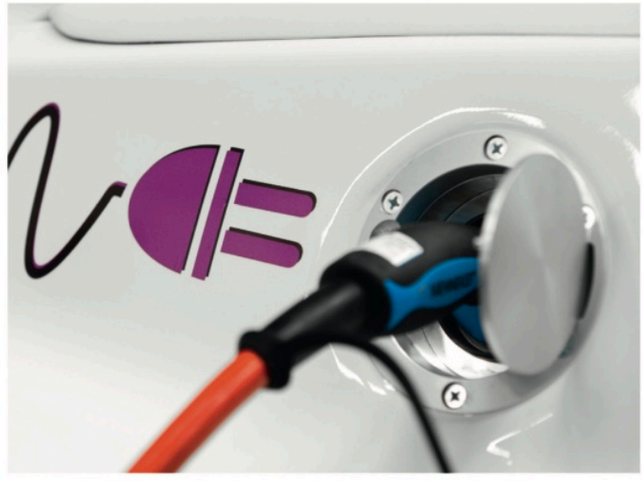

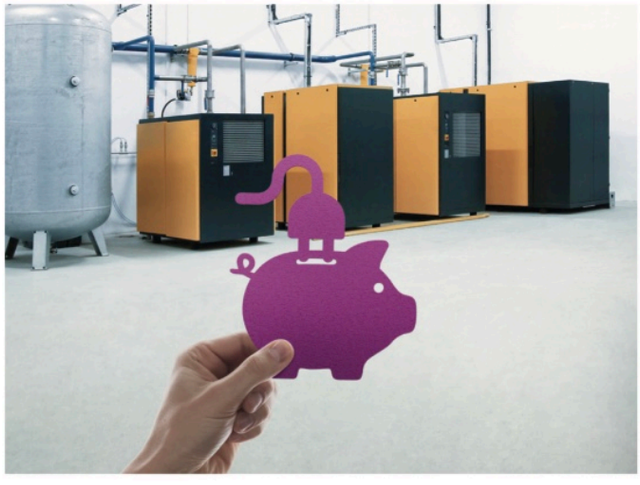

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Overview

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

Sunday, May 19

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

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

Education Courses (8:00 am – 5:00 pm) – ***registration required***

- Advanced Lubrication 301: Advanced Additives – **200 C**
- Basic Lubrication 103 – **104 A**
- Electric Vehicles 101 – **200 I**
- Grease 101 (in partnership with NLGI) – **200 DE**
- **NEW!** Machine Learning and Artificial Intelligence in Tribology (Half-day course): 1:00 pm – 5:00 pm – **200 B**
- Metalworking Fluids 105: Introduction of Metal Forming Fluids – **200 H**

Education Course Breaks – **Foyer**

Invitation Only: STLE Section Leadership Training
4:30 pm – 5:45 pm – **200 J**

Ticked Event/Invitation Only: Student and New Member Networking Reception
6:00 pm – 7:30 pm – **Seasons**

Monday, May 20

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

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

Technical Sessions (8:00 am – 10:00 am)

1A • Tribochemistry I – **101 B**
1B • Tribotesting I – **101 C**
1C • Contact Mechanics I – **101 D**
1D • Synthetic Lubricants and Hydraulics I – **101 E**
1F • Nanotribology I – **101 G**
1G • Surface Engineering I – **101 H**
1I • Commercial Marketing Forum I – **101 J**
1J • Electric Vehicles I – **200 DE**

Networking/Refreshment Break
10:00 am – 10:30 am – **Grand Ballroom Foyer**

Opening General Session: Keynote Address
10:30 am – 12:00 pm – **Grand Ballroom**

- **"Tribology in the New Space Economy"**
  Speaker: **Brian Dykas,** Ph.D, PE, Senior Materials and Process Engineer, Blue Origin

Lunch (on your own) – 12:00 pm – 1:40 pm

Commercial Exhibits and Posters
12:00 pm – 5:00 pm – **Exhibit Hall B**

Technical Sessions (1:40 pm – 5:00 pm)

2A • Tribochemistry II – **101 B**
2B • Tribotesting II – **101 C**
2C • Contact Mechanics II – **101 D**
2D • Grease I – **101 E**
2F • Nanotribology II – **101 G**
2G • Surface Engineering II – **101 H**
2I • Commercial Marketing Forum II – **101 J**
2J • Electric Vehicles II – **200 DE**

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

STLE Sustainability Forum
5:00 pm – 6:00 pm – **Seasons**

Networking Reception
6:00 pm – 7:30 pm – **Hilton Minneapolis**

Exhibition hours

- **Monday, May 20** (12:00 pm – 5:00 pm)
- **Exhibitor Appreciation Hour** (3:00 pm – 4:00 pm)
  Evonik Raffle (3:30 pm) – Must be present to win.
  (Booth #303)

TIME	SESSION 1A Tribochemistry I Room 101 B	SESSION 1B Tribotesting I Room 101 C	SESSION 1C Contact Mechanics I Room 101 D
8:00 am – 8:40 am	The Activation Volume in Tribochemistry: What it Means and How to Calculate It, W. Tysoe, p. 34	Development of Within-Cycle Variable Slide-Roll Ratio Test Geometries, G. Plint, p. 35	A Semi-Analytical Transient Model of Elastohydrodynamic Mixed Lubrication Bearings Under Electrical Loads, R. Jackson, p. 36
8:40 am – 9:00 am	Contact Mechanics Correction of Activation Volume in Mechanochemistry, C. Qu, p. 34	Development of a High-Stress Abrasion Test for Engineering Materials, K. Budinski, p. 35	Contact Electrification-Induced Electroadhesive Axisymmetric Contact Model, Y. Xu, p. 36
9:00 am – 9:20 am	Molecular Dynamics Study of MAC Lubricants for Aerospace Applications, D.Miliate, p. 34	Effect of Nitrogen-Rich Atmosphere on Fuel Lubricity Standards using HFRR, BOCLE, and SLBOCLE, C. Matzke, p. 35	Thermoelastic Contact Simulation with Reciprocating Motion and Worn Surfaces, S. Liu, p. 36
9:20 am –9:40 am	The Effects of -H and -OH Termination on Adhesion of Si-Si Nanocontacts Examined Using Molecular Dynamics and Density Functional Theory, J. Schall, p. 34	Viscosity Measurement In-Situ Under Pressure Using Ultrasound. R. Dwyer-Joyce, p. 35	Inside Sliding Contact: Relationships Between Third Body Formation and Contact Waves, M. Renouf, p. 36
9:40 am – 10:00 am	The Role of Shear Stress in ZDDP Tribofilm Formation at the Single Asperity Level, K. Sato, p. 34	Experimental Analysis of Pasting of Brushed DC Motors, R. Dzhafarov, p. 35	An Investigation of Hertz Theory as Applied to Spinning, Bouncing Balls, J. Streator, p. 36
10:00 am – 10:30 am	**Break**	**Break**	**Break**
10:30 am – 11:30 am			

	SESSION 2A Tribochemistry II Room 101 B	SESSION 2B Tribotesting II Room 101 C	SESSION 2C Contact Mechanics II Room 101 D
1:40 pm – 2:20 pm	Analytical Tribology With a High Resolution 6 Axes Tribometer, J. Fontaine, p. 44	Recent Advances in Design and Development of Tribotesting for Electric Vehicle Lubricants, D. Yiyuan Khoo, p. 45	
2:20 pm – 2:40 pm	Microscale Tribochemistry of Diamond-Like Carbon Coatings, B. Borovsky, p. 44	Electrified Benchtop Tribology Grease Testing, A. Byron, p. 45	A Multiscale Modeling System for Simulating a Radial Pump Plunger to Observe and Improve Tribological Performance, H. Soewardiman, p. 46
2:40 pm – 3:00 pm	Selective Coating on Metal Surfaces with Friction-Assisted Electrodeposition, Y. Song, p. 44	A Novel Approach for Tribological Evaluation of Textured Surfaces from Additive Manufacturing, T. Martin, p. 45	Design Improvement of Clearing Plate in a Biomass Comminution System through Contact Analysis, L. Lin, p. 46
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:20 pm	Friction and Wear Behavior of Gaseous and Volatile Fuels Using a Sealed Tribometer, J.Wong, p. 44	Correlating Wear Performance with Lubricant Properties of Real Used Heavy-Duty Diesel Engine Oils, T. Kirkby, p. 45	Exploring the Mechanics of Triboelectric Nanogenerators via In-Situ Experiments, D. Mulvihill, p. 46
4:20 pm – 4:40 pm	Chemical Compatibility of Metal Oxide Nanoparticles and Lubricant Co-Additives, I. Lahouij, p. 44	Threaded Fastener Joints: Friction Control with Soft Coatings, S. Glavatskih, p. 45	Influence of Poroelasticity and Unloading Rates in Enhancement of Gel Adhesion, W. Lee, Melih Eriten, p. 46
4:40 pm – 5:00 pm	The Effect of Lubricant Contamination with Water on Friction Modifiers Tribofilm Properties, A. Morina, p. 45	Tribotesting Business Meeting	Contact Mechanics Business Meeting
5:00 pm – 6:00 pm			

SESSION 1D
Synthetic Lubricants and Hydraulics I

Room 101 E

Hydraulic Fluid Performance Demonstrations According to ASTM D7721 – Energy Savings Validated with Shear-Stable, High-VI Technology, R. Gomes, p. 37

Zn-Free Strategies to Meet Bosch Rexroth Hydraulic Performance, J. Dickstein, p. 37

Performance of Novel & Sustainable Synthetic Ester Base Oils with Hybrid Functionality, M. Greaves, p. 37

Technical and Scientific Perspective from Using Polyglycol on a Composition of Compressor Lubricants, E. Lima, p. 37

Energy Efficient Compressor Lubricants for Low-GWP Refrigerant Systems, J. Kontra, p. 37

Break

Synthetic Lubricants & Hydraulics Business Meeting

SESSION 1F
Nanotribology I

Room 101 G

Revealing the Structure-Property Relationships of Amorphous Carbon Tribofilms on Platinum-gGld Nanocrystalline Alloys, F. DelRio, p. 38

Atomistic Simulations of Chemomechanics at Electrified Interfaces, A. Krishnamoorthy, p. 38

Chemical Absorption-Induced Hysteretic Friction Behavior of Supported Atomically Thin Nanofilm, P. Egberts, p. 38

Bridging Atomistic and Continuum Scales Simulations for the Modelling of Mechanochemical Interactions and Tribofilm Growth, D. Dini, p. 38

Break

8:00 am – 8:40 am

8:40 am – 9:00 am

9:00 am – 9:20 am

9:20 am –9:40 am

9:40 am – 10:00 am

10:00 am – 10:30 am

10:30 am – 11:30 am

SESSION 2D
Grease I

Room 101 E

Recipes for Success: The Impact of Various Promoter Systems on Calcium Sulfonate Complex Grease Performance, J. Kaperick, p. 47

An Improved Model to Describe Oil-Separation Properties of Lubricating Greases, F. Hogenberk, p. 47

Tribology and Grease Lubricated Ball Bearings, P. Lugt, p. 47

Exhibitor Appreciation Break

Controlling Micropitting on Wind Turbine Main Bearings, M. Ingram, p. 47

Fast Screening of Wear Regimes in a Four Ball Setup, L. Lopes, p. 47

SESSION 2F
Nanotribology II

Room 101 G

Coatings That Manufacturing Themselves: Formation, Interface Transfer, and Performance of Tribosintered Metal Oxide Coatings, R. Carpick, p. 48

Surface Oxide Layers Dictate Interfacial Adhesion of Cold-Sprayed Bulk Metallic Glass Single Particles, F. DelRio, p. 48

Observing and Modeling the Wear Process of Heterogeneous Interface, X. Tang, p. 48

Exhibitor Appreciation Break

Nanolubricants for Increasing the Lifetime of Machine Elements and Cutting Tools for Machining Processes, L. Pena-Paras, p. 48

Analytical Friction Models for Molecular Adsorbates, W. Tysoe, p. 48

Molecular Dynamics Analysis of Polymer Friction in Heterogeneous Surface, H. Washizu, p. 49

