The 2024 STLE Tribology & Lubrication for E-Mobility Conference

Oct. 23-25

Detroit Marriott at Renaissance Center, Detroit, Mich. (USA)

STLE Tribology & Lubrication for 2024 EMobility Conference

Conference highlights:

- Expert-led presentations from leading companies and organizations with an interest in e-mobility
- Networking opportunities

Topic areas include:

- Electric vehicle hardware
- Electric vehicle drivetrain efficiency
- Testing for electric vehicles
- Thermal management
- Charging and battery electrification
- Grease for electric vehicles
- Lubricant formulation
- Sustainable mobility and more

If you are interested in presenting, please submit your abstract by June 14 at **https://stle.submittable.com/submit**.

Visit **www.stle.org/EMobility** for program, hotel and registration information or scan the QR code:

Registration will be open in summer 2024.

To learn more about sponsorship opportunities, contact Tracy Nicholas VanEe at ***emeraldcomminc@yahoo.com***, (847) 430-6767.

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THURSDAY

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Overview

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

Thursday, May 23

Onsite Registration
6:30 am – 12:00 pm – **Convention Center Foyer**

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

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

- **NEW!** Electric Vehicles 202 – **200 FG**

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

7A • Materials Tribology V – **101 B**
7B • Condition Monitoring III – **101 C**
7C • Metalworking Fluids I – **101 D**
7D • Rolling Element Bearings II– **101 E**
7E • Environmentally Friendly Fluids II – **101 F**
7F • AI and Machine Learning I – **101 G**
7J • Electric Vehicles VII – **200 DE**
7K • Wear I – **200 B**
7L • Nonferrous Metals I – **200 A**

Networking/Refreshment Break
10:00 am – 10:40 am – **Foyer**

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

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

8A • Materials Tribology VI – **101 B**
8C • Metalworking Fluids II – **101 D**
8D • Rolling Element Bearings III – **101 E**
8E • Environmentally Friendly Fluids III – **101 F**
8F • AI and Machine Learning II – **101 G**
8K • Wear II – **200 B**

Networking/Refreshment Break
3:00 pm – 3:20 pm – **Convention Center Foyer**

TIME	SESSION 7A Materials Tribology V Room 101 B	SESSION 7B Condition Monitoring III Room 101 C	SESSION 7C Metalworking Fluids I Room 101 D
8:00 am – 8:20 am	The Direct Effect and Slip Strengthening in Nanoscale Rate-and-State Friction, J. McClimon, p. 122	Oil Analysis Addresses Changes in Diesel Engine Design and New Lubricant Formulations, M. Holloway, p. 124	The Role of Metalworking Fluid Microbicides in an Increasingly Restrictive Regulatory Environment, F. Passman, p. 126
8:20 am – 8:40 am			
8:40 am – 9:00 am	Low Friction Achieved by Diamond-Like Carbon Sliding on Ice Surface, Y. Liu, p. 122	Non-Invasive Detection of Cracks in Bearing Steel Using Ultrasound, G. Nicholas, p. 124	The Added Value of Friction Measurements L. Lopes, p. 126
9:00 am – 9:20 am	PTFE-Cr Systems: Tribofilm Dependance on Counterbody Material, M. Sidebottom, p. 122	Innovative Approach for Evaluating Dispersancy in New Lubricating Oils, G. Natarajan, p. 124	Improving the Sustainability of Metal Cleaners with Ether Carboxylic Acid, J. Grüber, p. 126
9:20 am – 9:40 am	Lubricious Yet Tough Fabric Composites at Cryogenic Temperature by Sulfonated Polyether-Ether-Ketone Reinforcement, Z. Wang, p. 122	Enhanced Water Separation from Hydrocarbon-based Lubricating Oils with a Novel, Multilayered Hydrophobic, Hydrophilic Coalescer, J. Duchowski, p. 125	Sustainability Strategies from the Perspective of a Performance Additive Manufacturer, M. Stapels, p. 126
9:40 am – 10:00 am	Determining the Rolling Resistance of Golf Balls, K. Budinski, p. 122	Simplifying Condition Monitoring Starting with Fluid Analysis, R. Clark, p. 125	Petrolatum- and Sulfonate-Free Coatings or Long-Term Outdoor Corrosion Protection, A. Hadler, p. 126
10:00 am – 10:40 am	**Break**	**Break**	**Break**
10:40 am – 11:00 am	Tribological Performances of PEEK Reinforced with Lamellar and Granular Particles, K. Delbé, p. 124	Measurement of Wear Debris in Oil Released During Endurance Testing of Bearings and Gears, K. Matsumoto, p. 125	Towards a More Realistic Approach to Ranking Lubricant Emulsions and Tool Metallurgies with ASTM D-3233A Pin & Vee Block Method, L. Lopes, p. 126
11:00 am – 11:20 am	On the Tribology of PEEK-Based Composites, S. Gupta, p. 124	Development of Oil Monitoring System for Construction Machinery . . . H. Akita, p. 125	Machining High-Alloyed and Stainless Steel Without Chlorinated Paraffins, W. Rehbein, p. 128
11:20 am – 11:40 am	Testing Strategy for Polymer Materials – Accelerating Data Production Towards AI?, L. Lopes, p. 124	Condition Monitoring of Lubricants with New RGB and NIR Portable Sensors, K. Kojima, p. 125	A Comparative Analysis in Metalworking Fluids, J. Justice, p. 128
11:40 am – 12:00 pm			Naturally Derived Surfactants for Multiple Uses In Metalworking Fluids, G. Bryant, p. 128
	SESSION 8A **Materials Tribology VI**		**SESSION 8C** **Metalworking Fluids II**
	Room 101 B		**Room 101 D**
1:40 pm – 2:00 pm	Do Oxide Coatings Strengthen Metal Nanoparticles?, T. Jacobs, p. 140		Tribological Properties of Metalworking Fluid Lubricity Additives on Different Metals, Y. Philip p. 141
2:00 pm – 2:20 pm			Role of Polymers in Quenching Fluids, J. Scherger, p. 141
2:20 pm –2:40 pm	Tribological Performance of ATSP Composites in Simulated Lunar Environments for Sealing Applications, M. Akif Rahman, p. 140		Mapping Extreme Pressure Additive Activation from Lathe Machining on High Strength Steel, R. Weber, p. 141
2:40 pm – 3:00 pm	Study of Cast Iron Piston Ring Tribology for Aerospace Application and Discussion of Lessons Learned During Testing, M. Makowiec, p. 140		Boundary Lubricant Additive Multimetal Optimization for AISI 1018 Steel, Aluminum, and Copper Alloys . . . , T. McClure, p. 142
3:00 pm – 3:20 pm	**Break**	**Break**	**Break**
3:20 pm – 3:40 pm	Tribological Performance of Advanced Polymers for Hydrogen Environment Applications, A. Raut, p. 141		Increasing Metalworking Fluid Performance with Amino Alcohols and Alkanolamides, K. Havelka, p. 142
3:40 pm – 4:00 pm	The Droplet-Luminescence Excited by Contact Electrification on Polymer Surface, S. Zhu, p. 141		MWF Formulations and Performance Testing Using Estolides, M. Lutz, p. 142
4:00 pm – 4:20 pm			Overview on Tribometric Screening Methods for Forming and Metalworking, A. Schneider, p. 142
4:20 pm – 4:40 pm			Fluid Fusion- Enhancing Performance and Longevity . . . Sustainable Metalworking Fluids, J. Ziobro, p. 142
			(4:40 – 5 pm) Metalworking Fluids Business Meeting

