their superlubricity. Overall, these and other novel approaches involving solid lubricants are leading the way for the design and production of next-generation solids that can further increase efficiency, reduce carbon footprint, as well as extend machine life in future moving mechanical systems.

[1] Superlubricity (2nd Edition), Erdemir, A., Martin J.M., Luo, J., Editors; Elsevier, Amsterdam, 2020.

2:40 pm – 3:00 pm

4002627: Friction and Wear of Composite MXene/MoS_2 Coating Under Dry and Hydrocarbon-Lubricated Conditions

Ali Zayaan Macknojia, Diana Berman, Andrey Voevodin, Samir Aouadi, University of North Texas, Denton, TX; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Friction and wear-related failures remain the greatest problems in moving mechanical assemblies operating under various conditions. This study demonstrate lubricity achieved by spray-coating solution-processed multilayer Ti3C2Tx-MoS2 blends onto rough 52100-grade steel surfaces. Blends exhibited lower frictional performance for individual pristine materials, MoS2 and Ti3C2Tx, under high pressure, sliding speed. Study investigated the processing, structure, and property correlation to gain a deeper understanding of the underlying phenomena. Raman spectroscopy, scanning electron microscopy, and transmission electron microscopy results revealed the formation of an in-situ robust tribolayer responsible for the outstanding performance observed at high contact pressures and sliding speeds. This study has broad implications for the development of solid lubricants that can operate under extreme conditions and low viscosity fuel environment, inspiring further research and development in this field.

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

4:00 pm – 4:40 pm

3994581: Elucidating the Chemical and Structural Characteristics of Mechanocatalytically-Formed Carbonaceous Films on Platinum-Gold Surfaces

Filippo Mangolini, Camille Edwards, Hsu-Ming Lien, The University of Texas at Austin, Austin, TX; Tomas Babuska, John Curry, Frank DelRio, Michael Dugger, Sandia National Laboratories, Albuquerque, NM; Jason Killgore, National Institute of Standards and Technology, Boulder, CO

Nanocrystalline Pt-Au alloys have emerged as a promising class of wear-resistant materials for various applications, including electrical contacts and electromechanical devices. While the formation of carbonaceous layers on Pt-Au alloys has been reported to decrease friction in tribological tests carried out with different countersurface materials, remarkably little is still known about their chemistry and structure. Here, we employed four different Pt-Au alloys ([Au] from 0 at.% to 10 at.%) to perform contact pressure-dependent tribological experiments in nitrogen gas containing trace organics. The results of the multi-technique analytical characterization of the mechanocatalytically-formed, carbon-rich surface layers did not only shed light on their chemical composition and local atomic structure, but also revealed insights into the dependence of the mechanocatalytic activity of Pt-Au alloys on the Au content. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

4:40 pm – 5:00 pm

4000873: Environment Dependence of MoS_2-Based Dry Film Lubricants

Samuel Leventini, Ashlie Martini, University of California, Merced, Merced, CA; Tysen Mulder, Brian Dykas, Scott Kihara, Blue Origin, LLC, Kent, WA

MoS_2 is an effective and widely used dry film lubricant (DFL) coating in space applications, but its friction and wear life behavior are very sensitive to the environment, particularly humidity. Materials like Ni or Au can be co-sputtered with MoS_2 to form nanocomposite coatings that can exhibit reduced environmental sensitivity when compared to non-composite MoS_2 films. This study seeks to quantify the environmental sensitivity of three MoS_2-based DFLs; one non-composite ("pure") MoS_2 film, a MoS_2 + Ni nanocomposite film, and a MoS_2 + Sb_2O_3 + Au nanocomposite film. The study utilized unidirectional sliding tests in both open air and in a nitrogen-filled enclosed chamber to measure differences in friction and wear life between the two environments. Samples and wear tracks were examined using X-ray photospectroscopy and scanning electron microscopy to characterize the elemental composition and surface topography at high magnification.

5:00 pm – 5:20 pm

3996626: Investigation of MoS_2-Coated NITINOL60 for Triboelements in Extreme Environments

Adam DeLong, Catherine Fidd, Thomas Lockhart, Brandon Krick, Florida State University, Tallahassee, FL; Tomas Babuska, John Curry, Steven Larson, Sandia National Laboratories, Albuquerque, NM; Christopher DellaCorte, The University of Akron, Akron, OH; Samuel Howard, NASA Glenn Research Center, Cleveland, OH; William Scott, Matthew Mazurkivich, Sara Rengifo, NASA Marshal Space Flight Center, Huntsville, AL

60NiTI is a pseudo-shape memory alloy with excellent corrosion resistance, high strain to failure, and a hardness of 60HRC (~8GPa). These properties give NITINOL60 the potential to be used in triboelements for harsh environments like space. Dry film lubricants, like MoS_2, have a low

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vapor pressure, low operating temperatures, and long life giving it the potential to be used in space. Although MoS_2 is compatible with most bearing steels, its compatibility with 60NiTi is not well documented. 60NiTi and 440C stainless steel substrates had magnetron sputtered MoS_2 coatings with and without Ti interlayers to compare the wear and adhesive properties of MoS_2 coated 60NiTI samples to 440C with the same coatings. Wear and scratch tests showed both 60NiTi and 440C substrates with Ti interlayer had improved wear life and bond strength compared to samples without Ti interlayers.