Nanotribology Business Meeting

1:40 pm – 2:20 pm

2:20 pm – 2:40 pm

2:40 pm – 3:00 pm

3:00 pm – 4:00 pm

4:00 pm – 4:20 pm

4:20 pm – 4:40 pm

4:40 pm – 5:00 pm

5:00 pm – 6:00 pm

MONDAY >>

TIME	SESSION 1G Surface Engineering I Room 101 H	SESSION 1I Commercial Marketing Forum I Room 101 J	SESSION 1J Electric Vehicles I Room 200 DE
8:00 am – 8:40 am		BYK Additives for Industrial Lubricants and Greases, M. Boehmer, p. 40	
8:40 am – 9:00 am	Exploring the Tribological Behavior of Additively Manufactured Al-6061 Alloy for Space Applications, P. Das, p. 40	Chevron Phillips Chemical Company – Synfluid® PAO as a More Sustainable Solution, K. Hope, p. 40	Testing Approaches for Developing and Validating EV Fluids, F. Sarti, p. 42
9:00 am – 9:20 am	Exploration of Spectrum Data from Non-Destructive Surface Roughness Measurement Techniques of Additively Manufactured Ti-6Al-4V, R. Jackson, p. 40	DL Chemicals – Engineered Ethylene Propylene Copolymer System with High Performance Capability: Beyond Conventional OCP (Olefin copolymers), H. Kim, p. 42	Oil Immersed Energized Copper Circuit Board Test Understanding, H. Thaker, p. 42
9:20 am – 9:40 am	Physics-Informed Machine Learning to Improve Manufactured Surfaces, T. Jacobs, p. 40	Colonial Chemical: Enabling the New-generation Metalworking Fluid Formulation, S. Tang, p. 42	Shaft Voltage Causes Bearing and Lubricant Degradation, S. Hausner, p. 42
9:40 am – 10:00 am		LANXESS – Hybase® GFX500: The Development of a Novel Incidental Food Contact Calcium Sulfonate, R. Dworet, p. 42	
10:00 am – 10:30 am	Break	Break	Break

TIME	SESSION 2G Surface Engineering II Room 101 H	SESSION 2I Commercial Marketing Forum II Room 101 J	SESSION 2J Electric Vehicles II Room 200 DE
1:40 pm – 2:00 pm	Enabling High-Performance Surface of Biodegrade WE43 Magnesium Alloys via Laser Shock Peening, W. Wang, p. 49	Optimol Instruments – Diversity of Tribological Testing with Optimol Instruments From Standard to Innovative Methods, A. Schneider, p. 50	Efficient Shear Stable Thickeners for the Heavy-Duty EV Market – Theory, Application, Proof, A. Kurchan, p. 51
2:00 pm – 2:20 pm	Application of LST on Cutting Inserts Used in CNC Machining of Aluminum Alloys to Increase Their Performance, D. Maldonado-Cortés, p. 49x	Functional Products: Everything You Need to Know About PPDs From Functional Products, M. Woodfall, p. 50	
2:20 pm – 2:40 pm	Understanding the Correlation Between Surface Topology and Lubrication Performances of Quasi-Random Nanostructure Surfaces by Using Deterministic Lubrication Models, H. Zhang, p. 49	The Lubrizol Corporation – Improved Microbial Control for Metalworking Fluids, G. Kirsch, p. 50	The Energy Efficiency Improvement Effect of Low Viscosity Engine Oil with MoDTC in a Large Displacement Engine, K. Yamamoto, p. 52
2:40 pm – 3:00 pm	A Novel Approach to Lubrication – Interactions Between Gadolinium-Doped DLC Coatings and Phosphorus-Based Ionic Liquids, T. Omiya, p. 49	Biosynthetic Technologies – Estolide Technology for Sustainable and High-Performance Lubricant Technology, M. Kriech, p. 51	Lubricants Requirements for Electrified Heavy Duty Drive Trains, T. Murr, p. 52
3:00 pm – 4:00 pm	Exhibitor Appreciation Break	Exhibitor Appreciation Break	Exhibitor Appreciation Break
4:00 pm – 4:20 pm	The Influence of Geometry and Test Conditions on Lifetime and Endurance of Solid Film Lubricants. Testing Strategy and Data Production Method Enabling AI?, L. Lopes, p. 50	Advancion Corporation – Advancion – A New Name, A Fresh Approach, A Trusted Partner, M. Lewis, p. 51	Thermal Conductivity Enhancement of EV Fluids by Carbon Nanotubes, C. Kumara, p. 52
4:20 pm – 4:40 pm	Structure and Friction Performance of Sulfonitrocarburizing Layer Prepared by Plasma Nitrocarburizing and Low Temperature Ion Sulfurizing, Z. Zhang, p. 50	Evonik – VISCOPLEX Products for Emulsion Retention in Engine Oils, M. Hauschild, p. 51	Beyond the Battery – A Holistic View of Thermal Management Fluids in BEVs, G. Brown, p. 52
4:40 pm – 5:00 pm	Preparation of Thin-Film Transistors by Surface Energy-Directed Assembly, J. Zhang, p. 50	ExxonMobil – SpectraSyn™ Base Stocks: Elevating Group II Base Stocks to Meet High Performance Specifications, M. Patel, p. 51	
5:00 pm – 6:00 pm	Surface Engineering Business Meeting		

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Monday, May 20, 2024
8:40 a.m.

Minneapolis Convention Center
Room 101J

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Session 1A • 101 B

Tribochemistry I

Session Chair: Cinta Lorenzo Martin, Argonne National Laboratory, Argonne, IL

Session Vice Chair: TBD

8:00 am – 8:40 am

4002101: The Activation Volume in Tribochemistry: What it Means and How to Calculate It

Wilfred Tysoe, University of Wisconsin-Milwaukee, Milwaukee, WI

The activation volume gauges the effect of stresses on chemical reaction rates but is only a volume because the conjugate variable of a stress has the units of volume. It can be calculated using the Stearn-Eyring postulate; that it is a product of an activation length, comprising a vector from the initial – and transition-states, and the area over which the stress acts. The activation volume depends both on the direction of the applied force and the nature of the reaction. We discuss how the activation volume can be obtained by calculating the effect of an applied stress on the initial- and transition-state structures and show that the calculated results are in good agreement with the available experimental data. The compliances of these states, obtained from quantum calculations, can also be used to show that the applied stress only modestly influences the activation volume under the experimental conditions that can easily be obtained in the laboratory.

8:40 am – 9:00 am

3987831: Contact Mechanics Correction of Activation Volume in Mechanochemistry

Cangyu Qu, Lu Fang, Robert Carpick, University of Pennsylvania, Philadelphia, PA

Activation volume is the key variable in mechanochemistry describing the effect of stress on reaction rate. However, its physical interpretation remains uncertain and significant discrepancies exist in recent tribology experiments. Here, we analyze the contact mechanics of the standard stress-assisted thermal activation model and find that, in some cases, a large correction is needed. We consider the force-dependent contact area and the nonuniform stress distribution, which were previously overlooked, leading to a correction function. For validation, we study the formation of antiwear tribofilms from zinc dialkyldithiophosphates (ZDDP). Combining colloidal-probe and regular AFM, we show that these and prior literature results, which are widely scattered if treated with the standard model, are in excellent agreement with our corrected model. This provides an accurate method for determining activation volumes and provides insights for interpretating them for elucidating tribochemistry.

9:00 am – 9:20 am

4000886: Molecular Dynamics Study of MAC Lubricants for Aerospace Applications

Daniel Miliate, Ashlie Martini, University of California, Merced, Merced, CA; Andrew Clough, Peter Frantz, Stephen. Didziulis, The Aerospace Corporation, El Segundo, CA

The development of multiply alkylated cyclopentane (MAC) lubricants has been instrumental in addressing challenges in space tribology. However, it is unclear how and why these lubricants ultimately fail, making predictions of performance and service lifetime difficult. Previous work suggested consumption of the MAC lubricants is due in part to lubricant degradation and subsequent volatility in the space environment. The objective of this study was to use molecular dynamics simulations to understand the mechanisms of degradation and volatility of MAC lubricants. Simulations with reactive and non-reactive potentials were used to model 1,3,4-tri-(2-octyldodecyl) cyclopentane under various conditions to understand lubricant properties and reaction pathways. The findings here contribute to a better understanding of MAC lubricant consumption in aerospace applications.

9:20 am – 9:40 am

4003869: The Effects of -H and -OH Termination on Adhesion of Si-Si Nanocontacts Examined Using Molecular Dynamics and Density Functional Theory

James Schall, North Carolina Agricultural and Technical State University, Greensboro, NC; Brian Morrow, Judith Harrison, US Naval Academy, Annapolis, MD; Robert Carpick, University of Pennsylvania, Philadelphia, PA

Contact between silicon asperities and substrates terminated with -H and -OH functional groups is simulated using reactive molecular dynamics. Adhesion is low at full adsorbate coverages. As the coverage reduces, adhesion increases by factors of ~5 and ~6 for -H and -OH terminated surfaces, respectively, due to the formation of covalent bonds. In contrast, replacing -H groups with -OH groups while maintaining full coverage leads to negligible increases in adhesion indicating that marked increases in adhesion require unsaturated sites. Density functional theory calculations were performed to investigate the energetics of Si (111) surfaces terminated by -H or -OH groups. Both DFT and MD calculations predict the correct trends for the bond strengths: Si-O > Si-H > Si-Si. This work supports the contention of prior experimental observations that strong increases in adhesion after sliding Si-Si nanoasperities over each other is due to removal of passivating species on the Si surfaces.

9:40 am – 10:00 am

4006387: The Role of Shear Stress in ZDDP Tribofilm Formation at the Single Asperity Level

Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Tokyo, Japan

ZDDPs form reaction film exerting antiwear properties by preventing metal/metal contacts. Zhang et al. reported that shear stress accelerated tribofilm formation using MTM-SLIM. However, while the tribofilm formation was generated by single asperity contacts, this aspect has not been extensively studied. The purpose of this study is to examine the effects of shear stress on ZDDP tribofilm formation at the single asperity level. To explore the effect of shear stress at a single asperity, we employed in-situ AFM techniques and assessed compression/shear stresses using FEM. Our results showed that tribofilm growth was prominent under high compression stress. Based on the correlations between compression/shear stresses and tribofilm thickness, only compression stress showed a significant relation with tribofilm thickness during initial sliding cycles. In our presentation, we will report the effects of shear stress on the tribofilm growth, extending our focus on longer sliding durations.

10:00 am – 10:30 am – Break

Session 1B • 101 C

Tribotesting I

Session Chair: George Plint, Phoenix Tribology Ltd., Kingsclere, Newbury, United Kingdom

Session Vice Chair: Kenneth Budinski, Bud Labs, Rochester, NY

8:00 am – 8:40 am

3988407: Development of Within-Cycle Variable Slide-Roll Ratio Test Geometries

George Plint, James Morley, Phoenix Tribology Ltd., Kingsclere, Newbury, United Kingdom

Wear occurs in conjunction with dissipation of frictional energy, generated by the combination of load and sliding speed. Most tribometers provide variable loading, but few offer within-cycle dynamic loading. Other than reciprocating tribometers, most tribometers provide control of sliding or sliding-rolling velocity, but not within-cycle, dynamically varying, velocity. Various contacts (primarily gears and cams) are subject to both dynamically varying load and slide-roll ratio. We know that in a reciprocating tribometer, with sufficient stroke length, wear rate and mechanism vary with stroke position, hence local sliding velocity. This type of test can go some way towards modelling adhesive wear and scuffing in gears and cams but cannot be used for modelling wear and failure mechanisms associated with contacts subject to within-cycle, continuously variable, slide-roll ratios. This paper reviews the development and use of a number of novel variable slide-roll ratio test geometries.

8:40 am – 9:00 am

3988827: Development of a High-Stress Abrasion Test for Engineering Materials

Kenneth Budinski, Bud Labs, Rochester, NY

The ASTM B611 high-stress (produces crushing of abrasive particles) abrasion test for cemented carbides has been the gold standard for comparing the abrasion resistance of cemented carbides. However, this test does not work on steels and other materials because of adhesive interaction between the test specimen and the test's steel wheel. This project was initiated to explore the feasibility of using a dry particle crushing test rig to replace the ASTM B611 test. Test were conducted to determine the test repeatability and the applicability of the test to cemented carbides, hard steel (type D2 at 60 HRC), and a zirconia/alumina ceramic. It was determined that the test had good repeatability and produced material abrasion resistance rankings that were consistent with industry observations. It is concluded that this test can be a direct replacement for the ASTM B611 test with applicability to all of the candidate materials that may be considered for high-stress abrasion applications.