SESSION 7D Rolling Element Bearings II Room 101 E	SESSION 7E Environmentally Friendly Fluids II Room 101 F	SESSION 7F AI and Machine Learning I Room 101 G	
A Novel Multiphase CFD Model for Investigating the Flow Dynamics of Aerated Bubbles in Bearing Lubrication, U. Arya, p. 128	The Most Sustainable Way to Recycle Used Motor Oil, U. Le, p. 130	From Empiricism to Strategy – Targeted Development of Hybrid Plastic-Based Tribological Materials . . ., A. Schlarb, p. 132	**8:00 am – 8:20 am**
	A Comparison of Life Cycle Assessments for Different Types of Estolide Production, T. Thompson, p. 130		**8:20 am – 8:40 am**
Lubrication of Cylindrical Roller Bearing Cage Pockets in Oil Bath Environment, S. Aamer, p. 128	U.S. Soy: The Sustainable Solution for Lubricants, R. Balee, p. 130	Predictions for Formation and Friction of Tribo-Sintered Metal Oxide Antiwear Coatings, P. LaMascus, p. 132	**8:40 am – 9:00 am**
In-Situ Measurement of the Inlet Meniscus Position and Contact Starvation, W. Gray, p. 129	Biobased Base Oils for Lubrication Fluids, L. Nelson, p. 130	Unlocking the Potential of Ensemble Machine Learning in Tribology, M. Marian, p. 132	**9:00 am – 9:20 am**
In-Situ Measurement of EHL Film Temperature in Cylindrical Roller Thrust Bearings Using Thin-Film Sensors, M. Manjunath, p. 129	Biobased Ionic Liquid for Conductive Lubricants, P. Struelens, p. 132	Machine Learning Assisted Condition Monitoring Using Acoustic Emission Technology on Rotating Mechanical Components, N. Murthy, p. 133	**9:20 am – 9:40 am**
Study: Tribological Properties of Rolling Bearing Under Lubrication with Diketone Lubricants, S. Du, p. 129	Using Molecular Modelling to Anticipate Future Toxicity Classifications of Antioxidants . . ., S. Lucazeau, p. 132	Grinding the Gears of Knowledge – and End-to-End Framework for Tribological Data, I. Bagov, p. 133	**9:40 am – 10:00 am**
Break	**Break**	**Break**	**10:00 am – 10:40 am**
Micropitting, Macropitting, and Scuffing Using Commercial Wind Turbine Greases, R. Erck, p. 129	Synthesis and Lubricant Properties of Isostearic and Isooleic Based Biolubricants, B. Sharma, p. 132	Gaussian Processes Regression – A Powerful Machine Learning Tool for Elastohydrodynamic Film Thickness Predictions, W. Habchi, p. 133	**10:40 am – 11:00 am**
Transfer Film Formation in Dry-Lubricated Rolling Contacts Based on Molybdenum, D. Konopka, p. 129	. . . Interaction Between Biofuels & Lubricating Oils in Achieving IMO's GHG Reduction Goals, S. Rezaee, p. 132	Prediction of Slender-like Elastohydrodynamic Contacts by Machine Learning Methods, M. Marian, p. 133	**11:00 am – 11:20 am**
High Speed E-Motor Bearings for Electric Vehicles, J. Modi, p. 129		Artificial Intelligence in Simulation and Model Generation, H. Grillenberger, p. 133	**11:20 am – 11:40 am**
			11:40 am – 12:00 pm

SESSION 8D Rolling Element Bearings III Room 101 E	SESSION 8E Environmentally Friendly Fluids III Room 101 F	SESSION 8F AI and Machine Learning II Room 101 G	
Propagation of Surface-Initiated Fatigue Cracks . . . to Fatigue Life Predictions, A. Kadiric, p. 144	Sustainable High-Performance Lubricants and Greases, G. Herve, p.145	Autonomous Measurements Powered by Machine Learning, Y. Liu, Rama p. 146	**1:40 pm – 2:00 pm**
			2:00 pm – 2:20 pm
Automated Cage Optimization Using Machine Learning, H. Grillenberger, p. 144	Lubricant Requirements for Low GWP Refrigerants in HVAC&R Applications., W. Akram, p. 145	Application of Machine Learning to Pour Point Prediction of Transesterified Bio-oils for Biolubricant Production, G. Díez Valbuena, p. 146	**2:20 pm –2:40 pm**
Bearing Rotor Housing System Modelling, A. Shafiee, p. 144	Sustainable Sourcing and Traceable Mass Balance – Unveiling the Path to Environmentally Friendly Fluids, S. Basu, p. 145		**2:40 pm – 3:00 pm**
Break	**Break**	**Break**	**3:00 pm – 3:20 pm**
Modeling Raw Material CO_2 Emissions to Reduce the Bearing Industry Carbon Footprint, S. Melnik, p. 144			**3:20 pm – 3:40 pm**
A Fast and Efficient Calculation Method for Pitch Bearing . . ., R. Duquesne, p. 144			**3:40 pm – 4:00 pm**
Frictional Torque Investigations of Radially Preloaded Cylindrical Roller Bearings, T. Wittek, p. 144			**4:00 pm – 4:20 pm**
Effect of Cage Wear on Lifetime of Cryogenic Bearing Under Various Load Conditions, Y. Lee, p. 145			**4:20 pm – 4:40 pm**