Session 4C • 101 D

Lubrication Fundamentals II: Marine Lubrication

Session Chair: Xin He, Syensqo, Levittown, PA

Session Vice Chair: Nicole Dörr, AC2T research GmbH, Wiener Neustadt, Austria

2:00 pm – 2:40 pm

4004463: Alternative Energy Carriers – Impact of Ammonia on Engine Oil Performance

Nicole Dörr, Adam Agocs, Charlotte Besser, AC2T research GmbH, Wiener Neustadt, Austria; Maria Rappo, Nicolas Obrecht, TotalEnergies, Courbevoie, France

Decarbonization requires fundamentally different energy systems enabled by using alternative energy carriers such as green electricity and green fuels which are preferably free of carbon such as hydrogen and ammonia. Ammonia is especially considered as future fuel for marine vessels. However, there is little knowledge about the interaction of ammonia and its combustion products with engine oils. This paper reports on a methodology based on artificial oil alteration and performance tests which was designed to elaborate corrosion properties, deposit formation, and load-bearing capability of fresh and aged engine oil. It could be shown that the selected performance parameters were severely impacted by the presence of ammonia or nitrogen dioxide compared to air. Exemplarily, nitrogen dioxide contamination resulted in higher oxidation and acidification of the oil than ammonia or air.

2:40 pm – 3:00 pm

4004576: Oil Film Thickness of Two-Stroke Marine Diesel Engines at Different Operating Conditions

Oliver Spenceley, University of Sheffield, Leeds, United Kingdom

In light of emergent maritime emission legislations, ensuring increased efficiency and emission reduction in marine engines is paramount. A pragmatic approach to these requisites involves meticulous management of cylinder lubricant oil within the combustion chamber, specifically the film thickness. A non-invasive system, leveraging ultrasonic technology, has measured the leading, instantaneous and trailing films as a piston ring passes the transducer on a full-scale marine test bed through a range of operating conditions. This work emphasizes the commercial viability of ultrasonic technology as an in-situ, non-destructive tool for continuous monitoring and data acquisition over extended operational periods, revealing interplays between lubrication, operational parameters, and emissions outside of a laboratory. This approach enables the strategic optimization of lubricant feed rates, thereby boosting engine efficiency, curbing emissions, and ensuring compliance with sustainability.

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

4:00 pm – 4:20 pm

3982139: Base Oil Properties Effect on Friction, Oil Film Thickness and Pressure Characteristics – Comparison to Multigrade Oils

Polychronis Dellis, National Technical University of Athens, Athens, Attiki, Greece

Various base lubricants' rheological behavior was assessed as well as their additive chemistry, in an idealized single-ring simulating test rig. Different oils are tested, the properties of which are provided by the manufacturer. The successful sensor implementation at the single-ring test rig in the past, enabled robust and reliable testing for different test cases. Oil film thickness, overall friction, oil film pressure measurements are derived from the fitted sensors at different speed, load and temperature conditions. Trends from the measurements are demonstrated and a useful comparison to the multigrade lubricant testing from previous studies is provided, in terms of cavitation (initiation and development), viscosity, power losses and absolute measurements. These datasets assessment will promote the likely field performance of base finished monograde marine engine lubricants.

4:20 pm – 4:40 pm

3997421: The Impacts of Biodiesel on Properties of Marine 4-Stroke Diesel Engine Oil

Jie Zhang, Richful Lube Additive Co. Ltd., Xinxiang, Henan, China

Biodiesel as one of the alternative fuels in future had attracted more and more attention from researchers and customers. Biodiesel has been proved to be applied in marine transport without any modification of engine system. Due to its recyclable raw material, Biodiesel is considered as a fuel choice to achieve carbon neutral in shipping industry. But biodiesel contains more oxygen content compared with traditional diesel from petroleum. Because of fuel dilution, risk from biodiesel remains to properties of marine 4-stroke diesel engine oil. In this paper, simulating tests were carried out to measure anti-oxidation, anti-corrosion, detergency and friction control abilities for marine engine oil, and bench test was run to measure the general performance of it.