9:00 am – 9:20 am

3989113: Effect of Nitrogen-Rich Atmosphere on Fuel Lubricity Standards using HFRR, BOCLE, and SLBOCLE

Caleb Matzke, Briana Segal, Nikhil Murthy, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Fuel lubricity has a large impact on system wear in mixed and boundary lubrication regimes found in high pressure fuel pumps, however lubricity standards do not simulate fuel pump environments or reproduce observed pump damage. ASTM D5001 Ball-on-Cylinder Lubricity Evaluator (BOCLE) is used for evaluating lubricity of aviation turbine fuels, while ASTM D6079 High-Frequency Reciprocating Rig (HFRR) is used for diesel fuels. Scuffing Load BOCLE (SLBOCLE) measures scuffing failure in severe conditions in diesel fuels. All are conducted in air rather than the low-oxygen environment found in fuel pumps. We compared the three standards in both air and nitrogen gas environment for a wide range of fuels. We also observed differences in wear and fuel ranking due to the presence/absence of oxygen on fuel lubricity measurements for all fuels. We compare the three testing methods and discuss the differences between them using microscopy and spectroscopy of the wear scars produced from each method.

9:20 am – 9:40 am

3991105: Viscosity Measurement In-Situ Under Pressure Using Ultrasound

Rob Dwyer-Joyce, Gladys Peretti, The Leonardo Centre for Tribology, The University of Sheffield, Sheffield, United Kingdom; Nathalie Bouscharain, Fabrice Ville, University of Lyon, INSA Lyon, Villeurbanne, France; Nicole Dörr, Markus Varga, AC2T research GmbH, Wiener Neustadt, Austria

Machines in industry transmit motions under various speeds and loads, leading to high temperatures, shear rates, and pressures in contacts. Lubricant viscosity is crucial to separate surfaces in contact and ensure good efficiency. Viscosity depends on the operating conditions; its monitoring can thus prevent failures. Conventional viscometers cannot operate in contacts and cannot easily replicate high pressure. Ultrasound is an in-situ and non-destructive technique that has been used for predictive maintenance and to measure wear or film-thickness. Recently, adding a matching layer improved the sensitivity of shear waves to liquids and thus led to new opportunities to measure lubricant viscosity using ultrasound. A high-pressure cell is instrumented with ultrasonic equipment. Several fluids are pressurized from ambient pressure up to 500 MPa. Ultrasound signals are acquired as well as temperature and pressure recordings. The impact of pressure on the ultrasound measurement is assessed.

9:40 am – 10:00 am

3998051: Experimental Analysis of Pasting of Brushed DC Motors

Roman Dzhafarov, Daniel Braun, Stephan Diez, BMW AG, München, Germany

Modern automobiles are equipped with many components in which DC motors are used. A possible failure mechanism in case of brushed DC motors can be so-called pasting. While operating the DC motor some carbon brush debris accumulates in the commutator's insulating air gaps. It clogs the slots with conductive carbon paste resulting in a loss of insulation resistance between the commutator segments. This phenomenon affects the motors efficiency and finally triggers the failure of the electric motor. The significant influencing parameters of this process are humidity, load regimes and the composition of the carbon brushes. The aim of this work is to derive the scientific understanding of the physical and contact mechanical phenomena behind the process of pasting as well as to show the interactions between the commutator, carbon and the used lubricants by different environmental conditions.

10:00 am – 10:30 am – Break

Session 1C • 101 D

Contact Mechanics I

Session Chair: Daniel Mulvihill, University of Glasgow, Glasgow, Scotland, United Kingdom

Session Vice Chair: TBD

8:00 am – 8:40 am

4004711: A Semi-Analytical Transient Model of Elastohydrodynamic Mixed Lubrication Bearings Under Electrical Loads

Robert Jackson, Jack Janik, Auburn University, Auburn, AL; Sudip Saha, University of North Dakota, Grand Forks, ND

In electric vehicles stray currents can occur due to leakages from the inverter transferring power from the batteries to the motor. These stray currents will seek to cross the fluid film in the rolling element bearings and gears. To cross the insulating lubricant film in the bearings. In so doing, an arc may form and damage the metal bearing surfaces. The current work presents a semi-analytical model of this using closed-form EHL models and modifying them for mixed lubrication and electrical contact. This is done by including a solid rough surface asperity contact model and a flow factor modified lubrication model. Transient effects are also included to consider changes in speed and other parameters during operation. The result is a model that is able to approximately predict the probability of surface damage and electrical properties of the bearings. The predictions are compared to testing and the damaged regions are in qualitative agreement.

8:40 am – 9:00 am

4012275: Contact Electrification-Induced Electroadhesive Axisymmetric Contact Model

Yang Xu, Hefei University of Technology, Hefei, China

Contact electrification (CE) is a universal phenomenon that occurs at the contact interface where tribo-charges transfer from one surface to another. These CE-driven charges can have a significant impact on the adhesive contact. However, these electrostatic charges are commonly ignored in the adhesive test. In the present work, a theoretical model is developed to study the CE-induced electroadhesive axisymmetric contact between a dielectric elastic parabolic surface and a dielectric rigid flat. Systems of non-linear equations are derived when two surfaces are in contact and separation phases, respectively. The results of the analytical model are validated by the recently developed full self-consistent numerical model. The effect of CE on the normal traction, interfacial gap, hysteresis loop and dissipated energy are quantitatively explored. The depth-dependent adhesive test is revisited using the analytical model to show that CE may also be a key factor for depth-dependent hysteresis.

TLT Meet and Greet

Make sure to stop by the STLE membership booth in the Convention Center foyer across from the Registration Desk and talk to TLT Editor Dr. Selim Erhan and TLT Publisher/Editor-in-Chief Rachel Fowler on **Monday, May 20** (9:00 am –10:00 am). They'd love to hear any comments, questions, or suggestions you have about TLT, the official monthly magazine of STLE.

9:00 am – 9:20 am

4004997: Thermoelastic Contact Simulation with Reciprocating Motion and Worn Surfaces

Shuangbiao Liu, Q. Jane Wang, Yip-Wah Chung, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Frictional heating results in temperature rise and thermoelastic deformation of contacting materials. The heat flux is the product of friction coefficient, pressure, and velocity, which can be constant or varying. Steady-state problems or transient cases with constant velocity have been studied extensively, but transient problems with time-dependent heat flux, such as that subjected to a reciprocating motion, have not previously been explored. Furthermore, worn surfaces involving roughness change and wear debris are inevitable; the latter phenomena have profound impact on temperature transients and local deformation and may provide deeper insights into asperity contact evolution. This work consists of numerical simulations of interfacial thermal field and thermoelastic contact with measured worn surfaces to reveal surface evolution under the reciprocating motion. The results provide better understanding of results derived from laboratory tests and actual tribological systems.

9:20 am – 9:40 am

3987354: Inside Sliding Contact: Relationships Between Third Body Formation and Contact Waves

Mathieu Renouf, Alfredo Taboada, Université de Montpellier, Montpellier, France; Francesco Massi, Sapienza University, Rome, Italy

The analysis of sliding contacts is complex because they are the site of many phenomena (elastic accommodation, dissipation, degradation) involving many different physical effects (mechanical, thermal, physico-chemical). Through numerical simulation at the interface scale, based on discrete element simulations, we focus on the dynamic behavior of dry contacts and more particularly on the initiation of shear. We analyze the generation and evolution of the third body and its impact on the contact waves evolving in the structure.

9:40 am – 10:00 am

4006032: An Investigation of Hertz Theory as Applied to Spinning, Bouncing Balls

Jeffrey Streator, Prairie View A&M University, Prairie View, TX

Hertzian contact theory, which has been around for more than a century, is predicated on quasi-static deformation mechanics. This aspect of Hertzian theory is worthy of note given that Hertzian contact theory, in particular, and (quasi-static) elasticity theory, in general, are routinely applied to bodies that are far from static. The question, arises, therefore, as to the degree of applicability of Hertzian theory to short-lived contacts. For the current work, the validity of Hertzian contact theory for contacts of short duration is investigated. Polished steel balls are dropped from varying heights above polished steel slabs at various spin rates. The spin behavior of the balls before, during, and after the impact is recorded. A mathematical model based on Hertzian contact theory is developed. Predictions of the model are compared to experimental results.

10:00 am – 10:30 am – Break

Session 1D • 101 E

Synthetic Lubricants and Hydraulics I

Session Chair: Ryan Fenton, BASF Corporation, Tarrytown, NY

Session Vice Chair: Paul Norris, Afton Chemical Ltd., UK, Bracknell, United Kingdom

8:00 am – 8:40 am

4000842: Hydraulic Fluid Performance Demonstrations According to ASTM D7721 – Energy Savings Validated with Shear-Stable, High-VI Technology

Ricardo Gomes, Frank-Olaf Maehling, Thilo Krapfl, Evonik Oil Additives, Darmstadt, Germany

The fluid power industry sees an increasing need for reliable energy-efficient solutions. The efficiency of hydraulic fluids can be quantitatively compared according to the ASTM D7721 practice that defines minimum technical requirements for conducting tests with two or more hydraulic fluids, whereby in particular the last revision of year 2022 also refers to real world investigations. Hydraulic applications in the mobile and stationary applications (i.e., excavators and injection molding machines), are described in more detail. Our publication discusses test procedures and results on such equipment with monograde and shear stable high VI hydraulic fluids. The selection of a high VI hydraulic fluid with proper viscosity and shear stability is critical to obtain optimum system response and guarantee high long-term performance. The experiments confirm that shear stable polyalkylmethacrylates are the most suitable VI improvers to formulate energy-efficient hydraulic fluids.

8:40 am – 9:00 am

4002669: Zn-Free Strategies to Meet Bosch Rexroth Hydraulic Performance

Joshua Dickstein, Ryan Konrad, The Lubrizol Corporation, Wickliffe, OH

In addition to transmitting power, hydraulic fluids are responsible for lubricating hydraulic pumps, motors, and other system components. One of the many performance demands on the fluid includes protecting pumps against excessive wear. The market is demanding improved performance from hydraulic fluids and the high pressure/speed Bosch Rexroth RFT-APU-CL pump/motor test is considered a benchmark for high performance hydraulic fluids. Antiwear protection is usually accomplished through addition of zinc dialkyl dithiophosphates (ZDDP) which form protective sacrificial layers in tribological contacts. Fluids lacking ZDDP antiwear components are often unable to provide sufficient tribological protection of the brass parts to meet the Bosch Rexroth pump test requirements. However, there is a growing demand for zinc-free fluids that can deliver the same level of performance. This paper will describe efforts to overcome these performance challenges with zinc-free hydraulic additive formulating.

9:00 am – 9:20 am

3983883: Performance of Novel & Sustainable Synthetic Ester Base Oils with Hybrid Functionality

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

Secondary Polyol Ester™ base oils are a new family of API Group V synthetic base oil. The versatility of this platform chemistry allows for the possibility of creating a very diverse range of novel hybrid base fluids and performance additives. It is possible to control many functional and environmental performance properties that are critical to lubricant performance by carefully choosing the synthetic precursors. The performance of a range of new biodegradable base oils across the ISO-32 to 460 viscosity range will be illustrated. Their impressive hydrolytic, shear and oxidation stability will be discussed. Concepts for using them as deposit control additives and friction modifiers in alternative base oils will also be highlighted.

9:20 am – 9:40 am

3991059: Technical and Scientific Perspective from Using Polyglycol on a Composition of Compressor Lubricants

Eduardo Lima, Dow Chemical Brazil, São Paulo, Brazil

Perspective from relevant dimensions attributed to polyglycol as a high-performance and differentiated synthetic base lubricant technology applied to compressor systems, exploring from the polyglycol synthesis process to the technical attributes.