THURSDAY >>

TIME	SESSION 7J Electric Vehicles VII Room 200 DE	SESSION 7K Wear I Room 200 B	SESSION 7L Nonferrous Metals I Room 200 A
8:00 am – 8:40 am	Synergies of Surface Finish, Coatings & Additive Chemistry on Friction and Wear at the Piston Ring and Cylinder Liner Interface, L. Speed, p. 134	PQ versus FerroQ: Understanding In-Service Lubricant Ferrous Debris Quantification, D. Swanson, p. 135	Simulating Friction in Aluminum Hot Rolling Emulsions on the Lab Scale, P. Bakermans, p. 138
8:40 am – 9:00 am	Lubricants for Electrified Commercial Vehicle (Part I) Benchmarking Transmission Efficiency . . ., H. Hahn, p. 134	A Digital Twin Approach for Evaluating the Real-Time impact of Ice Collision Loads on Wear Development in Ship's Stern Tube Bearings, A. Saleh, p. 135	Hot Rolling Emulsions and the Importance of Antioxidant Additives, B. Poynor, p. 138
9:00 am – 9:20 am	Lubricant Durability Evaluation in a 15L Hydrogen Internal Combustion Engine, V. Kalaskar, p. 134	Measuring Wear the Right Way, M. Malburg, p. 135	How Metalworking Emulsions Evolve During Usage – The Effects of High Temperatures and Contamination, A. Viat, p. 138
9:20 am – 9:40 am	Design and Characterization of Environmentally-Friendly Heat Transfer Liquids for Electric-Vehicle Battery Packs, I. Karathanassis, p. 134	Utilizing Vibration Analysis for Friction Prediction and Scuffing Prevention, J. Horng, p. 136	Lubricity Additives for Fully Synthetic, Nonferrous Formulations, B. Arnold, p. 138
9:40 am – 10:00 am	Investigation of the Discharge Voltage in EV Motor Bearings, L. Guo, p. 134	Surface Integrity, Microstructural Evolution and High Temperature Fretting Wear of Wrought and Additively Manufactured Inconel . . ., A. Beheshti, p. 136	The Effects of High Magnesium Metallic Debris on the Lubrication Fluid From Condition Monitoring Testing, S. Wheeler, p. 138
10:00 am – 10:40 am	Break	Break	Break
10:40 am – 11:00 am	A Comprehensive Study Comparing Several Fluids Heat Transfer Performance in an E-Machine, V. Kalaskar, p. 135	A Quantitative Study of the Galling Resistance of Superalloys Based on Nickel and Cobalt, M. Fahrmann, p. 136	Oxidation of Aluminum Hot Rolling Oils – A Case Study, J. Leimhofer, p. 138
11:00 am – 11:20 am		Influence of White Etching Layer on Rail Surface to Rail Wear Behavior . . ., Y. Yang, p. 136	New Polymeric Antiwear Additives for Non-Ferrous Metalworking Fluids, L. Luz, p. 140
11:20 am – 11:40 am	Innovating Aeration Measurement for Enhanced Vehicle Lubrication Systems, A. Khoraych, p. 135	The Multifunctional Properties of Amine-Neutralized Phosphate Esters Antiwear Additives, E. Amerio, p. 136	Bio Source Oil for Aluminum Cold Rolling, G. Burette, p. 140
11:40 am – 12:00 pm		Wear Business Meeting	Phosphonate from Used Cooking Oil as Biobased Lubricant, G. Bantchev, p. 140
12:00 pm – 12:30 pm			Nonferrous Metals Business Meeting

TIME	SESSION 8K Wear II Room 200 B
1:40 pm – 2:00 pm	Tribological Properties of Lubricating Oils Derived From Plastic Wastes Under Electrified Conditions, S. Lee, p. 146
2:00 pm – 2:20 pm	Effect of High-Pressure Hydrogen Gas on the Friction and Wear of PTFE Composite, K. Ishii, p. 146
2:20 pm –2:40 pm	Effects of Trace Moisture on Tribo-Film Formation, . . . Qi. Chen, p. 147
2:40 pm – 3:00 pm	Effect of the Accelerated Cryogenic Ageing on Mechanical and Tribological Properties of PEEK and PI Composites, M. Nikonovich, p. 147
3:00 pm – 3:20 pm	Break
3:20 pm – 3:40 pm	Study on the Friction Temperature Fieldand Wear Characteristics of Polymer Materials, Y. Xia, p. 147
3:40 pm – 4:00 pm	Strategy to Enhance the Wear Resistance of PTFE/ Kevlar Fabric Liner . . ., W. Xiong, p. 147
4:00 pm – 4:20 pm	The Impact Corrosion Has on the Particle Wear Emissions Generated From Different Brake Rotor Material, I. Ghouri, p. 147


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Session 7A • 101 B

Materials Tribology V

Session Chair: Nikhil Murthy, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Session Vice Chair: TBD

8:00 am – 8:40 am

3998813: The Direct Effect and Slip Strengthening in Nanoscale Rate-and-State Friction

John McClimon, University of Pennsylvania, Conshohocken, PA; Khagendra Baral, Izabela Szlufarska, University of Wisconsin-Madison, Madison, WI; David Goldsby, Robert Carpick, University of Pennsylvania, Philadelphia, PA

Rate-and-state friction (RSF) describes the history-dependent friction seen in many materials. This behavior can be predicted by semi-empirical laws that describe time- or slip-dependent strengthening of the interface. An assumption of these laws is that there is a speed-dependent contribution to the response, referred to as the "direct effect," which is fully separable from the state effects. Our recent experiments and associated mechanistic modeling suggest that this contention is erroneous, and we will present results of experiments tailored to demonstrate that this is so. Additionally, we will present results demonstrating a phenomenon known as "slip strengthening" is operative at the nanoscale and quantify its effect on interface strengthening. This phenomenon is critical to the validity of an empirically successful variant of the RSF laws, but mechanistic explanations for its existence are currently lacking.

8:40 am – 9:00 am

4004755: Low Friction Achieved by Diamond-Like Carbon Sliding on Ice Surface

Yuan Liu, Tsinghua University, Beijing, China

Reducing friction between sports equipment and ice surface is crucial for improving performance on ice at the Winter Olympics. With the aim to reveal the underlying mechanism of the friction on ice surface, we investigated the different materials sliding on ice surface. We have demonstrated an amazing finding that the diamond-like carbon (DLC) film has achieved lower friction when sliding on the ice surface. After the DLC film slid on the ice surface, the proportion of sp2 significantly increased, indicating graphitization in the contact area, ultimately reducing the ice friction coefficient. Moreover, we have characterized the materials surface by sum frequency vibrational spectroscopy (SFG), furthermore, to confirm the arrangement of the water molecules at the surfaces. Here, we propose an innovative friction model considering the arrangement of water molecules. This work may provide a basis for the further study of reducing friction mechanism under water and application of DLC films.