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Technical Presentation:

» **Mon. 9:00 AM • Session 1D - Room 101E**
Synthetic Lubricants and Hydraulics I
"Performance of Novel & Sustainable Synthetic Ester Base Oils with Hybrid Functionality" Martin Greaves

CMF Presentation:

» **Tues. 2:20 PM • Session 4I - Room 101J**
"Secondary Polyol Ester™ Technology – Expanding the Portfolio of Novel Sustainable Base Oils" Martin Greaves

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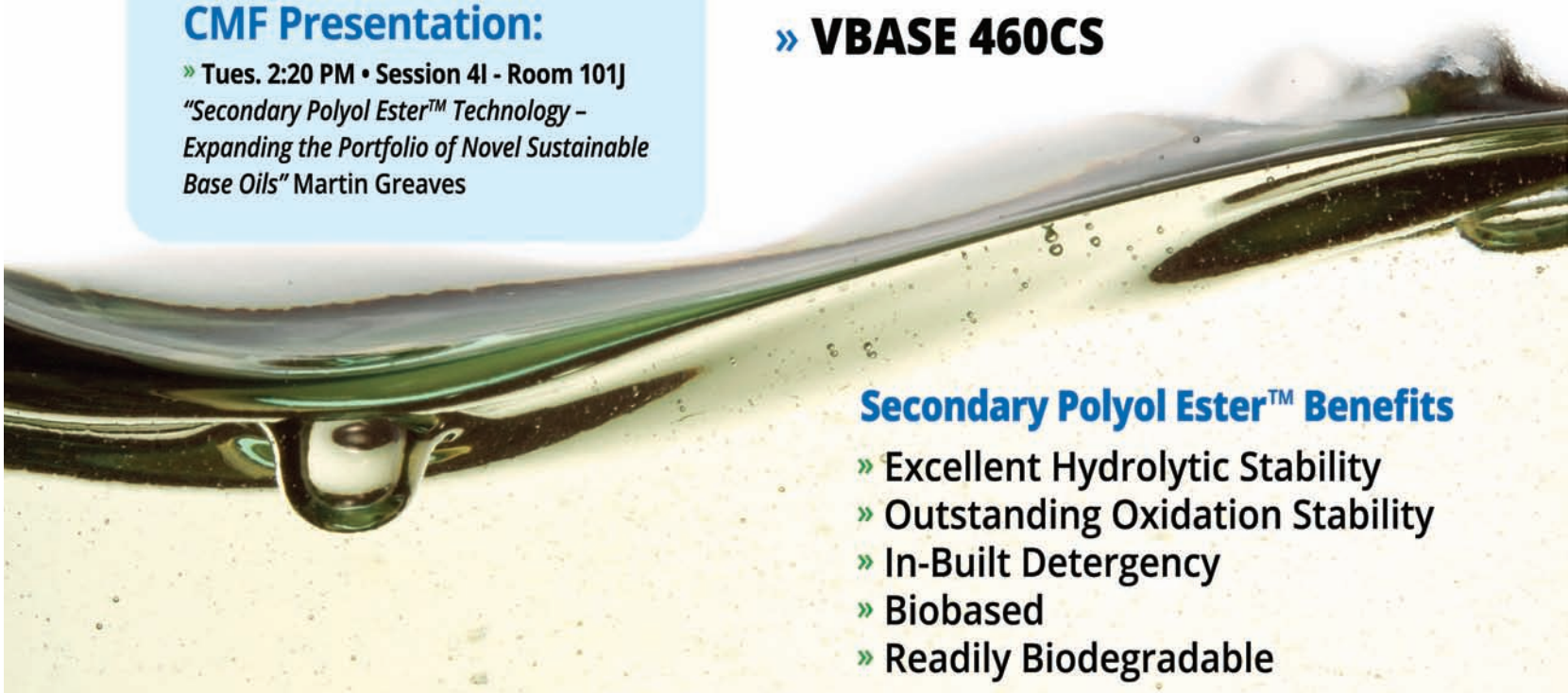

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Session 4D • 101 E

Grease III

Session Chair: Lang Chen, ExxonMobil, Annandale, NJ

Session Vice Chair: Salil Bapat, Purdue University, West Lafayette, IN

2:00 pm – 2:40 pm

4001725: Influence of Processing on Polyurea Grease from Preformed Thickener

Cindy Liu, Lauren Huffman, Matthew Thorseth, Pete Rozowski, Dow Chemical Company, Midland, MI

Preformed urea thickeners have gained attention in recent years as new and safer way to polyurea greases. We studied thickening process of grease formation from a preformed urea thickener, and we found post-production homogenization largely boost the viscosity and yield stress. Furthermore, different types of homogenizers showed effects on grease consistency, and the dispersion and microstructures of the thickener were examined by microscope and TEM. The work provided that shear throughout grease manufacturing is essential to maximize its thickening power.

2:40 pm – 3:00 pm

3999326: Multiscale Approach for the Consideration of Limited Grease Availability in the Tribological Component Design

Cesar Pastor, Robert Bosch GmbH, Renningen, Germany

The majority of the tribological design elements used in industrial applications are greased and sealed for life. The maintenance is therefore reduced to a minimum being extremely cost-effective. Nevertheless, important questions arise at early development phases as: How much or which type of grease is needed? Is the grease active lubricating the contact or is there a risk of starvation or failure? Increasing computational capabilities open new scenarios in which costly experiments can not only be avoided but also a great number of parameters can be numerically replicated before having physical samples or prototypes. A multiscale approach is proposed for systems with risk of limited lubricant availability, specifically greased contacts. From system (macro) level to contact (micro) level, different modelling methods are used to show how the grease behavior affects the contact conditions through the lubricant presence at the vicinity of contact and the alteration of the meniscus geometry.