9:40 am – 10:00 am

3998770: Energy Efficient Compressor Lubricants for Low-GWP Refrigerant Systems

Justin Kontra, Frank-Olaf Maehling, Evonik Oil Additives, Horsham, PA; Xin Ding, Eckhard Groll, Davide Ziviani, Purdue University, West Lafayette, IN

Approaches to improve the efficiency of positive displacement compressors have focused mostly on design and refrigerant choice, while the development of high viscosity index (VI) lubricants to boost performance remains underutilized. Ideal lubricants protect surfaces, enhance sealing at compression interfaces, improve efficiency, and are compatible with low-GWP refrigerants. To measure the impact of high VI lubricants in these systems – formulations containing shear stable poly (alkyl methacrylates) were evaluated. These lubricants combine high VI, compatibility with several classes of refrigerant, and robust thermal/oxidative and hydrolytic stability. On a hot gas bypass test stand, steady state data points were measured using transcritical CO_2 compressors. The fluids containing poly (alkyl methacrylates) and VI of up to 200 demonstrated strong performance over a wide range of operating conditions and viscosity grades, while maintaining high oil stability in the CO_2 environment.

10:00 am – 10:30 am – Break

10:30 am – 11:30 am

Synthetic Lubricants & Hydraulics Business Meeting

Session 1F • 101 G

Nanotribology I

Session Chair: Lang Chen, ExxonMobil, Annandale, NJ

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

8:00 am – 8:40 am

3997970: Invited Talk: Revealing the Structure-Property Relationships of Amorphous Carbon Tribofilms on Platinum-gGld Nanocrystalline Alloys

Frank DelRio, Tomas Babuska, David Adams, Ping Lu, John Curry, Brad Boyce, Sandia National Laboratories, Albuquerque, NM; Filippo Mangolini, Camille Edwards, The University of Texas at Austin, Austin, TX; Jason Killgore, National Institute of Standards and Technology, Boulder, CO

Platinum-gold (Pt-Au) nanocrystalline alloys have exhibited coefficients of friction as low as 0.01 and specific wear rates of about 10^{-9} mm^3 N^{-1} m^{-1}, largely due to the formation of carbon-based tribofilms. In this work, we examine the tribofilm structure-property relations via high-throughput and high-resolution measurements as a function of Pt-Au composition. As the Au solute content increased, average grain size decreased and grain boundary (GB) segregation increased, which translated to a decrease in modulus via a rule-of-mixtures approximation and an increase in hardness from GB stabilization. Moreover, steady state-friction and wear decreased with Au content; low Au-content films showed substrate wear, while high Au-content films showed stable tribofilm growth. Finally, the tribofilm bonding configuration and viscoelastic properties were found to be consistent with hydrogenated amorphous carbon films. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

8:40 am – 9:00 am

4006170: Atomistic Simulations of Chemomechanics at Electrified Interfaces

Aravind Krishnamoorthy, Texas A&M University, College Station, TX

Designing more efficient mechanical energy transmission across electric powertrains requires a deeper understanding of molecular mechanisms of reactivity and chemomechanics at electrified interfaces. We perform density functional theory calculations and reactive molecular dynamics simulations to understand the surface reactivity and evolution of tribolayers at in electrified and non-electrified contact. Specifically, atomistic simulations of polyalphaolefin (PAO) lubricants in contact with naturally-oxidized steel surfaces describe the decomposition of lubricant molecules leading to the formation of amorphous, non-protective FeC-rich tribolayers, which degrade upon mechanical loading. The formation of Fe-C bonds is enhanced by higher temperatures, presence of electric fields and reducing agents in PAO. Insights from these simulations can provide design rules for realizing more protective tribolayers that are stable under extreme conditions of friction, temperature and electrification.

9:00 am – 9:20 am

4001738: Chemical Absorption-Induced Hysteretic Friction Behavior of Supported Atomically Thin Nanofilm

Philip Egberts, Chaochen Xu, University of Calgary, Calgary, Alberta, Canada

The hysteretic friction behavior of supported atomically thin nanofilms with chemical absorption was studied using atomic force microscopy (AFM) experiments. Samples of graphene, h-BN, and MoS_2 exfoliated onto silicon wafers and chemical reagents such as ethanol and acetone were evaporated in the vicinity of the nanofilms. It was found that the surface friction of nanofilms was increased with the with absorption of the reagents. A correlation between the hydrophobicity of the evaporated solvent and the measured friction was observed, indicating the essential role of the chemical absorption in the 2D nanofilm/substrate in tuning the friction behaviors of supported 2D materials.

9:20 am – 10:00 am

4079115: Bridging Atomistic and Continuum Scales Simulations for the Modelling of Mechanochemical Interactions and Tribofilm Growth

Daniele Dini, Stavros Ntioudis, James Ewen, Imperial College London, London, United Kingdom; C. Turner, University of Alabama, Tuscaloosa, AL

Generally, the investigation of thin films over experimentally-relevant timescales (i.e., seconds, minutes, hours) becomes infeasible through standard low-level methods (e.g., ReaxFF/NEMD or DFT) and typically demands the use of a multiscale modeling framework. We have therefore recently developed a numerically efficient and easy-to-implement off-lattice kMC framework. The proposed hybrid off-lattice kMC/MD framework relies on predefined transition events, therefore relaxing the limitations associated with on-the-fly methods and unlocks the possibility for off-lattice kMC simulations on amorphous systems involving different elementary events (e.g. reactions, adsorption/desorption, diffusion) over experimental timescales (i.e., seconds, minutes, hours). The method is tested to study thermal decomposition (and film growth) of TCP molecules on FE surfaces. This study represents a crucial step towards the virtual screening of lubricant additives to optimize tribological performance.

10:00 am – 10:30 am – Break

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Session 1G • 101 H

Surface Engineering I

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

Session Vice Chair: Piash Bhowmik, University of North Dakota, Grand Forks, ND

Session Starts at 8:40 am

8:40 am – 9:00 am

4003937: Exploring the Tribological Behavior of Additively Manufactured Al-6061 Alloy for Space Applications

Pial Das, Sougata Roy, Iowa State University, Ames, IA; Matthew Mazurkivich, William Scott, Sara Rengifo, Marshall Space Flight Center NASA, Huntsville, AL

The use of additive manufacturing of Al6061 alloy provides additional freedom to fabricate custom parts with intricate geometries. Interestingly, the tribological performance of additively manufactured Al6061 components has remained relatively unexplored till date. In this study, we carried out a comprehensive investigation into the additive manufacturability and tribological performance of Al6061 alloy. Wire Arc Additive Manufacturing (WAAM) and Laser-Powered Direct Energy Deposition (LP-DED), two prominent metal AM routes were leveraged to fabricate test samples. Furthermore, TiC reinforced Al metal matrix composites (MMC) were developed with varied reinforcement percentages. Post fabrication, detailed microstructural characterization and tribological behavior in vacuum was conducted with detailed analyses of dominant wear mechanisms. This is the first time, an exhaustive discussion focusing DED and WAAM printed Al parts for space applications are presented in this study.

9:00 am – 9:20 am

4005694: Exploration of Spectrum Data from Non-Destructive Surface Roughness Measurement Techniques of Additively Manufactured Ti-6Al-4V

Robert Jackson, Loren Baugh, Samsul Arfin Mahmood, Kyle Schulze, Auburn University, Auburn, AL

Additive manufacturing is becoming an increasingly popular alternative for manufacturing high quality parts across a wide range of applications. A critical property that directly affects the fatigue life of an additively manufactured part is surface roughness. Understanding effective methods for characterizing surfaces and obtaining critical surface features that are responsible for catastrophic failures of the additively manufactured parts is critical to understanding their performance. Comparing different surface measurement techniques provides insight into the benefits and shortcomings of different working principles when representing a surface with scan data. It is important to identify what data is significant with respect to understanding specimen behavior, and an exploration of the spectrum of the scan data can be used to extrapolate additional potentially useful data even generating new data representing an area from a single surface profile.

9:20 am – 9:40 am

4043072: Physics-Informed Machine Learning to Improve Manufactured Surfaces

Tevis Jacobs, Lars Pastewka, Surface Design Solutions, Pittsburgh, PA

Surface topography controls the performance and reliability of surfaces in applications from automotive and aerospace to medical devices and consumer electronics. Yet too often our strategies to find the optimal surface finish rely on trial-and-error testing. While great strides have been made in the theory and simulation of roughness-dependent surface performance, it remains difficult to translate this into the design and control for manufacturing. Recently, significant advances have been made in the science-guided optimization of surface topography. First we will review the physical models that predict performance relevant to real-world manufacturing scenarios. Then we will present recent advances in the use of physics-informed machine learning to improve surfaces. The use of AI eliminates the dependence on traditional roughness parameters and enables the direct modification of key performance indicators such as production efficiency, product lifetime, and product performance.

9:40 am – 10:00 am

Open Slot

10:00 am – 10:30 am – Break

Session 1I • 101 J

Commercial Marketing Forum I

Session Chair: TBD

Session Vice Chair: TBD

8:20 am – 8:40 am

4084435: BYK Additives for Industrial Lubricants and Greases

Maximilian Boehmer, BYK-Chemie GmbH, Wesel, North Rhine-Westphalia, Germany

In the world of industrial lubricants, the effective management of foam, the improvement of grease viscosity and the stabilization of solid particles are key challenges. BYK proves to be a reliable supplier, offering a range of additive solutions for the lubricant sector. At the forefront of our offering are silicone and silicone-free defoamers that have been carefully developed to meet the requirements of all API classes. These defoamers are an indispensable tool to reduce foaming and ensure optimal performance in various applications. In parallel, BYK presents organoclays tailored to elevate the viscosity and stability of lubricating greases. Moreover, our dispersing additives stabilize solid particles such as graphite, MoS2, PTFE, and an array of other fillers within lubricating oils. From perfect particle dispersion to anti-sedimentation and maintaining viscosity under high loads, our solutions are precisely tailored to the diverse challenges encountered in the lubricants market.

8:40 am – 9:00 am

4093494: Chevron Phillips Chemical Company – Synfluid® PAO as a More Sustainable Solution

Ken Hope, Tom Malinski, Chevron Phillips Chemical Company, The Woodlands, TX

The sustainability needs of the world are driving enhanced focus on how products are made and used. To meet these needs, there are many new and developing applications where Synfluid® PAO can aid in energy and emissions reduction. These are typically based upon the physical property requirements of developing applications centered around the frictional properties and longevity of the fluid. This presentation will demonstrate the impact of PAO usage on energy reduction in the transportation and industrial sectors, which highlights the benefit side of the sustainability equation.

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1I

9:00 am – 9:20 am

4090696: DL Chemicals – Engineered Ethylene Propylene Copolymer System with High Performance Capability: Beyond Conventional OCP (Olefin copolymers)

Hoon Kim, DL Chemical Co. Ltd., Daejeon, Republic of Korea

Viscosity index is an empirical parameter indicating the resistance to viscosity change of a fluid with temperature variation. High VI is favorable as it means less thinning at high temperature. High VI can be achieved by addition of polymeric VM (viscosity modifiers). Although higher Mw is preferred for high TE (Thickening Efficiency) and high VI, higher Mw materials are more prone to the degradation under shear and are less shear stable. Because shear force tends to concentrate in the middle of the chain and so, the longer polymer chain is easier to break down. Shear stability is measured by viscosity loss after shearing. Along this line, DL Chemical has developed a series of engineered OCPs with high HTHS viscosity and excellent shear stability based on its unique metallocene catalyst technology that can control the key properties of the OCP system. In this presentation, we will introduce our latest OCP product along with its performances in terms of HTHS viscosity and shear stability.

9:20 am – 9:40 am

4091450: Colonial Chemical: Enabling the New-generation Metalworking Fluid Formulation

Steven Tang, Colonial Chemical Inc., South Pittsburg, TN

Many factors are shaping the new-generation metalworking fluids formulation. This presentation will examine those key factors and explore how to enable the performance expected for the next-generation metalworking fluids from additive perspectives.

9:40 am – 10:00 am

4093241: LANXESS – Hybase® GFX500: The Development of a Novel Incidental Food Contact Calcium Sulfonate

Ross Dworet, Lanxess Corporation, Shelton, CT; Wayne Mackwood, Jeremy Brideau, Lanxess Canada Co./Cie, Toronto, Ontario, Canada

LANXESS Application Technology performed a deep-dive study on what makes an ideal H1 CSC grease resulting in a next gen Overbased Calcium Sulfonate (OBCS), Hybase® GFX500, and platform. CSC Greases see wider adoption in the market including H1 versions requiring a high quality and performance OBCS. With 60+ years of OBCS and 20+ years in H1 CSC greases learning, LANXESS reexamined H1 grease formulations focused on emerging regulatory trends. The outcome, Hybase GFX500, a new performance OBCS, was developed to meet incidental food contact approval suitable to produce a high performance H1 finished grease. Compared to standard CSC grease, a grease thickened with Hybase GFX500 shows equal or better core performance combined with improved low temperature properties and improved oxidation life. LANXESS will demonstrate how it has leveraged its history in OBCS tech to develop the next-gen H1 OBCS offering superior performance while addressing evolving regulatory and performance challenges.