9:00 am – 9:20 am

4082116: PTFE-Cr Systems: Tribofilm Dependance on Counterbody Material

Mark Sidebottom, Faysal Haque, Miami University, Oxford, OH

Certain reinforcing particles (e.g., activated carbon, -Al2O3, etc.) composited with PTFE reduce wear by 3-4 orders of magnitude when slid against 304 SS. Recently, PTFE-Cr, PTFE-Ti, and PTFE-Mn composites achieved similar excellent wear performance when slid against Brass 260. However, these composites showed mixed performance against 304 SS (moderate to ultralow wear). In this study, Cu 110, Zn-galvanized steel, 304 SS, and Brass 260 counterbodies were tested against PTFE-Cr to understand how counterbody properties affect tribological performance. High variation in friction (μ~0.15-0.28) and wear (8x10-9 mm3/Nm < K < 1x10-6 mm3/Nm) were exhibited. Electron microscopy, optical microscopy, profilometry, and surface energy measurements were taken to understand the factors that influenced tribofilm development. Transfer film morphology was highly dependent on the counterbody the PTFE-Cr composite slid against, which likely contributed to the differences in tribological performance.

9:20 am – 9:40 am

4000606: Lubricious Yet Tough Fabric Composites at Cryogenic Temperature by Sulfonated Polyether-Ether-Ketone Reinforcement

Zidan Wang, Tsinghua University, Beijing, China

A novel PTFE/Nomex fiber fabric composite reinforced by sulfonated polyether-ether-ketone (PN-SPEEK) was designed and fabricated, which has comprehensive properties with self-lubricity, high strength and toughness at wide cryogenic temperature range. The tensile strength and toughness were increased by 16.9% and 64.3% at -160°C compared to conventional phenolic-formaldehyde-reinforced fabric (PN-PF). Within the temperature range of -160°C to 25°C, the variation of friction coefficient for PN-SPEEK was flattened between 0.086 and 0.126, which increased dramatically to approximately 0.2 with decreasing temperatures for PN-PF. The transfer film was analyzed comprehensively and thoroughly, demonstrating that the improved stable lubricity was primarily attributed to favorable formation of tribofilm composed of plenty of PTFE and strong chelation between SPEEK and iron base in transfer film. The developed PN-SPEEK is greatly expected for engineering applications.

9:40 am – 10:00 am

3977914: Determining the Rolling Resistance of Golf Balls

Kenneth Budinski, Bud Labs, Rochester, NY

Over the past decade or so, colored golf balls have gained significant popularity. Some golfers believe that the bright colors make the balls easier to find in high grass. Similarity there is a belief among golfers that the colored balls do not roll as good in putting (high rolling resistance) as traditional white balls. This project was initiated to answer that question. The ASTM G194 standard test for determining the rolling resistance of spherical shapes was used to measure the rolling resistance of traditional white golf balls (new and used), new colored balls with a shiny surface finish, and new colored balls with a dull (non-reflective) surface finish. Tests were conducted on simulated grass (carpet) and on a practice putting green at a traditional public golf course. The test ball is rolled down the fixed height ramp and the distance traveled after exiting the ramp is measured. It was determined that shiny colored balls have lower rolling resistance than traditional new white balls.

10:00 am – 10:40 am – Break

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7A

10:40 am – 11:00 am

4006736: Tribological Performances of PEEK Reinforced with Lamellar and Granular Particles

Karl Delbé, Jean Denape, France Chabert, École Nationale d'Ingénieurs de Tarbes, Tarbes Cedex, France; Marie Doumeng, BioTanah, Pau, France; Florentin Berthet, Institut Clément Ader, Albi, France; Olivier Marsan, CIRIMAT, Toulouse, France

PEEK is a polymer used in high-performance engineering, which can be enhanced by adding specific fillers. Granular fillers (SiC and Al2O3) reinforce the mechanical properties, while lamellar fillers (h-BN and graphite) are solid lubricants. This study collected experimental results using the same thermoforming process and tribological parameters and analyzed the effect of the filler's nature, size, and content. The researchers found a link between debris emission and the modification of the interfacial adhesion between the PEEK macromolecules and the reinforcement. High graphite content produced a large amount of wear and debris, while granular fillers or low graphite rates exhibited moderated plastic deformation and slight debris emission.

11:00 am – 11:20 am

4003254: On the Tribology of PEEK-Based Composites

Surojit Gupta, University of North Dakota, Grand Forks, ND

In this paper, we will present some of the recent research in our group on the design and development of polyether ether ketone (PEEK) and particle-reinforced PEEK-matrix composites for different tribological applications in lubrications. In addition, we will present recent research in our group on high temperature tribological studies. The study also quantifies the tribological performance of these materials to explore unique applications where sustainable practices can be implemented using ethanol as a green lubricant, and PEEK as a recyclable polymer. PEEK is a semi-crystalline thermoplastic polymer with high strength, thermal stability, chemical resistance, and wear resistance. Performance-demanding applications usually implement thermosets which are not easily recyclable, whereas thermoplastics are. Hence these new studies will further accelerate the development of PEEK-based composites for demanding applications.

11:20 am – 11:40 am

3984344: An Efficient Testing Strategy for Polymer Materials – Accelerating Data Production Towards AI?

Lais Lopes, Dirk Drees, Pedro Baião, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Erik Schwartz, Sabic HPP, Bergen op Zoom, Netherlands

The tribological properties of engineering polymers are usually characterized by the ASTM D3702 Thrust washer method; a constant pressure and velocity sliding wear test. Although this approach has its advantages, the typical test duration makes it an inefficient method, especially when statistical data are required. We present an alternative approach to data production, that could enable AI to understand and predict structure-functional property relationships. The multi-station test method produces 10 times more data, and we show sufficient correlation with historic thrust washer data on more than 20 internally lubricated variations. An additional benefit of our methodology is the easy creation of wear evolution graphs for each material, showing distinctly different behavior for different material classes. The high efficiency and low running costs make this an attractive wear production method, helping to develop new formulations, as some additives come under regulatory scrutiny.

Session 7B • 101 C

Condition Monitoring III

Session Chair: Alfredo Garcia, Luval SA, Santiago, Region Metropolitana, Chile

Session Vice Chair: Marc Yarlott, Veolia North America, Vancouver, WA

8:00 am – 8:40 am

4002562: Oil Analysis Addresses Changes in Diesel Engine Design and New Lubricant Formulations

Michael Holloway, SGS, Highland Village, TX

Every year heavy equipment engine manufacturers design product for reduced weight, increased power, lower emissions, and better fuel economy. This seminar highlights changes in the design and how lubricant manufacturers are adjusting to these changes. Oil manufacturers are constantly looking to produce the next generation formula to work in concert with the engine makers. These formulations use new ingredients that require your oil analysis lab to be constantly up to date. This presentation explores the new designs for diesel engines from all the major OEMs as well as what you can expect to see in terms of the oil formulas that are used in these applications and how oil analysis can be used to diagnose issues with new engines and keep an eye on the new oils being introduced.