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

4:00 pm – 4:20 pm

4000256: Estimating Grease Degradation at the Inlet of a Cylindrical Roller Bearing Using CFD and Experimental Data From the Grease Worker

Robert Meijer, University of Twente, Enschede, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

One of the mechanisms that limits the lifetime of lubricating grease in a rolling bearing is mechanical degradation by shear. Shear results in a change of the micro-structure of the thickener–oil system, leading to a change in bleed and consistency. A novel approach will be presented, where the grease worker can be used to measure the rheological properties of a grease in situ, while aging the grease, giving the change in rheology as a function of the imposed mechanical energy. A CFD model is used to calculate the power density, shear rate and temperature distribution of the grease inside the grease worker and for the inlet of a cylindrical roller bearing under pure rolling conditions. This is used to estimate the actual degradation of the grease leaving the contact.

4:20 pm – 4:40 pm

3998241: A Simple and Novel Method Determining the Suitability of a Grease Related to the White Etching Crack Phenomenon

Saba Mottaghi, Julian Wald, TUNAP GmbH & Co. KG, Wolfratshausen, Bavaria, Germany

A novel, but simple methodology is presented to predict conflicts that might appear in the life cycle of grease lubricated bearings. Greases in high-speed bearings are exposed to high centrifugal forces leading to grease loss in the contact zone by slinging. This grease will stay and not contribute further to lubrication. The re-entry of the grease from starving to the contact, is random and will happen incidentally. While standard rheometry simulates the shear and temperature related viscosity, less attention is paid on the aspect of the structural rearrangement of a grease by temperature. Grease loss in high-speed bearings by centrifugal force displacement may be crucial in applications such as White Etching Cracks (WEC). As WEC is commonly attributed to marginal lubrication, friction and static electricity, the aspect of centrifugal force induced grease loss becomes critical. A way how to measure the changes in the "inner" structure of a grease by a simple methodology is presented.

4:40 pm – 5:40 pm

Grease Business Meeting

Session 4E • 101 F

Biotribology II

Session Chair: Meagan Elinski, Hope College, Holland, MI

Session Vice Chair: Quentin Allen, Brigham Young University, Provo, UT and Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile

2:00 pm – 2:40 pm

4004279: Best Practices – Rheological and Tribological Testing of Soft Materials

Kartik Pondicherry, Paul Staudinger, Anton Paar GmbH, Graz, Austria; Julius Heinrich, Anton Paar Germany, Ostfildern, Germany

Anyone who has spent a reasonable amount of time in a testing lab understands the complexities associated with developing novel test and analysis methodologies. Even after that, implementing the process is still challenging. Over the past decade, the authors have been often approached to clarify on some of the basic operating processes encountered during rheological and tribological testing and this work is aimed at addressing this issue. It provides some clarifications on areas such as sampling, sample handling, choice of test geometries, configurations, parameters, etc. Additionally, aspects of data acquisition and handling are also presented here. This topic assumes a greater significance for softer materials such as tissues, hydrogels, etc., as their viscoelastic properties play a significant role in determining their tribological characteristics. This work also covers case studies on select bio-tribological interfaces and also presents lessons learned in the process.

2:40 pm – 3:00 pm

4004005: Sliding Induced Integration of Nanoparticles into Hydrogel Surfaces

Meagan Elinski, Connor Bovia, Griffin Gleeson, Brianna Couturier, Lauren Buckley, Morgan Platz, Hope College, Holland, MI

Dynamic interactions between nanoparticles and soft materials will be increasingly encountered in the body as nanomaterials continue to be explored for a range of therapeutic applications. However, little is known about the surface effects of nanoparticles sliding against soft material surfaces. This work seeks to gain a fundamental understanding of the interactions between nanoparticles and hydrogels at sliding interfaces. Utilizing polyacrylamide (PAM) hydrogels, in situ macroscale friction tests were conducted with a rheometer with a tribology adapter. Comparing different nanoparticle compositions, citrate capped gold nanoparticles exhibited a 50% increase in friction relative to water due to hydrogen bonding, vs nanodiamonds exhibiting a 50% decrease in friction due to a higher solution viscosity. Post-sliding characterization of the PAM surfaces with confocal Raman microscopy and SEM imaging points towards integration of the nanoparticles within the hydrogel matrix.