10:00 am – 10:00 am – Break

Session 1J • 200 DE

Electric Vehicles I

Session Chair: Cole Frazier, Southwest Research Institute, San Antonio, TX

Session Vice Chair: TBD

Session Starts at 8:40 am

8:40 am – 9:00 am

4003758: Testing Approaches for Developing and Validating EV Fluids

Flavio Sarti, TotalEnergies, Solaize, France

As new electric powertrain technologies continue to evolve, new and promising prospects for multi-functional EV fluids are emerging, which raises the question of how to develop and validate them. This work shows how TotalEnergies implements a novel testing approach that integrates traditional laboratory standards with in-house methods based on vehicle fleet tests and entire system rigs (2EM & 3EM configurations). This approach aims to shorten the testing time and improve the reliability of the results, by introducing a new and more representative level.

9:00 am – 9:20 am

4004847: Oil Immersed Energized Copper Circuit Board Test Understanding

Hitesh Thaker, Scott Campbell, Infineum USA L.P., Linden, NJ

The development of new generation hybrid and electric vehicles with oil-cooled motors has created the need of dedicated fluids with improved efficiency and material compatibility. Copper compatibility especially in an energized e-motor environment is gaining a lot of attention in the automotive industry. An energized copper corrosion test (ECT) has been developed to study the impact of e-fluids on energized copper surfaces. The test is still evolving with variation different parameters including temperature, time, copper board setup and stacking. Understanding the impact of these parameters is key to developing new test methods and screen e-fluid candidates with better copper compatibility.

9:20 am – 9:40 am

4005529: Shaft Voltage Causes Bearing and Lubricant Degradation

Simon Hausner, Flucon, Barbis, Germany

Induction or capacitive charge, especially in electric machines operated at high frequencies, causes potential differences in the bearings, which can lead to spontaneous discharge through the otherwise insulating bearing lubricant. These electrical breakdowns damage the surfaces of the rolling elements and the bearing shells, creating pitting, fluting patterns, and reducing the lifetime of electric drives. The bearing lubricants must act as a countermeasure to these effects. Lubricants must be developed to provide sufficient isolation in the EHD contact or make discharge impossible through increased electrical conductivity. Utilizing an isolated assembly to measure the electrical impedance of a loaded thrust bearing and evaluate lubricants' ability to conduct discharge currents depending on operating conditions, various lubricants and film thicknesses were tested; this generated, detected, and evaluated breakdowns in tribological films, correlating them with bearing damage and life.

9:40 am – 10:00 am

Open Slot

10:00 am – 10:30 am – Break

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Session 2A • 101 B

Tribochemistry II

Session Chair: Filippo Mangolini, The University of Texas at Austin, Austin, TX

Session Vice Chair: TBD

1:40 pm – 2:20 pm

3988134: Analytical Tribology With a High Resolution 6 Axes Tribometer

Julien Fontaine, Antoine Normant, Galipaud Jules, Frédéric Dubreuil, CNRS/Ecole Centrale de Lyon, Ecully Cedex, France

In order to better understand tribological phenomena, a traditional approach consists in performing some surface analysis inside and outside the wear tracks. These analyses are frequently structural or chemical, sometimes mechanical. In this work, we use a high-resolution environment-controlled tribometer, based on a six axes force sensor, to probe existing wear tracks on hydrogenated amorphous carbon (a-C:H) films. This original approach helps understanding the respective role of surface modifications on the a-C:H coated flat or on the facing steel pin on the achievement of superlow friction. These experiments are combined with more traditional analytical means, like in situ XAES or AES analyses or ex situ SEM or AFM observations. The growth of a carbon-rich tribofilm on the steel counterpart appears necessary but not sufficient to reach superlow friction. Changes on the topography and chemistry of the a-C:H film seems also paramount.

2:20 pm – 2:40 pm

4005299: Microscale Tribochemistry of Diamond-Like Carbon Coatings

Brian Borovsky, Maureen Bowen, Ana Colliton, Hind Flaih, Eskil Irgens, Lucas Kramarczuk, Griffin Rauber, Zachary Van Fossan, Jordan Vickers, St. Olaf College, Northfield, MN; Seokhoon Jang, Seong Kim, Pennsylvania State University, State College, PA; Zhenbin Gong, Junyan Zhang, Lanzhou Institute of Chemical Physics, Lanzhou, China

We present results from a study of sliding friction on hydrogenated diamond-like carbon (H-DLC). We load a stainless-steel microsphere onto a H-DLC surface coated onto quartz crystal microbalance (QCM). By resonating the QCM, we generate a reciprocating shear motion at the interface with track lengths of 1 to 100 nm and a frequency of 5 MHz. The QCM performs friction measurements with the normal load fixed at values between 5 μN and 1 mN. These measurements can be sustained even when a secondary lateral motion is superimposed using a piezo stage, with a track length of 20 μm and frequency of 40 Hz. Our results show that adding microscale sliding causes a substantial reduction in friction detected by the QCM, after which a transfer film is observed on the tip. We associate this with the "running-in" behavior of H-DLC and its shear plane chemistry. We explore relationships between the sliding distance, contact size, and the tribochemistry of the transition to low friction sliding.

2:40 pm – 3:00 pm

4003327: Selective Coating on Metal Surfaces with Friction-Assisted Electrodeposition

Yang Song, ChenXu Liu, Yonggang Meng, Tsinghua University, Beijing, China

Nanocrystalline FeCoNi alloys were selectively deposited on a specified zone of a GCr15 bearing steel surface from the nonaqueous electrolyte with a novel friction-assisted electrodeposition (FAED) process. The results revealed that the friction load and deposition time played a significant role in controlling the surface morphology and thickness of the deposits. A uniform element distribution on the cross-section of the deposited film was observed. Moreover, the as-deposited layer shows a matching mechanical property to GCr15 substrate including hardness and complex modulus. This work demonstrates that friction can provide fresh surface for crystal nucleation and eliminate "tip effect" for grain refine, meanwhile, the energy input from friction effectively promotes the reduction reaction. The monitoring of friction coefficient during FAED process can be used to estimate the stage of deposition layer growth.

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

4:00 pm – 4:20 pm

4001225: Friction and Wear Behavior of Gaseous and Volatile Fuels Using a Sealed Tribometer

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

The quest to reduce CO_2 emissions is leading to a transition from liquid hydrocarbon fuels such as gasoline and diesel to low carbon gaseous fuels such as methane, hydrogen and ammonia, as well increased use of gasoline/ethanol blends. In practical terms it is quite difficult to measure the tribological properties of these fuels; for gases because of containment issues and, for gasoline/ethanol blends, because they undergo selective evaporation and thus change composition during testing at elevated temperature. In this presentation we describe the use of a sealed tribometer, an HPR, to measure the friction and wear properties of both these classes of fuels. Based on the results obtained, the ability of these fuels to form tribofilms and their underlying mechanisms of action are discussed.

4:20 pm – 4:40 pm

3981340: Chemical Compatibility of Metal Oxide Nanoparticles and Lubricant Co-Additives

Imène Lahouij, Adam Nassif, Zhengyuan Peng, Frédéric Georgi, Pierre Montmitonnet, MINES Paris PSL Research University, Sophia Antipolis, France

Nanoparticles (NPs) have been extensively studied for their potential use for lubrication due to their promising tribological properties. However, the interactions between NPs and the lubricant additive package can be complex, leading to either synergetic or antagonist effects. This can in turn influence the composition and robustness of the tribofilms. Here, we attempt to better understand how specific properties of metal oxide NPs, such as size, chemistry and density influence their compatibility with commercial additives. Various formulations were prepared using three commercially available additives and two different metal oxide NPs. Tribological experiments were conducted at boundary regime using pin-on-disc tribometer. The chemical composition of the tribofilms and their mechanical robustness were evaluated using respectively XPS and in situ SEM micro-mechanical testing setup. In the light of these results, the interaction mechanisms between NPs and additives are discussed.

4:40 pm – 5:00 pm

4025582: The Effect of Lubricant Contamination with Water on Friction Modifiers Tribofilm Properties

Ardian Morina, Ajay Pratap Singh Lodhi, University of Leeds, Leeds, United Kingdom

The appropriate use of chemical additives in lubricants can mitigate the impact of friction and wear in mechanical systems. Under severe conditions, these additives undergo tribochemical reactions, creating a low-friction tribofilm. However, presence of water in lubricant adversely affects the tribofilm's growth and effectiveness. This study aims to: I.) analyse the chemical composition of the tribofilm both with and without water in real-time, and II.) study the effect of film growth on the dynamics of friction and wear. Several formulated oils containing organic (OFM) and inorganic (MoDTC) friction modifiers have been tested using a bespoke pin-on-disc tribometer integrated with Raman spectroscopy for real-time tribofilm analysis. SEM-EDS and FIB-TEM were also employed to obtain tribofilm chemical composition and thickness. The paper will discuss the effect of water contamination on tribofilm composition and its tribological performance relevant to the lubrication of hybrid engines.

Session 2B • 101 C

Tribotesting II

Session Chair: Damien Yiyuan Khoo, Bruker Nano Inc.,San Jose, CA

Session Vice Chair: Amani Byron, University of California, Merced, Merced, CA

1:40 pm – 2:20 pm

4002289: Recent Advances in Design and Development of Tribotesting for Electric Vehicle Lubricants

Damien Yiyuan Khoo, Melinda Bullaro, Bruker Nano Inc., San Jose, CA

The demand for new lubricants capable of withstanding the severe conditions in electric vehicle (EV) powertrains increases as the electric mobility gains its momentum. High starting torques, high speeds, and uncontrollable electrical currents passing through contact points create difficulties for EV lubricant testing. Conventional tribotesters are not developed for effective lubricant analysis in electrified environments. This study presents a modular benchtop tribometer equipped with a power source and a resistance data logger to evaluate the tribological performance of various EV lubricants under electrified conditions with varying sliding conditions. The findings suggest that the presence of electrical current at contact interfaces significantly affects friction, electrical contact resistance, and wear. Consequently, the electrified tribological testing methods explored in this study could potentially offer faster and more precise screening of electric/hybrid lubricants.

2:20 pm – 2:40 pm

3999049: Electrified Benchtop Tribology Grease Testing

Amani Byron, Ashlie Martini, University of California, Merced, Merced, CA; Tushar Khosla, Vishal Khosla, Rtec Instruments, San Jose, CA

Standard benchtop tests for grease tribology were modified to evaluate the effect of electric current on grease lubrication. Friction and wear performance with current were compared to results obtained using industry standards for commercially available electric motor greases. Then, test parameters were modified such that the benchtop conditions mimicked those in electric vehicle applications as closely as possible. Results were analyzed in terms of the effect of current on lubricant properties as well as the tribological interface itself.

2:40 pm – 3:00 pm

3999441: A Novel Approach for Tribological Evaluation of Textured Surfaces from Additive Manufacturing

Tobias Martin, Q. Jane Wang, Jian Cao, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Textured surfaces from laser powder bed fusion additive manufacturing (AM) possess unique tribological properties. Wear volume and steady-state friction are important characteristics; however, in boundary lubrication, material removal overlooks wear debris caught by surface texture and its effect on roughness parameters. Two measurements are proposed based on reciprocating ball-on-flat tribotests, affected and retained material, describing the amount of material participating in the contact and the portion of affected material remaining on the surface, as opposed to being removed. From this information emerge new avenues to understand how surfaces evolve. The results reveal, among other characteristics, that as-built AM surfaces readily retain wear debris, decreasing the wear track's maximum profile height and RMS slope. Though AM surfaces have more affected material than polished surfaces, this retaining behavior, with appropriate texture orientations, results in similar wear volumes.