8:40 am – 9:00 am

3988388: Non-Invasive Detection of Cracks in Bearing Steel Using Ultrasound

Gary Nicholas, William Gray, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, United Kingdom; Marc Ingram, Ingram Tribology Ltd., Carmarthen, United Kingdom

Wind turbine gearbox bearings often fail due to axial cracks linked with white-etching cracks (WECs). Typically, analyzing these failed bearings requires a destructive process where the bearing is sectioned and then examined under a microscope for WECs. This process can be lengthy, especially when searching blindly for areas with high concentration of WECs in large bearings. In this study, ultrasound was trialed as a potential technique to pinpoint regions of high WEC concentrations, facilitating targeted sectioning in those specific areas. WECs were generated within two bearing steel roller specimens using a MPR test rig with critical lubricants. A focused probe was used to transmit ultrasonic waves to the WEC concentrated specimen within a water bath. Amplitude as well as non-linear behavior of ultrasonic reflections were used to deduce the presence of cracks within the roller specimens.

9:00 am – 9:20 am

4004953: Innovative Approach for Evaluating Dispersancy in New Lubricating Oils

Ganesh Natarajan, Sara Rezaee, Ramaratnam Visweswaran, Aparna Bala, Viswa Group, Houston, TX

Soot particles, a common by product of incomplete fuel combustion, often infiltrate the lubricating oil system through gas blowby. Soot contaminated oils lead to wear and the fouling of critical machine components, including injectors and exhaust lines. Lube oils are formulated with Dispersant additives to counter this problem which are designed to keep these contaminants suspended and prevent them from coalescing into larger, filter-clogging particles and minimizing deposition on machinery. For in-service oils, traditional test methods are available to

assess their dispersancy properties. In this study, we have developed a new method for evaluating the dispersancy properties of fresh lubricating oils under different levels of soot contamination. By creating standard samples and assessing them using enhanced blotter spot techniques, this lab developed method enables a comparison of the dispersancy properties of fresh oils across various brands which can lead to informed decision-making.

9:20 am – 9:40 am

4001287: Enhanced Water Separation from Hydrocarbon-based Lubricating Oils with a Novel, Multilayered Hydrophobic, Hydrophilic Coalescer

John Duchowski, Christian Adam, Johannes Staudt, Hydac FluidCareCenter GmbH, Sulzbach, Saar, Germany; Christian Mueller, HYDAC Technology Corporation, Bethlehem, PA

A liquid separator (coalescer) was devised from a multilayered hydrophobic, hydrophilic filter media sheets pleated into a cylindrical structure. The coalescer was applied to extract water from several, differently formulated hydrocarbon lubricating oils in several different applications. Excellent separation efficiencies have been observed with the 32 cSt and 46 cSt turbine lubricating oils. However, and most notably, the separator has proven itself highly effective in extracting water from the highly viscous 220 cSt and even 460 cSt Morgoils where water poses a serious operational problem. Several examples of both the laboratory results as well as practical field applications will be described and discussed.

9:40 am – 10:00 am

4000883: Simplifying Condition Monitoring Starting with Fluid Analysis

Randy Clark, POLARIS Laboratories®, Indianapolis, IN

Today, we have multiple condition-monitoring tools at our disposal. Although each tool is beneficial, the data they provide can sometimes be overwhelming and confined to specific systems, necessitating users to log in to multiple platforms and analyze the combined data to determine the state of the equipment. In this presentation, we will discuss the advantages of integrating condition monitoring tools into a single platform view and generating work orders automatically based on the criteria set by the user.

10:00 am – 10:40 am – Break

10:40 am- 11:00 am

4003902: Measurement of Wear Debris in Oil Released During Endurance Testing of Bearings and Gears

Kenji Matsumoto, TOYO Corporation, Koto-ku, Tokyo, Japan; Yuji Mihara, Tokyo City University, Setagata-ku, Tokyo, Japan

We have developed a new instrument for measuring wear debris in lubricating oil using the laser shading method. This device has noise immunity, automatic sampling, de-aeration in oil, and remote operation. Using this device, we conducted durability tests on ball bearings and gears and continuously measured particles in the oil during the tests. The results showed that the measurement method was effective in monitoring the condition of the gear during sliding. In the future, this device could be used to monitor the condition of rotating parts in remote locations to detect failures before they occur and to keep maintenance costs low.

11:00 am – 11:20 am

4085308: Development of Oil Monitoring System for Construction Machinery – Investigation of Monitoring Method of Biodegradable Hydraulic Oil and Monitoring System Using Color Difference Sensor

Hideki Akita, Hiroki Ensyuu, Michio Sugawara, Akira Kurasako, Hitachi Construction Machinery Co., Ltd., Tsuchiura, Japan

Currently, oil condition monitoring systems are in operation for hydraulic oil and engine oil in construction machinery. This system is in operation almost all over the world, with the exception of some regions, and the number of units in operation has reached 0,000 and is increasing every year. This system utilizes IoT to "visualize" oil status changes and notify customers of sudden abnormalities. In this time, we will report on the following: 1.) Proposal of monitoring methods other than mineral oil and their results; 2.) Current status of sensors other than physical quantity sensors, including color difference sensors and 3.) Possibility of a stand-alone oil condition monitoring system.

11:20 am – 11:40 am

4090295: Condition Monitoring of Lubricants with New RGB and NIR Portable Sensors

Kyoko Kojima, Hitachi, Ltd., Kokubunnji, Tokyo, Japan

The condition monitoring of lubricants has great effects such as life cycle cost reduction and operation rate improvement of equipments, oil consumption reduction, that is, reduction of carbon dioxide emission. Although online monitoring is very powerful, there have been challenges in retrofitting. The solution to the problem is on-site diagnostics using portable sensors. A new portable sensor that can measure lubricants without contact have been developed. RGB and near-infrared(NIR) sensors can be mounted on. A new RGB sensor is inexpensive, easy to use, and suitable for diagnosing oil degradation. The NIR sensor has high performance and can obtain information on the composition of oil and contamination of water below the saturated water content, which cannot be understood by RGB colors. Near-infrared spectroscopy can be used to quantify multiple items by using machine learning. In addition, it can be operated seamlessly on-site and online monitoring.