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

4:00 pm – 4:20 pm

4005448: Polyglycerol-Functionalized Nanodiamonds for Improved Lubrication of Artificial Joints in Simulated Body Fluid

Mohammad Eskandari, Asghar Shirani, Diana Berman, Ali Zayaan Macknojia, University of North Texas, Denton, TX

Friction and wear are the major causes of osteoarthritis, the degenerative joint disease-causing pain and loss of functioning in the elderly population. propose to use diamond nanoparticles (NDs) in natural and artificial joints as the remedy to alleviate or even reverse friction and wear-induced damage. NDs, functionalized with polyglycerol to add to their biocompatibility and dispersibility, are introduced to the sliding interfaces of common polymer-on-metal and metal-on-metal implant systems and subjected to tribological evaluation. A detailed analysis of the produced wear tracks is employed to unravel the effect of surface functionalization of NDs and to optimize the concentrations needed for effective and prolonged friction and wear reduction. The findings suggest that the surface reactivity of NDs significantly affects their performance as non-toxic biolubricants.

4:20 pm – 5:00 pm

Biotribology Business Meeting

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Session 4F • 101 G

Seals I

Session Chair: Aaron Harcrow, Ultool, LLC, Duluth, GA

Session Vice Chair: Jing Tang, Ultool LLC, Duluth, GA

2:00 pm – 2:40 pm

4001211: Numerical Study of Textured Impulse Gas Seals

Noel Brunetiere, Jean Bouyer, Institut Pprime, Futuroscope Chasseneuil Cedex, France; Andriy Zahorulko, Sumy State University, Sumy, Ukraine

Impulse gas seals are a kind of mechanical seals equipped with deep grooves on both seal faces to generate a load carrying capacity and avoid contact and wear of the rings during operation. One face has feeding grooves connected to the high-pressure side and the other face has chambers that are periodically facing the feeding grooves during rotation. The mechanism of load generation in the fluid film is due to a transient impulse periodic process of chambers pressure feeding and pressure release. The behavior of these seals is thus complex compared to spiral groove gas seals. In this presentation a numerical study of an impulse gas seal is carried out. The effect of the seal design parameters is analyzed.

2:40 pm – 3:00 pm

4031054: Experimental Study of EHD Seals

Aaron Harcrow, Jing Tang, Hanping Xu, Ultool LLC, Duluth, GA; Sevki Cesmeci, Georgia Southern University, Statesboro, GA

The EHD seal is a non-contact shaft seal with an elastic sleeve surrounding the shaft with a narrow gap in between. Simulation results show that it restricts the gap leakage through self-adjusting deformation under pressure differentials, thereby improving energy efficiency and limiting wear. A preliminary test rig was utilized to confirm estimated EHD seal performance by simulating different seal materials, geometries and working fluids. This work was reported in a separate presentation. For supercritical carbon dioxide (sCO2) applications up to 35 MPa pressure and 700°C, EHD seals will be tested in a complex, dynamic test rig having flow conditions similar to the Brayton cycle. Three test phases: Phase 1, an EHD seal fabricated from 316 SST was tested with a fixed rotor and ambient temperature N2. Results confirmed a throttling effect beginning around 800 psi (5.52 MPa), Phases 2&3, work ongoing, the seal will be incrementally exposed to higher working fluid temperatures, pressures and rotor RPM.

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

4:00 pm – 4:20 pm

4004004: Topology Optimization for Low-Leakage and Low-Friction Surface Textured Face Seal

Iwa Ou, Eagle Industry Co., Ltd., Sakado-shi, Saitama-Ken, Japan; Kentaro Yaji, Osaka University, Suita, Osaka, Japan

A face seal with both low leakage and low friction was realized by surface texturing technology [1]. A surface texture consists of several micro-grooves. The friction coefficient and leakage rate are estimated by pressure distribution solved by the Reynolds equation. In a conventional way, shape optimization is carried out using a genetic algorithm, which restricts the degree of freedom and performance. We adopted topology optimization which is one of the gradient-based optimizations capable of generating free-form shapes. Several studies [2,3] based on the level

set method have been carried out, which can only use one depth. Owing to the recent development of laser processing technology, the depth of the surface texture can be precisely and accurately controlled industrially. Therefore we propose topology optimization based on the density method and present computational and experimental results in the presentation.

4:20 pm – 4:40 pm

4012791: A Low-Leakage and Low-Drag Elastohydrodynamic Seal for Supercritical Carbon Dioxide Turbomachinery

Mohammad Fuad Hassan, Sevki Cesmeci, Mohammad Towhidul Islam, Ali Akbor Topu, Md Wasif Hasan, Jonah Henry, Joshua Bunting, Georgia Southern University, Statesboro, GA; Hanping Xu, Aaron Harcrow, Jing Tang, Ultool, LLC, Duluth, GA; Shuangbiao Liu, North - western University, Evanston, IL; David Dewis, Consultant, Bath, ME

Current Supercritical carbon dioxide (sCO_2) turbomachinery suffers from high leakage rates, which is creating a major roadblock to the full realization of sCO_2 power technology. As a potential solution, we propose an elastohydrodynamic (EHD) scalable, high-temperature, high-pressure shaft end seal for sCO_2 turbomachinery. In this study, we experimentally carried out a proof-of-concept study for the proposed seal design and proved that the EHD seal restricts the leakage to minimal values at high pressures. The maximum leakage rate recorded was 272.51 LPM at 5.00 MPa. Following that, the leakage rate began to drop down to 108.72 LPM as the pressure increased to 15.00 MPa, generating a bell-shaped curve. At a 95% confidence level, the estimated confidence intervals for the mean were ±1.81 LPM and ± 2.58 LPM for pressures of 5.00 MPa and 15.00 MPa, respectively. These preliminary findings suggest that the proposed EHD seal design can potentially be applied to sCO_2 turbomachinery.