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

4:00 pm – 4:20 pm

4004486: Correlating Wear Performance with Lubricant Properties of Real Used Heavy-Duty Diesel Engine Oils

Thomas Kirkby, Tom Reddyhoff, Imperial College London, London, United Kingdom; Joshua Smith, Jacqueline Berryman, Mark Fowell, Infineum UK Ltd., Abingdon, United Kingdom; Claes Frennfelt, Patrick Holmes, Volvo Group Trucks Technology, Greensboro, NC

Soot levels in engine oils have increased due to longer service intervals and the drive to reduce emissions. This leads to problematic wear of components, especially in heavy-duty diesel engines. We have previously revealed the soot wear mechanism for a single soot-containing used engine oil. Here, we conducted rubbing tests on 11 used, soot-containing heavy-duty engine oil samples from engine dynamometer and real-world field trials. Regression analysis was used to correlate the wear volumes with 55 oil properties. This showed the single most important oil property in predicting wear volume to be Total Acid Number, TAN (low TAN —> high wear). Low wear also correlated with soot particle size/circularity, suggesting an abrasive mechanism, and pre-test calcium concentration. The reasons for these correlations and the resulting insights into heavy-duty engine wear mechanisms will be revealed in the presentation.

4:20 pm – 4:40 pm

4088646: Threaded Fastener Joints: Friction Control with Soft Coatings

Sergei Glavatskih, KTH Royal Institute of Tribology, Stockholm, Sweden

Threaded fasteners are a key technology in aerospace, automotive industry, power generation, rail transport, etc. To ensure an optimum friction range and protect the bolts against corrosion, coatings are used. New environmentally friendly coatings (mostly zinc-based) that replace chromium VI containing ones may give rise to a larger variation and uncertainty in friction. For environmental reasons and competitiveness, industry is also adopting new fastener tightening techniques. These trends have led to new behavior in the torque tightening curves of threaded fasteners, further complicating an already uncertain picture in the use of this ubiquitous component. Friction in

the underhead contact dominates and, unfortunately, surface conditions in this contact are often overlooked. In this talk we show how a change in surface conditions (humidity, residues of cutting fluids, manufacturing method) may change friction behavior, affecting the clamp force and reliability of the joint.

4:40 pm –5:40 pm

Tribotesting Business Meeting

Session 2C • 101 D

Contact Mechanics II

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

Session Vice Chair: TBD

Session Starts at 2:20 pm

2:20 pm – 2:40 pm

3981100: A Multiscale Modeling System for Simulating a Radial Pump Plunger to Observe and Improve Tribological Performance

Henry Soewardiman, Shuangbiao Liu, Yip-Wah Chung, Q. Jane Wang, Northwestern University, Evanston, IL; Nikhil Murthy, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

The plunger-bore interface of a high-pressure radial fuel pump is critical for the efficient delivery of high-pressure fuel. This interface has a clearance of at most a few microns and is easily subjected to misaligned plunger motion. This misalignment prompts scuffing under marginal lubrication conditions. Presented here is a multiscale modeling system of the pump, aiming to understand and quantify the behavior at the interface during a pumping cycle. This system couples the system-scale plunger motion and pumping mechanism with a comprehensive analysis of critical rubbing conditions, including the impact of surface roughness and solid-solid contact. The plunger performance is evaluated through the film thickness, pressure, and leakage. Surface design schemes are proposed, and their impact on the pump performance are evaluated to support a robust and efficient plunger-bore interface.

2:40 pm – 3:00 pm

4011644: Design Improvement of Clearing Plate in a Biomass Comminution System through Contact Analysis

Lianshan Lin, James Keiser, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN; Chris McKiernan, David Lanning, Forest Concepts, Auburn, WA

The Crumbler rotary shear system was designed to achieve ideal feedstocks with small but equal sizes, which can improve flowability therefore to reduce costs and energy. Apart from improving the wear resistance of major components, accelerating the feedstock flow through the rotary shear machine plays an equivalent role in improving its efficiency and saving the cost simultaneously. This study focuses on optimizing the clearing plate in the Crumbler rotary shear system to enhance feedstock flowability and improve wear resistance. We employ analytical analysis and finite-element simulations to investigate the impact of surface curvature on contact pressure from wood particles. The optimized clearing plate is expected to extend its lifetime and enhance wood chips' flowability. Field tests with the newly designed clearing plates validate the advantages. The methodology and validation techniques offer valuable insights for addressing wear problems in similar static components.

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

4:00 pm – 4:20 pm

3991076: Exploring the Mechanics of Triboelectric Nanogenerators via In-Situ Experiments

Daniel Mulvihill, Charchit Kumar, Gaurav Khandelwal, Elias Bokedal, Nikolaj Gadegaard, University of Glasgow, Glasgow, United Kingdom

With the increasing use of sensors and self-powered devices, the need for sustainable and distributed power sources has become increasingly high. In this regard, a new energy harvesting technology, based on triboelectric nanogenerators (TENGs), is emerging. Lately, TENG research has grown considerably, but the fundamental governing mechanisms are still not fully understood. In this work, nominally flat rough surfaces were fabricated using micro-molding techniques. A bespoke test rig was developed, based on repeated contact-separation mode, to concurrently measure the electrical signal, contact force, and contact area. Tests were performed to investigate the contact area and load dependent electrical response. Automated image analysis macros were developed to process the contact interface images. The comprehensive electro-mechanical investigation results provide an improved understanding of tribo-electrification in TENGs at a small scale and a correlation with localized contact areas.

4:20 pm – 4:40 pm

4015264: Influence of Poroelasticity and Unloading Rates in Enhancement of Gel Adhesion

Wonhyeok Lee, Melih Eriten, University of Wisconsin-Madison, Madison, WI

Hydrogels, polymeric networks swollen with water, exhibit time/rate-dependent adhesion due to their poroviscoleastic constitution. In this study, we conduct probe-tack experiments on gelatin and investigate the influence of water drainage and unloading rate on pull-off forces and work of adhesion. We also utilize in-situ contact imaging to monitor separation kinematics and interfacial crack speeds. At maximum drainage and unloading rates corresponding to subsonic interfacial crack speeds, we observe an order of magnitude enhancement in adhesion. Through relaxation tests, we identify a quick viscoelastic relaxation response followed by a slow poroelastic relaxation regime. We then explore the links between gels' relaxation response to the observed adhesion enhancement and discuss those findings with prior research on poroviscoelastic fracture and adhesion of various materials and existing models. The results could assist better design of bio-adhesives and tissue scaffold interfaces.

4:40 pm – 5:40 pm

Contact Mechanics Business Meeting

Session 2D • 101 E

Grease I

Session Chair: Cindy Liu, Dow Chemical Company, Midland, MI
Session Vice Chair: Lu Fang, Tesla, Redwood City, CA

1:40 pm – 2:20 pm

4005474: Recipes for Success: The Impact of Various Promoter Systems on Calcium Sulfonate Complex Grease Performance

Joseph Kaperick, Darryl Williams, Afton Chemical Corporation, Richmond, VA

The use of calcium sulfonate thickener systems has become increasingly popular due to recent market dynamics such as availability, pricing and labelling concerns of lithium-based soaps. While calcium sulfonate thickener systems offer enhanced performance, ingredients and recipes for making this class of thickener are varied and finding the optimal solution for a given application can be very complicated. In this study, various promoters were used to create greases from 300 TBN overbased calcium sulfonate detergent and the impact on finished grease performance was evaluated using a variety of different bench tests.

2:20 pm – 2:40 pm

3986417: An Improved Model to Describe Oil-Separation Properties of Lubricating Greases

Femke Hogenberk, Dirk Van Den Ende, Matthijn de Rooij, University of Twente, Enschede, Overijssel, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

The complex process where base oil is released from a lubricating grease to lubricate the contacts in a bearing (i.e., bleeding) is still not fully understood. For instance, its relation to the properties of the grease remains unclear. In this work, a model is presented to describe the process of bleeding on a porous medium. This model is based on several grease properties that are expected to be relevant to this process, e.g., the permeability and elasticity of the thickener matrix and the thickener-base oil affinity. Experiments were carried out to capture the flow of base oil from a grease sample into a piece of blotting paper. This was done for one type of grease with varying amounts of base oil. A comparison between experimental results and the presented model shows the ability of this model to describe the bleeding process.

2:40 pm – 3:00 pm

3981847: Tribology and Grease Lubricated Ball Bearings

Piet Lugt, Sathwik Chatra K R, Nicola De Laurentis, SKF Research and Technology Development, Houten, Netherlands

During the last decade great progress has been made in understanding the lubrication mechanisms in grease lubricated bearings. In this presentation we will give an overview of the model development in this area such as on the effect of churning on grease life, grease bleed and degradation, oxidation and the concept of "minimum" grease life.

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

4:00 pm – 4:20 pm

3983353: Controlling Micropitting on Wind Turbine Main Bearings

Marc Ingram, Thomas Baldwin, Ingram Tribology Ltd., Carmarthen, United Kingdom; Karl Petersen, Debottam Bose, Troels Moeller, Siemens Gamesa Renewable Energy A/S, Brande, Denmark

The main bearing of a wind turbine can sometimes exhibit a localized micropitting damage. Here we develop a test method to evaluate the ability of a grease to reduce micropitting, emulating the likely conditions at the wind turbine main bearing contact. We investigate the performance of the greases under three different conditions by varying the contact pressure and slide/roll ratios. We also investigate the effect of the greases on artificially generated dimples. These dimples emulate the occurrence of dents which can occur on bearings and act as initiation sites for further damage. We find that micropitting can occur around the edges of the dimples and greases can reduce this occurrence – helping grease manufacturers develop new products and wind turbine operators to select better performing products to increase reliability and wind turbine up-time.

4:20 pm – 4:40 pm

3980531: Fast Screening of Wear Regimes in a Four Ball Setup

Lais Lopes, Dirk Drees, Pedro Baião, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium

A fast-screening method is developed in four ball setup, to evaluate wear regimes more efficiently. Current ASTM methods require running multiple short tests over a range of loads. In this presentation, we show an alternative approach by an automated method. How to evaluate the results of this method, how parameters can be fine-tuned to suit ranges of products, and what new insights can be gained, are the results of this research. The level of correlation with other test methods is also examined. The method is initially focused on detecting the seizure regime, because once a lubricant enters this regime, all lubricating functionality is los in a normal application. Some indications to extend the method to the catastrophic failure range, called weld load, are made, but the real discussion is whether this weld load has any practical value. This approach intends to provide the additives and lubricants industry a new method to continually check and improve quality and performance.

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Session 2F • 101 G

Nanotribology II

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

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

1:40 pm – 2:20 pm

4005864: Invited Talk: Coatings That Manufacturing Themselves: Formation, Interface Transfer, and Performance of Tribosintered Metal Oxide Coatings

Robert Carpick, Parker LaMascus, Nwachukwu Ibekwe, Daniel Delghandi, Andrew Jackson, University of Pennsylvania, Philadelphia, PA; Pranjal Nautiyal, Oklahoma State University, Stillwater, OK; Gordon Lee, ExxonMobil, Annandale, NJ; Tobias Gellen, Robert Wiacek, Pixelligent LLC, Baltimore, MD

Metal oxides typically require temperatures above 1000°C to form solids. Metal oxide nanocrystals dispersed in lubricants can sinter at room temperature under tribological stress. The solid, surface-bound coatings formed prevent wear, scuffing, micropitting, and macropitting. We will discuss tribosintering mechanisms, reviewing its occurrence across many nanocrystals, substrates, co-additives, and tribological conditions. We will then discuss the coatings' durability when run in nanocrystal-free lubricants using a ball-on-disc tribometer with in situ film thickness measurement. Coatings made from multiple nanocrystals, including ZrO_2 and TiO_2, remain durable for 8 hours under boundary contact conditions that would otherwise cause scuffing. Further, when one surface is uncoated, transfer to the that surface occurs, which further increases the surface-protecting potential of these nanocrystals. We will discuss the mechanism of adhesive transfer and how it affects coating performance.