Session 7C • 101 D

Metalworking Fluids I

Session Chair: Nicole Clarkson, Barentz North America LLC, Lisle, IL

Session Vice Chair: Stephanie Cole, Münzing North America, LP, Bloomfield, NJ

8:00 am – 8:40 am

3989978: The Role of Metalworking Fluid Microbicides in an Increasingly Restrictive Regulatory Environment

Frederick Passman, Biodeterioration Control Associates, Inc., Princeton, NJ

During the past two decades, regulatory pressures against the use of microbicides in water miscible metalworking fluids has increased substantially. As a consequence of these pressures, the variety of available active substances has shrunk dramatically since 2000. In particular, regulatory agencies have conflated formaldehyde-condensate and formaldehyde toxicity. This presentation will review the history of metalworking fluid microbicide regulation – highlighting restrictions on formaldehyde-condensate microbicide use. It will also review the most commonly used active substances and the importance of testing microbicide efficacy in each metalworking fluid formulation in which a particular active substance will be used.

8:40 am – 9:00 am

3980496: The Added Value of Friction Measurements in the Pin & Vee Block Method

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

The popular standard Pin & Vee block test method is mainly used to determine forming or cutting lubricants' EP quality by testing until failure of the pin. This is the easiest way to run a test, but it can cause large variation in data because of minor variations in specimen strength and the stochastic nature of catastrophic failure. Besides, the lubricant behavior before catastrophic failure is equally important. Past researchers have used an initial increase of friction, 'torque pop-up', as additional lubricant performance information, but previously it wasn't easy to measure frictional torque accurately. The new generation Pin & Vee machines measure temperatures, frictional torque and the dimensional wear (wear teeth) online and allows us to gain more information out of the simple test setup. In this paper, the stochastic nature of the failure event is shown, and the improvements gained by recording the full data available from the instrument, as it correlates to tapping operations.

9:00 am – 9:20 am

3984273: Improving the Sustainability of Metal Cleaners with Ether Carboxylic Acid

Jan Grüber, Kao Chemicals GmbH, Emmerich am Rhein, Germany

Sustainability is one of the key drivers for the development of next-generation metal cleaning formulations. However, improved sustain - ability must not come at the expense of performance. Ether carboxylic acids are multifunctional high-performance additives and improve the overall performance of water-based cleaners. These readily biodegradable surfactants are able to extend the lifetime of the cleaning bath significantly by enhancing the tolerance against electrolytes and hard-water ions. Longer bath lifetime results in both less raw material and fresh-water consumption and minimized waste streams. The reinforcing effect of ether carboxylic acids on cleaning performance enables a higher throughput of cleaning cycles to realize a more ecological process. Combining better cleaning performance and the hydrotropic effect to adjust the cloud point allows to reduce the cleaning temperature. Balancing all the described beneficial effects will be key for developing sustainable metal cleaners.

9:20 am – 9:40 am

3987468: Sustainability Strategies from the Perspective of a Performance Additive Manufacturer

Michael Stapels, Kao Chemicals GmbH, Emmerich, Germany

While for decades optimum performance and a competitive price were the decisive factors for the success of a cooling lubricant on the market, sustainability aspects have recently come into focus. In particular, factors such as the product carbon footprint as well as renewable carbon content are at the center of these discussions. The presentation will address various strategies for formulating more sustainable metalworking fluids like, for example replacing mineral oil-based feedstocks by renewable or refined ones. The performance evaluation of this alternatives will lead in a critical discussion if the predominant focus on the carbon footprint always results in the most sustainable solution.

9:40 am – 10:00 am

3987878: Petrolatum- and Sulfonate-Free Coatings or Long-Term Outdoor Corrosion Protection

Amelia Hadler, Christopher Kabb, David Nickerson, Maria Shepherd, Britt Minch, The Lubrizol Corporation, Wickliffe, OH

Heavy duty rust preventives are used for long-term corrosion protection in applications such as underbody coatings for cars and trucks and maintenance coatings for outdoor metal frameworks or equipment. While these products offer excellent corrosion protection, their technology has remained unchanged over the years and largely relies on petrolatum- and sulfonate-based formulations, which can be dark in color, difficult to handle, and often show poor UV stability due to the chemical components used. This talk introduces a new polymer-based coating that is free of petrolatum and sulfonate chemistry, forming a clear, dry film with excellent corrosion protection and UV stability. This versatile technology is easy to handle and can be diluted in solvent and formulated with common additives to enhance usability and protection.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

3993724: Towards a More Realistic Approach to Ranking Lubricant Emulsions and Tool Metallurgies with ASTM D-3233A Pin & Vee Block Method

Lais Lopes, Dirk Drees, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Emmanouil Georgiou, Hellenic Air-Force Academy, Athens, Greece

ASTM D-3233A uses a Pin & Vee Block setup to evaluate the performance of cutting fluids. However, this procedure uses a specific steel-steel contact and a small volume of lubricant in a cup. In our previous work, we have modified this method to include different metallurgies (aluminum pins versus steel blocks) and tested with aqueous emulsions, rather than formulated oils. However, to go even closer to a cutting/forming application we have coated the Vee Blocks using electrodeposition and thermal spraying methods, to simulate existing cutting/forming tools used in the field. The aim is to investigate the effect of surface metallurgy on the performance (torque relates to energy

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consumption during manufacturing) and wear resistance of the cutting/forming tool. This modified approach attempts to provide an additional cost and time efficient method for ranking of cutting fluids and cutting/forming metallurgies, based on a setup that is already extensively available in the lubricants industry.

11:00 am – 11:20 am

3999427: Machining High-Alloyed and Stainless Steel Without Chlorinated Paraffins

Wilhelm Rehbein, LANXESS Deutschland GmbH, Mannheim, Germany

Chlorinated paraffins prevent adhesive wear between metal surfaces by forming pressure stable adsorption layers under standard metalworking conditions. However, with increased machining speeds, they tend to decompose and can cause chemical wear. Sulfurized esters or olefins are another class of commonly used EP additives that are versatilely used to reduce friction and to prevent adhesive wear in metalworking processes. Compared to chlorinated paraffins, sulfur carriers show many benefits in terms of toxicity, environmental impact and energy efficiency. Despite it is possible to replace chlorinated paraffins by sulfur carriers in most metalworking applications, it's still difficult to achieve a similar performance when machining high-alloyed or stainless steels. Based on tribological test results, the presentation shows how it is possible to meet or exceed the performance of chlorinated paraffins by chlorine-free metalworking fluids when machining high alloyed or stainless steels.

11:20 am – 11:40 am

3998301: A Comparative Analysis in Metalworking Fluids

James Justice, John Deere, Moline, IL

There is always a risk associated with change. With new technologies constantly being developed in the arena of metalworking fluids, there are some headwinds in evaluating and implementing different technologies. In a large-scale global production environment, the risk to possible increases in maintenance, downtime, scrap rates and other costs associated with a process change need to be mitigated. Our company has been on a multi-year journey to utilize and develop a set of tests to evaluate metalworking fluids prior to pursuing an in-production trial. This activity included baselining current technology both used within and outside of our factories. This is being utilized to move towards more aligned product chemistry in manufacturing and a globally scalable strategy. In addition, this data is being leveraged to attempt to predict improvements in other performance aspects of metalworking fluids beyond product cost to drive value from a TCO (Total Cost of Ownership) perspective.