4:40 pm – 5:00 pm

4018310: Optimal Design of Sealing Unit for Multi-Stage ROT (Radial Outflow Turbine) Considering Ratio of Tip Clearance

Yongbok Lee, Korea Institute of Science and Technology, Seoul, Republic of Korea; Yunseok Ha, Yeongdo Lee, University of Science and Technology, Seoul, Republic of Korea

This paper investigates the leakage phenomena and performance of radial outflow turbine (ROT) with various sealing unit configurations according to tip clearance in a steam environment. Computational fluid dynamics (CFD) analysis was conducted to analyze the various fluid passage phenomena at each stage of an ROT with a sealing unit. A tip clearance of 0.1 mm between the stator and rotor was set up, and the total energy heat transfer model with adiabatic no-slip walls was defined. The k-e turbulence model and scalable wall function were applied for the analysis. The inlet boundary conditions were the total pressure and temperature, and the mass flow rate ranged from 0.208 to 0.5 kg/s. The analysis was conducted according to circumferential velocity to check the flow phenomena and turbine performance. The flow phenomena occurring in each stage of the ROT were mainly investigated through energy dissipation and entropy contours to check the effect of various shroud configurations.

5:00 pm – 6:00 pm

Seals Business Meeting

Session 4I • 101 J

Commercial Marketing Forum IV

Session Chair: TBD

Session Vice Chair: TBD

2:00 pm – 2:20 pm

4092108: BASF – Emgard 7103 XFE 75W-85, a New Fuel Efficient, Shear Stable Axle Lubricant to Meet New US Green House Gas Emission Requirements

Arjun Goyal, Donna Mosher, BASF, Florham Park, NJ

EPA and NHSTA on behalf of DOT have enacted rules to reduce Green House Gas emissions in HD vehicles. OEMs developed new reduced weight axle designs and lower oil level in axle sump. To meet new 2027 GHG requirements, axle oils contribute to higher fuel savings and reduction in CO2 emissions. BASF's 75W-85 lubricant consists of a unique combination of synthetic base oil (PAO) and viscosity improver (thickener) which results in superior low-and-high temperature properties with excellent extended-length shear stability. Emgard 7103 lubricant meets the SAE J2360 and leading North American axle manufacturers rigorous extended drain specification requirements.

2:20 pm – 2:40 pm

4079639: VBASE® OIL Company – Secondary Polyol Ester™ Technology – Expanding the Portfolio of Novel Sustainable Base Oils

Martin Greaves, Jeff Dimaio, Zach Hunt, Ben Bergmann, Michelle DiMaio, VBASE Oil Company, Pendleton, SC

VBASE® Oil company has commercialized a novel family of Secondary Polyol Ester™ (SPE™) base oils that are high performance sustainable API Group V synthetic base oils in the range ISOVG 32-100. Our company is expanding our portfolio with new grades in the range ISOVG 100-460. SPE™ base oils have been 'Designed for Sustainability' by linking building blocks that have high levels of biodegradability to create novel base oils that can help formulators meet the highest technical performance and environmental accreditation requirements. The presentation will introduce the VBASE® Oil Company and highlight some of the unique properties and applications of SPEs. This oxygen-rich family of base oils, with in-built detergency, offers some special attributes such as excellent deposit control, hydrolytic stability, friction control and low heats of combustion making them a versatile building block for formulators of industrial, marine and automotive lubricants.

2:40 pm – 3:00 pm

4093023: The Lubrizol Corporation – Improved Performance for Open Gear Lubricant Systems

Jennifer Clark, Robet Dura, Gareth Fish, The Lubrizol Corporation, Wickliffe, OH

Open gear lubricant technology for heavy industrial equipment is continually evolving. Historically most base fluids for open gear applications were asphaltic and brightstock based, moving more recently towards Polyisobutylene to assist with visual inspection and to maintain viscosity. Though brightstock and PIB options are cost effective, they do not provide differentiating performance, and while polyalphaolefin (PAO) base oils have also been used to boost efficiency and lower operating temperatures; other more efficient alternatives are now available. As an alternative and complement to Brightstock, PIB and PAO, Lucant™ provides additional benefits in open gear applications. Lubricants

designed utilizing Lucant™ deliver lower operating temperatures, improved efficiency, reduced lubricant consumption, and work synergistically with Lubrizol's phosphorus-based chemistries. This presentation will provide an overview of Lucant™ and Lubrizol's additive benefits in open gear applications.