2:20 pm – 2:40 pm

4029106: Surface Oxide Layers Dictate Interfacial Adhesion of Cold-Sprayed Bulk Metallic Glass Single Particles

Frank DelRio, Michael Kracum, Ping Lu, Ian Winter, Michael Chandross, Thomas Hardin, Sandia National Laboratories, Albuquerque, NM

Cold spraying (CS) is a solid-state deposition process where microscale powder particles are accelerated at high speeds towards a substrate via expansion of a preheated gas through a diverging-converging nozzle. In this talk, we present an experimental and numerical study on the adhesion of CS bulk metallic glass (BMG) single particles on aluminum and steel substrates. On both substrates, it was found that the surfaces consisted of single particles and empty craters, with microstructural gradients across the particles. The coefficient of friction and adhesion energy were 0.24±0.02 and 35.4±3.3 MPa for the BMG-aluminum pair and 0.37±0.04 and 262.3±29.6 MPa for the BMG-steel pair, respectively. Molecular dynamics simulations showed that the change in adhesion was most likely due to differences in substrate oxide thickness and yield strength, but not due to variations in substrate density and mixing enthalpy. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

2:40 pm – 3:00 pm

4004615: Observing and Modeling the Wear Process of Heterogeneous Interface

Xin Tang, Tianbao Ma, Tsinghua University, Beijing, China

Understanding the wear process of heterogeneous interface between hard and soft phase is important to the fabrication of materials, such as improving the wear resistance of particle reinforced metal matrix composites and the accuracy of chemical mechanical polishing. However, the wear process can be hardly observed as the heterogeneous interfaces are usually buried under the surface. Here, we proposed a nanowear test method by combining the focused ion beam to expose the heterogeneous interface, atomic force microscopy to simulate an single asperity, and scanning electron microscope to characterize the wear evolution and interfacial damage. Three typical wear forms have been observed, i.e., merely matrix wear, particle fracture and particle pull-out. We found the increasing interfacial friction force would induce particle wear mechanism transition to fracture or pull-out, depending on the particle edge angle, tip edge angle, and the force required to pull out the entire particle.

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

4:00 pm – 4:20 pm

4001677: Nanolubricants for Increasing the Lifetime of Machine Elements and Cutting Tools for Machining Processes

Laura Pena-Paras, Demófilo Maldonado-Cortés, Martha Rodríguez-Villalobos, University of Monterrey, Nuevo Leon, San Pedro, Mexico

Machining is a commonly used manufacturing method in the metal-mechanic industry. Different approaches for cleaner production have been used to reduce wear along with the energy consumption of the process and increase the quality of the workpiece. For example, nano-particles have been explored as additives for lubricants for friction reducing and load bearing purposes. Laboratory studies performed have demonstrated significant enhancements in tribological properties of lubricants additized with nanoparticles. In this talk, recent studies by our group are presented showing the effect of adding nanoparticles into lubricants in the lifetime of machine elements and cutting tools for machining processes. Statistical methods were used to optimize the nanoparticle concentration in the lubricant. Results showed that the output parameters were significantly enhanced by adding nanoparticles to the lubricant, which can impact the efficiency of the manufacturing process and reduce costs.

4:20 pm – 4:40 pm

4002106: Analytical Friction Models for Molecular Adsorbates

Wilfred Tysoe, University of Wisconsin-Milwaukee, Milwaukee, WI

Atomic-scale nanoscale friction models, based on ideas from Tomlinson and Prandtl, conventionally use simple periodic sliding potentials to model the velocity and temperature dependences of the friction force, for example, as measured in an atomic force microscope. However, this approach is not well suited to describing the friction of adsorbed molecular overlayers, for example, self-assembled monolayers (SAMs) and of more complex potential energy surfaces. This is addressed by developing analytical models for more complex systems. In the first approach, we use the ideas of Evans and Polanyi, which develops a thermodynamic theory to analyze stress-dependent reaction rates and also use a simple model interaction potential between the tip and the outer surface of the organic substrate to develop analytical models for

molecular friction of self-assembled monolayers (SAMs) on surfaces, so-called friction modifiers.

4:40 pm – 5:00 pm

3998763: Molecular Dynamics Analysis of Polymer Friction in Heterogeneous Surface

Hitoshi Washizu, Kazuki Ito, Masaki Hayama, Yudai Ogawa, Tomohiro Kinjo, University of Hyogo, Kobe, Hyogo, Japan; Yuji Higuchi, Kyushu University, Fukuoka, Japan

Although friction and wear of polymer is interesting topic, less knowledge are obtained. This is because polymer have high structure, for example not only amorphous but crystal phase. In this talk we show recent analysis using molecular dynamics simulation to understand friction of polymers. Not only amorphous but crystal structure is prepared to understand the phenomena. Scanning the surface by metal ball, we can distinguish the friction and wear dynamics on each surface due to the sliding condition. Then hard particle such as carbon nanotubes are added to increase the surface strength. With the addition of nanotubes, the friction coefficient decreased which is consistent with the experiment. We also investigate the friction dynamics with bulk properties such as viscoelastic modulus.

5:00 pm – 6:00 pm

Nanotribology Business Meeting

Session 2G • 101 H

Surface Engineering II

Session Chair: Wenbo Wang, Oak Ridge National Laboratory, Oak Ridge, TN

Session Vice Chair: TBD

1:40 pm – 2:00 pm

4003750: Enabling High-Performance Surface of Biodegrade WE43 Magnesium Alloys via Laser Shock Peening

Wenbo Wang, Oak Ridge National Laboratory, Oak Ridge, TN; Wenjun Cai, Virginia Tech, Blacksburg, VA

Magnesium (Mg) alloys are promising candidates for use as degradable implant materials. However, the fast degradation of Mg alloys in physiological environments makes it challenging to ensure their structural integrity and adequate strength over the required time for complete tissue and bone healing. On the other hand, high surface friction and wear debris formation in load-bearing implants can produce an undesirable reaction. Hence, an effective method that optimizes the tribocorrosion resistance of Mg alloys is needed. In this study, the effects of nanosecond and femtosecond laser shock peening (LSP) techniques on the surface properties of WE43 Mg alloys under different treatment conditions and the resulting tribocorrosion behavior of WE43 Mg were investigated in simulated vivo physiological conditions. Materials characterization is combined with finite element simulations to reveal the beneficial effects of LSP.

2:00 pm – 2:20 pm

4002591: Application of LST on Cutting Inserts Used in CNC Machining of Aluminum Alloys to Increase Their Performance

Demófilo Maldonado-Cortés, Laura Pena-Paras, Renata Cruz Olace, Fabiola Alvarez del Bosque, Ana Paola Castillo Barraza, Universidad de Monterrey, San Pedro Garza Garc, Nuevo Leon, Mexico

In this investigation a method to increase wear performance of form drills used in CNC turning of aluminum alloys was studied. Two form drills were compared, one with LST and one without LST in order to find out if the application of laser surface texturing of these tools enhances their wear performance. The LST was applied as an array of micro-dimples with a 0.2 mm diameter, 100 µm of depth and a distance between each circle of 0.4mm. An increase of 80.11% of wear resistance was achieved.

2:20 pm – 2:40 pm

4004786: Understanding the Correlation Between Surface Topology and Lubrication Performances of Quasi-Random Nanostructure Surfaces by Using Deterministic Lubrication Models

Hongwei Zhang, Chicheng Ma, Chengjiao Yu, Hebei University of Technology, Tianjin, China; Shuangcheng Yu, Xingyi Metal Group, Haining, China

Surface topology has strong influences on the tribological performances of engineering surfaces such as contact, lubrication and adhesion. Researching mainly the effects of various periodic structures or randomly distributed surfaces. Quasi-random nanostructures (QRNS) surfaces, which were inspired by nature, have attracted interests in many research fields, because their possibilities to be self-assembled for scalable manufacturing. We numerically generated the QRNS by spectral density functions, and utilized an EHL model to characterize the lubrication performances of the QRNS surfaces under point contact condition. The influences of applied load, velocity, and lubricant viscosity on the EHL performance of various rough surfaces were investigated. Further, validation of results using CFD modeling. It was concluded that QRNS surface showed the optimal EHL performance among all the surfaces studied which might due to its unique topology connectivity and lubricant retention capabilities.

2:40 pm – 3:00 pm

4001578: A Novel Approach to Lubrication – Interactions Between Gadolinium-Doped DLC Coatings and Phosphorus-Based Ionic Liquids

Takeru Omiya, Albano Cavaleiro, Fabio Ferreira, University of Coimbra, Coimbra, Portugal; Filippo Mangolini, The University of Texas at Austin, Austin, TX

Improved approaches for friction and wear management could lead to dramatic reductions in greenhouse gas emissions. Among the materials, diamond-like carbon (DLC) coatings for their wear resistance and phosphorus-containing ionic liquids (ILs) for their friction reduction properties have attracted considerable attention. In this study, DLC coatings deposited by high-power impulse magnetron sputtering were doped with the rare earth metal gadolinium (Gd-DLC) and their sliding lubricity was evaluated in the presence of three different phosphorus-containing ILs. The test results showed a significant reduction in wear rate of approximately 80% when two different ILs were used. In addition, post-test wear tracks were observed using advanced surface observation equipment such as XPS and ToF-SIMS, which revealed details of the interaction between the ILs and the Gd-DLC coating. This comprehensive study is expected to lead to further optimization of the lubrication system design.

2G

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

4:00 pm – 4:20 pm

3987454: The Influence of Geometry and Test Conditions on Lifetime and Endurance of Solid Film Lubricants. Testing Strategy and Data Production Method Enabling AI?

Lais Lopes, Pedro Baião, Dirk Drees, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Nathan Pekoc, Everlube Products, Peachtree City, GA

Solid film lubricants are commonly evaluated with a few key standard methods, such as ASTM D2625, D2714, D2981, in a variety of pressures and motion profiles. Often these tests don't reveal a relationship between industrial operating conditions and the test method. In this work, selected solid film lubricants are subjected to different testing conditions, illustrating optimization of the formulation to operating conditions is possible, given enough know-how and experience both in formulation and in testing conditions. While some coatings are more suitable to high-speed unidirectional contact conditions, others can be more suitable for one-time fasteners, or for reciprocating test conditions. Further, the potential for a more efficient data production method is illustrated, opening the way for better statistics and data management, perhaps even AI analysis into structure-property relationships.

4:20 pm – 4:40 pm

4004606: Structure and Friction Performance of Sulfonitrocarburizing Layer Prepared by Plasma Nitrocarburizing and Low Temperature Ion Sulfurizing

Zhehao Zhang, Tsinghua University, Beijing, China

During plasma nitriding, a portion of the iron particles sputtered from the substrate combined with nitrogen to form iron nitride and cover the surface of the sample, giving the treated sample a gray appearance. In this work, ion sulfurization was intended to combine with plasma nitrocarburizing to form a sulfonitrocarburizing layer on 38CrMoAl. The samples treated with nitrogen, carbon, and sulfur at the same time showed violent COF fluctuations and poor wear resistance during the friction process. A dense and anti-friction sulfonitrocarburizing layer was prepared by plasma nitrocarburizing and then low temperature ion sulfurizing. Through process optimization, the sulfurizing layer achieved a balance between the anti-friction effect and the binding force. The composite structure of FeS polycrystals, sulfur-containing nanocrystals, and a nitrocarburizing layer made the sulfonitrocarburizing layer show an excellent anti-friction effect and wear resistance.

4:40 pm – 5:00 pm

4075913: Preparation of Thin-Film Transistors by Surface Energy-Directed Assembly

Jingwei Zhang, Tsinghua University, Beijing, China

The application of current processes to fabricate metal oxide patterns is hindered by their high cost, low resolution, low pattern fidelity or low throughput. To overcome these problems, surface energy-directed assembly (SEDA) process with a high applicability and a high efficiency is developed. Plasma treatment can generate a large number of hydroxyl groups on the surface of the substrate to form a hydrophilic surface, after photolithography, self-assembly monolayer (SAM) film was deposited on the patterned substrate using a chemical vapor deposition process to introduce hydrophobic groups. After removing the remaining photoresist, the photoresist protected hydrophilic pattern regions were exposed thereafter, realizing the fabrication of the functionalized substrate. Selective adsorption of metal oxide precursor solutions can be achieved using the substrates, metal oxide patterns is made after drying and post-treatment process. TFTs and even gate circuits can be prepared on this basis.