11:40 am – 12:00 pm

3993483: Naturally Derived Surfactants for Multiple Uses In Metalworking Fluids

Garret Bryant, Lucas Moore, Jordan Taylor, Colonial Chemical, South Pittsburg, TN

Metalworking fluids (MWFs) are applied to control temperature, reduce tool wear, ensure product quality, and make it possible to increase productivity. Generally, this is accomplished by combining a series of chemistries to bring the combined synergistic benefit desired by the overall fluid. Emulsion based MWF are typically very complicated and can contain upwards to ~ 7 individual components, including corrosion inhibitors, biocides, coupling agents, lubricity aids, emulsifiers, and oil emulsified in water. A series of naturally derived, modified Alkyl Polyglucoside (APG) chemistries were developed with the desire to reduce the complexity of these MWF emulsions by providing a single chemistry that is multifunctional and can be used as a corrosion inhibitor, emulsifier, and friction Reducer. This presentation will focus on the evaluation of these chemistries in such applications.

Session 7D • 101 E

Rolling Element Bearings II

Session Chair: Daulton Isaac, AFRI Turbine Engine Division, Wright-Patterson Air Force Base, OH

Session Vice Chair: Travis Shive, SKF USA Inc., Lansdale, PA

8:00 am – 8:40 am

3985471: A Novel Multiphase CFD Model for Investigating the Flow Dynamics of Aerated Bubbles in Bearing Lubrication

Ujjawal Arya, Farshid Sadeghi, Purdue University, Lafayette, IN

This study delves into the intricate flow dynamics of aerated bubbles within lubricating oil during bearing operation. To achieve this objective, a novel Computational Fluid Dynamics (CFD) model was prepared in Ansys Fluent, which simulates the movement of these bubbles within the bearing chamber. This model utilizes a coupled solver that incorporates a two-way transition algorithm between the Discrete Phase Model (DPM) approach, which was used to model bubble dynamics, and the Volume of Fluid (VOF) approach, which was used to depict oil starvation inside the cage pocket. Results from this CFD model were validated with the experimental observations for the bubble motion from the Counter Rotating Angular Contact ball bearing Test Rig (CRACTR). This coupled CFD model demonstrates an efficient and thoroughly validated modeling approach to examine the complex phenomenon of multiphase oil flow in bearing lubrication, adeptly accounting for the impact of both aeration and oil starvation.

8:40 am – 9:00 am

4000809: Lubrication of Cylindrical Roller Bearing Cage Pockets in Oil Bath Environment

Saeed Aamer, Farshid Sadeghi, Purdue University, West Lafayette, IN

This investigation aims to determine the effects of cage pocket conformality on lubrication in a cylindrical roller bearing (CRB) cage. A custom Bearing Cage Friction Test Rig (BCFTR) was configured with a sealed enclosure to emulate a lubricant bath environment. The enclosure includes CRB raceway segments and swappable cage pockets with adjustable pocket clearance. Three transparent cage segments were fabricated with differing pocket conformality with respect to the roller surface. A camera was used to visualize the in-situ lubricant flow within the roller-pocket contact for all cage types. An equivalent two-phase computational fluid dynamics (CFD) model was developed using Ansys Fluent software. The findings demonstrated that the impact of pocket conformality was two-fold. The least conformal pocket design experienced minimum pocket friction. However, the same design introduced challenges with retaining lubricant at the roller-pocket contact and increasing air entrapment in the oil.

9:00 am – 9:20 am

3986614: In-Situ Measurement of the Inlet Meniscus Position and Contact Starvation

William Gray, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, United Kingdom

Roller bearing starvation occurs when there is inadequate lubricant present at the contact inlet, which leads to an insufficient separating film and surface wear. The level of starvation can be determined by the position of the inlet meniscus, where the raceway and roller films meet. However, a measurement of this position is difficult as the meniscus is thin, in the micron range, occurs over a very small area, and is hidden deep within the rotating bearing. In this work, an ultrasonic technique is developed to measure the raceway film at the contact inlet in-situ. Then, using the theoretical roller film, the thickness of the meniscus is calculated. A Volume Fill Model is introduced which determines the position of the inlet meniscus from its thickness. Results show that load has a surprisingly large influence on starvation, due to contact area enlargement, making it harder for the meniscus to form an adequate distance away from the contact center to allow ample separation.

9:20 am – 9:40 am

3989802: In-Situ Measurement of EHL Film Temperature in Cylindrical Roller Thrust Bearings Using Thin-Film Sensors

Manjunath Manjunath, Patrick De Baets, Dieter Fauconnier, Ghent University, Ghent, East Flanders, Belgium; Martin Rekowski, Marcel Plogmeyer, Fraunhofer Institute for Surface Engineering and Thin Films IST, Braunschweig, Germany

We investigate the in-situ measurement of contact temperature in EHL in cylindrical roller thrust bearings (CRTB) using resistive thin-film sensors. The sensors, optimized for size and spatial resolution, are strategically embedded at various locations on the stationary bearing washer near the outer radius, the inner radius, and at the mean radius. This configuration should enable the measurement of temperature rise in both pure rolling and rolling-sliding regions of the CRTB. We plan extensive tests to explore how loads, speed, and supply oil temperature affect the temperature rise profile within the EHL film. Due to the higher slide-to-roll ratio at the washer's inner and outer radii, temperature profiles are expected to differ from the center, with higher peak temperatures. The measurements provide valuable insights into CRTB-lubricated contacts for the given operating conditions and serve as validation data for advanced TEHL computational tools developed in the same group.