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

4:00 pm – 4:20 pm

4095150: Evonik – High Performance, Energy Efficient Industrial Gear Oils Enabling Short-Timeline Cost Savings

Mark Petit, Evonik, Rochester Hills, MI

Industrial gear oils are a critical component in the efficient operation of machinery and equipment and the use of high-performance lubricants can significantly reduce energy consumption and maintenance costs. NUFLUX® is a high-performance industrial gear oil technology, proven by broad OEM approvals and multiple applications in the field. Besides high performance and oil life extension, the utilization of this cost-effective technology leads to a return of investment of only a few months. This paper will present selected Evonik in-house cases showing that energy savings are just an oil change away.

4:20 pm – 4:40 pm

4086170: ExxonMobil: Introducing Elevexx™ LAO and Exxal™ 1315 LE Alcohol

Kyle Lewis, ExxonMobil, Spring, TX

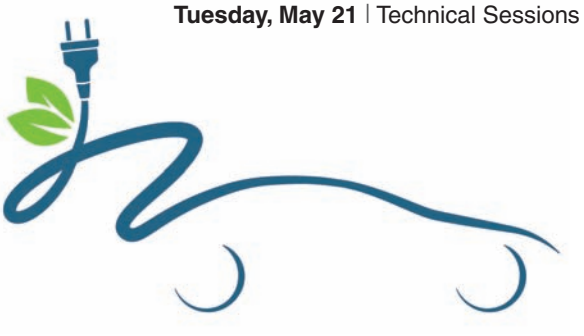
The global supply of materials serving the lubricant markets has been disrupted in recent years. Ensuring reliable access to critical chemical feedstocks is a priority for lubricant component producers. For more than 60 years, ExxonMobil has served the lubricants industry with chemical intermediate products. Backed by a global manufacturing and supply footprint, our higher olefins and Exxal™ alcohols are trusted as integral components of many additives and synthetic base stocks. ExxonMobil is once again leveraging its integration and manufacturing scale to bring high quality chemical products to the lubricants market. Global customers can confidently rely on our new Elevexx™ linear alpha olefins to strengthen your production of high-performance lubricant components. We have also grown our portfolio with Exxal™ 1315 LE, an LAO-derived alcohol, which can broaden your access to linear alcohols for the production of additives and esters.

4:40 pm – 5:00 pm

4094293: ExxonMobil – Alkylated Naphthalene: A Booster and a Base Stock

Manish Patel, ExxonMobil Chemical Company, Spring, TX

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



Session 4J • 200 DE

Electric Vehicles IV

Session Chair: Carlos Sanchez, Southwest Regional Research Institute, San Antonio, TX

Session Vice Chair: Vinod Radhakrishnan, Afton Chemical Corporation, Richmond, VA

2:00 pm – 2:20 pm

4006626: Probing the Effect of Electric Fields on Behaviors of Lubricant Additives Confined between Surfaces at the Molecular Level

Zhaoran Zhu, James Ewen, Daniele Dini, Imperial College London, London, United Kingdom

The increasing demand in electric vehicles has propelled advancements in lubricant technology for new operational environments under electric fields (EFs). However, it has been pointed out that the change in lubricating effect at electrified interface behave differently for bulk liquid-solid interfacial systems and nanoconfined systems, which are not well understood. Therefore, in this study, we perform nonequilibrium molecular dynamics (NEMD) simulations with a reactive force field (ReaxFF) to study the effect of EFs on phosphate-based lubricant additives, in between two metal surfaces, under nanoconfined and sliding conditions. Meanwhile, two charge equilibration methods implemented in NEMD are also investigated and compared, known as Qeq and QTPIE. These findings provide an atomistic understanding of the effect of EFs on lubricant additives' behaviors during the redox reactions.

2:20 pm – 2:40 pm

4005300: Viscosity Dependence of Oil Churning Losses in an Electric Vehicle Gearbox at High Speeds

Alexander MacLaren, Amir Kadiric, Imperial College London, London, United Kingdom; Ning Ren, Valvoline Ltd., Lexington, KY

The accelerating uptake of electric vehicles (EVs), and the drive to extend vehicle range has brought EV powertrain efficiency sharply into focus. The continuing trend towards reducing transmission oil viscosity has multimodal implications for both transmission efficiency and reliability. Predicting oil churning, the principal load-independent power loss, is a particular challenge as drive pinion speeds surpass the range of validity of existing models. Finding an optimum fluid viscosity for any given system therefore remains challenging. In this study, oil churning torques are measured in an EV drive unit over a wide range of transmission fluid viscosities. The transmission is temperature-controlled and instrumented to enable control of viscosity and torques derived by inertia rundown are compared to those obtained in the steady state. Finally, the task of optimizing lubricant viscosity to maximize both transmission efficiency and reliability is addressed.