5:00 pm – 6:00 pm

Surface Engineering Business Meeting

Session 2I • 101 J

Commercial Marketing Forum II

Session Chair: TBD

Session Vice Chair: TBD

1:40 pm – 2:00 pm

4084491: Optimol Instruments – Diversity of Tribological Testing with Optimol Instruments From Standard to Innovative Methods

Ameneh Schneider, Optimol Instruments, München, Germany

Optimol Instruments, headquartered in Munich, is an international leader in the manufacturing of tribological test systems. For more than 50 years, Optimol Instruments has been a trusted partner to customers with innovative technology, field-proven solutions, expert advice, and comprehensive services directly from Germany. As a technology leader with a strong practical orientation, we offer a wide range of fully developed lab scale test scenarios for tribological phenomena with high practical relevance. Comprehensive automation solutions offer advantages in terms of efficiency, cost-effectiveness, and quality assurance, giving our customers a significant advantage in the marketplace. In 2023 Optimol Instruments has invented the first H2-Tibocell for tribological testing under hydrogen atmosphere successfully. The presentation will show the audience various application examples from diverse sites of tribology – in everyday life to electrical vehicle, water-based coolants and much more.

2:00 pm – 2:20 pm

4088994: Functional Products: Everything You Need to Know About PPDs From Functional Products

Mike Woodfall, Functional Products, Macedonia, OH

Functional Products routinely works closely with customers to determine the best pour point depressant technology for their formulations. Every lubricant is unique, and with more novel base oils on the market, improving low temperature performance can be challenging. Whether you are formulating with mineral oils, synthetics, re-refined, or biobased base oils, come spend 20 minutes to gain an understanding of our products and the especially processes we use to improve low temperature performance of specialty lubricants.

2:20 pm – 2:40 pm

4091111: The Lubrizol Corporation – Improved Microbial Control for Metalworking Fluids

Gabe Kirsch, The Lubrizol Corporation, Wickliffe, OH

While the need for effective biocontrol in metalworking fluids is well established, legacy fungicide chemistries are known to have certain shortcomings, such as insoluble salt formation and inferior fluid concentrate stability. The relatively high cost of registering improved fungicides has also limited the expansion of user options in this market

space. As a solution to these concerns, Lubrizol has introduced CONTRAM™ MB7188, a highly concentrated, low dose fungicide based on BBIT (N-butyl-1,2-benzisothiazolin-3-one). Our talk will discuss features of this new product, including its benefits over incumbent technologies.

2:40 pm – 3:00 pm

4094102: Biosynthetic Technologies – Estolide Technology for Sustainable and High-Performance Lubricant Technology

Matthew Kriech, Biosynthetic Technologies, Indianapolis, IN

Biosynthetic® Technologies has developed a revolutionary new class of high-performance bio-based base-oils oils and additives for the lubricant and metalworking fluid markets. These novel sustainable additives use the patented Estolide technology and are biobased, biodegradable, non-bioaccumulative, and non-toxic. The Estolides provide exceptional performance with superior lubricity, film strength, biostability, hydrolytic stability, oxidation stability, and increased polarity on both ferrous and non-ferrous alloys. Estolides are synthetically produced natural feedstocks and have undergone a 3rd party audited life cycle assessment showing the benefits to carbon footprint reduction and sustainability. This 20-minute session will be a must for anybody looking to develop a sustainable, high-performance, metalworking fluids or lubricants.

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

4:00 pm – 4:20 pm

4088042: Advancion Corporation – Advancion – A New Name, A Fresh Approach, A Trusted Partner

Michael Lewis, Advancion Corporation, Buffalo Grove, IL

For over 80 years, Advancion has practiced the commercial process of propane nitration to manufacture unique additives used in a wide range of end markets. As market drivers have evolved in that time, so has our portfolio of functional additives supporting metalworking fluid applications. In addition to product portfolio expansion, Advancion's commitment to sustainabilty has also evolved as assessed by independent evaluators such as Ecovadis. The audience will learn how Advancion's purposeful development across market segments enables innovation, fuels quality improvement, and accelerates application knowledge in today's dynamic marketplace to refresh and remain relevant in modern metalworking formulations.

4:20 pm – 4:40 pm

4095966: Evonik – VISCOPLEX Products for Emulsion Retention in Engine Oils

Matthew Hauschild, Rhishikesh Gokhale, Evonik Oil Additives, Horsham, PA

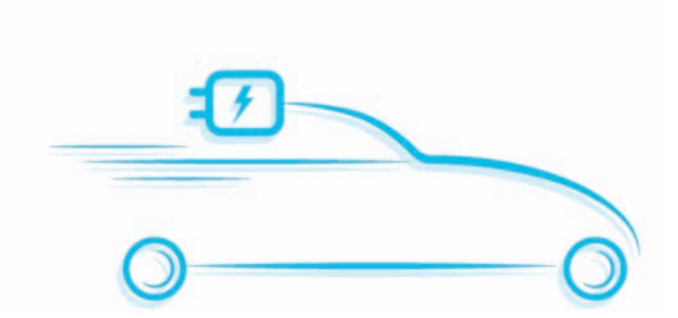
Production and adoption of hybrid electric vehicles is increasing globally, in addition hydrogen powered engines are progressing towards production in key vehicle segments. Oils in these engines will experience increased amounts of water as the result of lower operating temperatures and from hydrogen as a fuel. As a result, emulsion properties of oils will become increasingly more critical to the performance and protection of the engines of hybrid vehicles. Evonik VISCOPELX products can provide a solution to this growing market need.

4:40 pm – 5:00 pm

4094277: ExxonMobil – SpectraSyn™ Base Stocks: Elevating Group II Base Stocks to Meet High Performance Specifications

Manish Patel, ExxonMobil Chemical Company, Spring, TX

The automotive industry is facing challenges to meet increasingly higher performance demands. New low viscosity, low volatility (LVLV) base oil technology is required to address next generation engine oil formulation specifications such as API and ACEA or specific OEM requirements. While all Spectrasyn™ base stocks can improve performance, the LVLV PAO technology platform of SpectraSyn™ MaX 3.5 is unique in synergistically boosting the low temperature and low viscosity performance of group II and II+ base stocks. With this boost in performance, LVLV PAO increases formulation options for next generation lubricants. This presentation will demonstrate how SpectraSyn™ base stocks can elevate group II base stock performance to meet increasing specifications and expand base oil formulation options.



Session 2J • 200 DE

Electric Vehicles II

Session Chair: Thomas Wellmann, FEV, Auburn Hills, MI

Session Vice Chair: Andrew Velasquez, Southwest Research Institute, San Antonio, TX

1:40 pm – 2:20 pm

4004397: Efficient Shear Stable Thickeners for the Heavy-Duty EV Market – Theory, Application, Proof

Alexei Kurchan, Cargill Inc, Plainsboro, NJ; Kevin Duncan, David Gillespie, Cargill, Snaith, East Yorkshire, United Kingdom

Transmission fluids for light duty EVs trend ever lower in viscosity, however the high torque operating environment of heavy-duty EV powertrains will present much more severe operating conditions. This will place different demands on the fluid and require the use of thicker lubricants to prevent wear and maintain adequate lubrication. High viscosity (HV) thickeners are an efficient way to formulate fluids that meet these requirements. In this paper, we will show how design of experiments methodology can be used for new product development to prioritize R&D work and target desired product properties. The model that was developed was then used throughout the NPD process to aid process development and increase understanding. The performance of the HV thickeners will be demonstrated in benchtop tribological testing and confirmed in industry standard efficiency rig testing. Connecting product development to rig testing enables high quality structure-performance conclusions to be drawn.

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2:20 pm – 2:40 pm

4003572: The Energy Efficiency Improvement Effect of Low Viscosity Engine Oil with MoDTC in a Large Displacement Engine

Kenji Yamamoto, Ryo Hanamura, Koichi Takano, Shinji Iino, ADEKA Corporation, Tokyo, Japan

Recent studies on energy efficiency improvement with gasoline engine oil, achieved through viscosity reduction and the incorporation of effective friction modifiers (FM), have predominantly focused on 1.5 to 4-liter engines. While investigating the influence of viscosity and FMs in several engines with approximately 2-liter displacements, the authors have confirmed the impact of MoDTC-formulated low and ultra-low viscosity engine oils in enhancing energy efficiency. Conversely, it has also been observed that excessive viscosity reduction can lead to increased friction loss in certain engines. In this study, the effects of viscosity reduction and MoDTC in a large engine with over 5 liters of displacement, typically operated with engine oils of relatively high viscosity, were examined. While a negative impact of excessive viscosity reduction has been clearly identified compared to previous engines, a significant improvement in energy efficiency due to MoDTC has also been observed.

2:40 pm – 3:00 pm

3976801: Lubricants Requirements for Electrified Heavy Duty Drive Trains

Torsten Murr, Shell Global Solutions Deutschland, Hamburg, Germany

With the ongoing drivetrain electrification in the on-highway area, OEMs and manufacturers need to develop efficient & integrated EDUs. Zero emission vehicles were released by various OEMs. Different e-motor concepts are introduced to the market. For dry e-motors, where the copper parts are separated from the gearset, conv. GL-4/5 technologies can be used. For wet e-motors, where e-motor and reduction gear share one oil circuit, dedicated fluid are required. This allows more efficient, compact and integrated e-motor solution with one fluid. Important is that e-axles won't be compatible with conv. axle fluid. The high content of sulfur containing AW & EP additives, which are required for GL-5/SAE J2360 performance levels, are not compatible with the copper parts of the electric motor and can cause corrosion or electrical shortcuts. The wear protection of the gearset has to be balanced carefully to ensure the compatibility with the electrical parts. This requires innovative fluid concepts.

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

4:00 pm – 4:20 pm

4004779: Thermal Conductivity Enhancement of EV Fluids by Carbon Nanotubes

Chanaka Kumara, Harshvardhan Singh, Wenbo Wang, Jun Qu, James Haynes, Hsin Wang, Oak Ridge National Laboratory, Oak Ridge, TN; Ning Ren, Jacob Bonta, Edward Murphy, Roger England, Valvoline Global Operations, Lexington, KY

Carbon nanotubes (CNTs) have excellent thermal conductivity (TC) but tend to aggregate and precipitate when mixed into oil due to their poor suspendability. We utilized organic surface modification techniques to improve CNTs suspendability in non-polar electric vehicle (EV) base oils. CNTs were able to successfully suspend in a EV base oil at room temperature and 100oC using a combination of surface modification and dispersant. The CNT dimensional properties (length and diameter) and concentration appear to influence TC. Although the base oil TC is improved with increased CNT concentration, the oil viscosity also increases simultaneously, which will negatively impact the heat transfer efficiency. Surface-modified CNTs had less effect on the oil viscosity compared to the unmodified CNTs. By selecting the appropriate combination of CNTs and surface modification, we were able to improve the EV base oil TC by 8-12% after adding only 0.025 wt% of CNTs with little change to oil viscosity.

4:20 pm – 4:40 pm

4004696: Beyond the Battery – A Holistic View of Thermal Management Fluids in BEVs

Gareth Brown, Lubrizol Ltd., Hazelwood, Derbyshire, United Kingdom

The concept of direct immersion cooling for BEVs is gaining traction due to the significant advantages in battery performance and safety. However, battery cooling is just the start, a modern BEV requires thermal management beyond the battery. Thermal management of motors and inverters, as well as component integration is becoming ever more important. Today, BEV hardware designs vary significantly, and the role of thermal management fluids is unsettled. Certain solution providers are advocating for "universal" thermal management fluids, however the fluid performance requirements for BEV hardware vary significantly. At the other extreme, it is not feasible to have a dedicated fluid for each hardware component as the result is unnecessary complexity. This presentation will examine potential scenarios for balancing complexity with performance in delivery of BEV lubrication and thermal management, and how different solutions may arise depending upon system design and duty cycle attributes.

Meet and Greet with STLE Executive Director Rebecca Lintow

Make sure to stop by the STLE Membership Booth in the Minneapolis Convention Center foyer across from the Registration Desk to attend a special Meet and Greet with STLE's new Executive Director, Rebecca Lintow, CAE. This is a great opportunity for the STLE community to meet Rebecca and learn more about her and share any comments, questions, or suggestions you have about STLE. Meet Rebecca during these times:

- **Sunday, May 19** (3:00 pm – 4:00 pm)
- **Monday, May 20** (8:00 am – 9:00 am)
- **Wednesday, May 22** (2:00 pm – 3:00 pm)