4J

2:40 pm – 3:00 pm

4007600: Unraveling the Complex Tribochemistry of Lubricated Surfaces Under Electrified Sliding Conditions

Ali Erdemir, Pushkar Deshpande, Cagatay Yelkarasi, Seungjoo Lee, Texas A&M University, College Station, TX; Leonardo Farfan-Cabrera, Tecnologico de Monterrey, Monterrey, Nuevo Leon, Mexico

Electric vehicles (EVs) are becoming the provider of future transportation needs due to their environmental benefits. However, there exist some tribological challenges that can adversely impact the longer-term functionality of such vehicles due to stray electricity. In this presentation, we report some of the complexities that can adversely impact the tribochemistry and hence the formation of protective tribolayers under electrified sliding conditions. Specifically, using a wide range of surface and structure analytical techniques, we unravel the structural chemistry of tribofilms forming under electrified condition and relate such findings to friction and wear. Results show that the passage of electric current through the contact interfaces increases wear by the formation of harder and more abrasive debris particles mostly composed of iron oxides and carbides. These findings may help in the development of better fluids and materials to mitigate such wear problems in real applications.

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

4:00 pm – 4:20 pm

4005532: Optimization of EV Drivetrain Efficiency Through Lubricant Selection

Amir Kadiric, Joseph Shore, Imperial College London, London, United Kingdom

The ability to systematically study and minimize drivetrain losses provides an important avenue for improving the efficiency, and hence the range, of an EV. This paper uses a recently developed, tribological model for prediction of EV gearbox efficiency to systematically study the effect of lubricant properties, including viscosity, pressure-viscosity coefficient, thermal conductivity, and boundary friction coefficient on the EV drivetrain losses over real-road and standardized duty cycles. The model uses experimentally obtained lubricant rheology parameters to enable it to discriminate between nominally similar oils. The temperature evolution in the gearbox, including the effect of motor cooling, are accounted for through a suitable thermal network. The results are discussed in terms of relative importance of different fluid properties on EV efficiency and the overall efficiency gains that may be achieved through lubricant optimization.

4:20 pm – 4:40 pm

4015266: Simulation and Test-Based Methodologies for EDU Fluids Development

Thomas Wellmann, Jonathan Palmer, Kiran Govindswamy, FEV, Auburn Hills, MI

The use of innovative electrified propulsion systems is expected to play an important role in helping OEMs meet fleet CO_2 targets. A key aspect for customer acceptance of BEV's is the driving range. Hence, it is critical to increase the drivetrain efficiency without sacrificing vehicle performance. Due to the integration of power electronics, electric motors, and geartrain into one compact drive unit, unique system evaluations will be required. Specifically, the behavior of the e-fluids can have a significant influence on the EDU performance. This presentation will showcase key drivetrain components and how their performance can be evaluated via simulation and testing. Methods specifically for fluid development on sub-component level will be shown. Subsequently, fluid evaluations in a complete EDU will be discussed, and influence of fluids for cooling and lubrication will be highlighted. The influence of EDU efficiency to the drive range will be estimated using vehicle-level simulations.

4:40 pm – 5:00 pm

4005366: Electrified Rheology and Elastohydrodynamic Lubrication (EHL) Behavior of Graphene-Based Low Viscosity Lubricants for EV Application

Leonardo Farfan-Cabrera, Tecnologico de Monterrey, Monterrey, Mexico; Peter Lee, Carlos Sanchez, Southwest Research Institute, San Antonio, TX; Ali Erdemir, Texas A&M University, College Station, TX

Lubricants with carefully balanced levels of conductivity have been proposed as a promising option to overcome the shaft/bearing damage caused by currents present in electric drivelines. This can be achieved through the use of conductive fluids or by adding conductive agents like additives or nanoparticles to lubricating oils. Limited research has been published on the topic to elucidate this notion. Hence, in this work, a synthetic base oil (polyalphaolefin oil (PAO4)) and a Group II base oil were blended with 0.5 %wt./v of graphene nanoplatelets (GnPs), respectively. They were evaluated as potential nanolubricants for electrified environments. Their rheology, elastohydrodynamic, traction, and wear behavior were evaluated under non-electrified and electrified conditions using an adapted Anton Paar rheometer and a PCS mini traction machine (MTM). The changes in shear viscosity, traction coefficient, and wear of the nanolubricants under various electrical conditions are presented.

Exhibitor Appreciation Hour and Evonik Raffle

Two hours of dedicated exhibit time will occur at this year's trade show: Monday, May 20 and Tuesday, May 21 (3:00 pm-4:00 pm) in the Minneapolis Convention Center (Exhibit Hall B). All other annual meeting activities will be closed during this time, and refreshments will be served! Come view the industry's newest products and technologies from more than 100 companies.

As part of the **Exhibitor Appreciation Hour,** Evonik is hosting raffles on Monday and Tuesday, May 20 and 21, at 3:30 pm in the exhibit hall. You must be present at **Evonik Booth 303** at the time of drawing to win.

Evonik is raffling two Yeti blankets.