9:40 am – 10:00 am

4000280: Study on the Tribological Properties of Rolling Bearing Under Lubrication with Diketone Lubricants

Shaonan Du, Chenhui Zhang, Tsinghua University, Beijing, China

As an important executive component, angular contact ball bearings have strict requirements on their lubrication performance. This paper studied the effects of lubricant viscosity and type, loading force, bearing speed and lubricant addition amount on bearing friction coefficient. The morphology and composition of the bearing surface were analyzed through SEM and XPS. Systematic experimental results show that the reduction of lubricant viscosity, the increase of axial loading force, and the reduction of lubricant addition amount all contributed to the reduction of bearing friction coefficient. The friction coefficient of bearings lubricated by diketone lubricants was the lowest 0.00035, which was 86.4% lower than that of PAO lubricants of the same viscosity. Surface analysis found that when the lubricant contained components that can react with the bearing, corrosion pits will appear on the surface of the lubricated bearing balls.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4002987: Micropitting, Macropitting, and Scuffing Using Commercial Wind Turbine Greases

Robert Erck, Nicholaos Demas, Aaron Greco, Argonne National Laboratory, Lemont, IL

In this work, a benchtop test rig utilizing a three-ring-on-roller test configuration was used to investigate the efficacy of using two commercial wind turbine greases to reduce both micropitting and macropitting damage on high quality bearing steel samples. The greases incorporated Li complex thickeners with synthetic base oil viscosity of 460 cSt at 40 C. Two ring roughnesses and five grease resupply rates were used. Roller morphology was studied at four intervals during the runs, and reported results include roller images as a function of cycles (typically 0-5 Mcycle), ring images, and graphs of traction coefficients and roller roughnesses as a function of running time.

11:00 am – 11:20 am

4004386: Transfer Film Formation in Dry-Lubricated Rolling Contacts Based on Molybdenum

Dennis Konopka, Florian Pape, Gerhard Poll, Institute of Machine Design and Tribology, Garbsen, Lower Saxony, Germany

Rolling bearings are conventionally lubricated with oil and grease. Dry lubricants, extending the application range, become essential when oil or grease application is impractical. Solid lubricants must reduce friction and wear in machine elements. This study focuses on a molybdenum-based dry lubricating coating applied to bearing steel via PVD. The system includes a molybdenum reservoir with a top layer of molybdenum trioxide, crucial for lubrication and run-in. The goal is continuous regeneration of this top layer via tribo-oxidation. Prior research showed reduced friction, extended operating time, and reduced wear.* This study applies the coating to complex geometries using commercial radial cylindrical roller bearings. Experiments increased operating time and reduced wear. Material analysis methods (SEM, EDX) helped understand dry lubricant transfer and distribution to bearing components, protecting against wear and system failure.

*Konopka et al.: doi.org/10.3390/coatings12050591

11:20 am – 11:40 am

4016219: High Speed E-Motor Bearings for Electric Vehicles

Jitesh Modi, Schaeffler Group USA, Troy, MI

The performance of electrified powertrains is significantly dependent on their electric motors. Based on performance needs of future Electric vehicles, there are increasing trends of high voltage, compact, light-weight, efficient and high-speed motors. The standard bearings from conventional IC powertrains are not adequate to meet performance requirements of high-speed electric motors. While operating at very high speeds, these e-motor bearings should be capable to handle rigorous motor dynamics of rapid acceleration and deceleration, provide precise shaft guidance and running accuracy, lower NVH and above all higher efficiency with reduced friction and minimal self-heating. Innovative high speed bearing solutions with key design features will be discussed with supporting examples.

Session 7E • 101 F

Environmentally Friendly Fluids II

Session Chair: Selim Erhan, Process Oils, Inc., Trout Valley, IL

Session Vice Chair: Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA

8:00 am – 8:20 am

4078856: The Most Sustainable Way to Recycle Used Motor Oil

Uyen Le, Sherry Guo, Blue Tide Environmental, Baytown, TX

Used motor oil (UMO) is a potential hazard if it is not properly disposed of, but it can also be recycled into valuable products, contributing to sustainability. The recycling process consumes less energy and reduces emissions compared to traditional refining from crude oil. However, UMO, coming from different sources and containing contaminants, poses challenges to the recycling process, affecting the yield and quality of re-refined oil. To ensure high-quality recycled products, a fit-in-purpose screening process must in place to ensure to comply with regulations and be compatible with the refinery's design and technology. Enhancing technology and optimizing the re-refining process, including pre-treatment and advanced processes, makes UMO recycling more efficient. The high-quality products (VGO, Base Oil) from the recycling process can be used as valuable feedstock for other refining processes or as the primary ingredient for finished lubricants, which will be returned to consumers.

8:20 am – 8:40 am

4000928: A Comparison of Life Cycle Assessments (LCA) for Different Types of Estolide Production

Travis Thompson, Biosynthetic Technologies, Indianapolis, IN

The Life Cycle Assessment (LCA) tool is becoming increasingly important for characterizing the environmental impact of raw materials. Procurement teams today are inundated with vague terms like sustainability, bio-based carbon, and reduced emissions, oftentimes without understanding the validity or even the meaning of such claims. With the LCA tool, such terms can be better understood, allowing for more meaningful interpretations and comparisons. In this project, two cradle-to-gate LCAs were created for estolide products that use different feedstocks and manufacturing processes. Feedstocks such as coconut oil, soybean oil, and castor oil have been considered, as well as batch versus continuous processing. This report serves to compare the LCAs and discuss their differences.

8:40 am – 9:00 am

4004831: U.S. Soy: The Sustainable Solution for Lubricants

Ray Balee, Omni Tech International, Midland, MI

As one of the most readily available vegetable oils globally, U.S. soybean oil has continued to be a significant ingredient in lubricants. Renewable by nature, soybean derivatives are economical, consistent in quality and a reliable material. U.S. Soy is currently used as a raw material in thousands of products with diverse applications. The United Soybean Board is committed to bringing insight to companies fulfilling sustainability and supply chain goals while supporting development of new applications and improving products utilizing U.S. grown soy. Due to disruption in supply logistics, companies are rethinking their material supply sources for the future. Soybean oil has relatively stable production volumes year to year and has vast growing acreage and crushing facilities versus other seed oils. This translates to shorter supply chain and lower carbon footprint.

9:00 am – 9:20 am

4004976: Biobased Base Oils for Lubrication Fluids

Lloyd Nelson, Amanda Marquez, Kraton Chemical, Savannah, GA

Pine chemistry has been leveraged to develop SYLVASOLV™, 100% biobased content hydrocarbon oils with high solvency to compatibilize difficult-to-solubilize additives. The high solvency allows for effective solubilization of a wide range of lubricant additives in less time and at lower temperatures when compared to alternatives, while demonstrating outstanding compatibility with standard base oils. Sourced from responsibly managed forests, SYLVASOLV oils are 100% biobased, with a minimal carbon footprint. Additionally, these oils exhibit non-flammability and minimal VOC (CARB LVP-VOC certified). Our discussion will cover formulating metalworking fluids and automotive lubricants with SYLVASOLV. We will showcase how biobased hydrocarbon oils can enhance lubrication formulations by enabling the use of challenging high-performance additives. We'll also delve into their electrical, thermal conductivity, and hydrolytic stability.

9:20 am – 9:40 am

4000930: Biobased Ionic Liquid for Conductive Lubricants

Pieter Struelens, Oleon NV, Evergem, Belgium

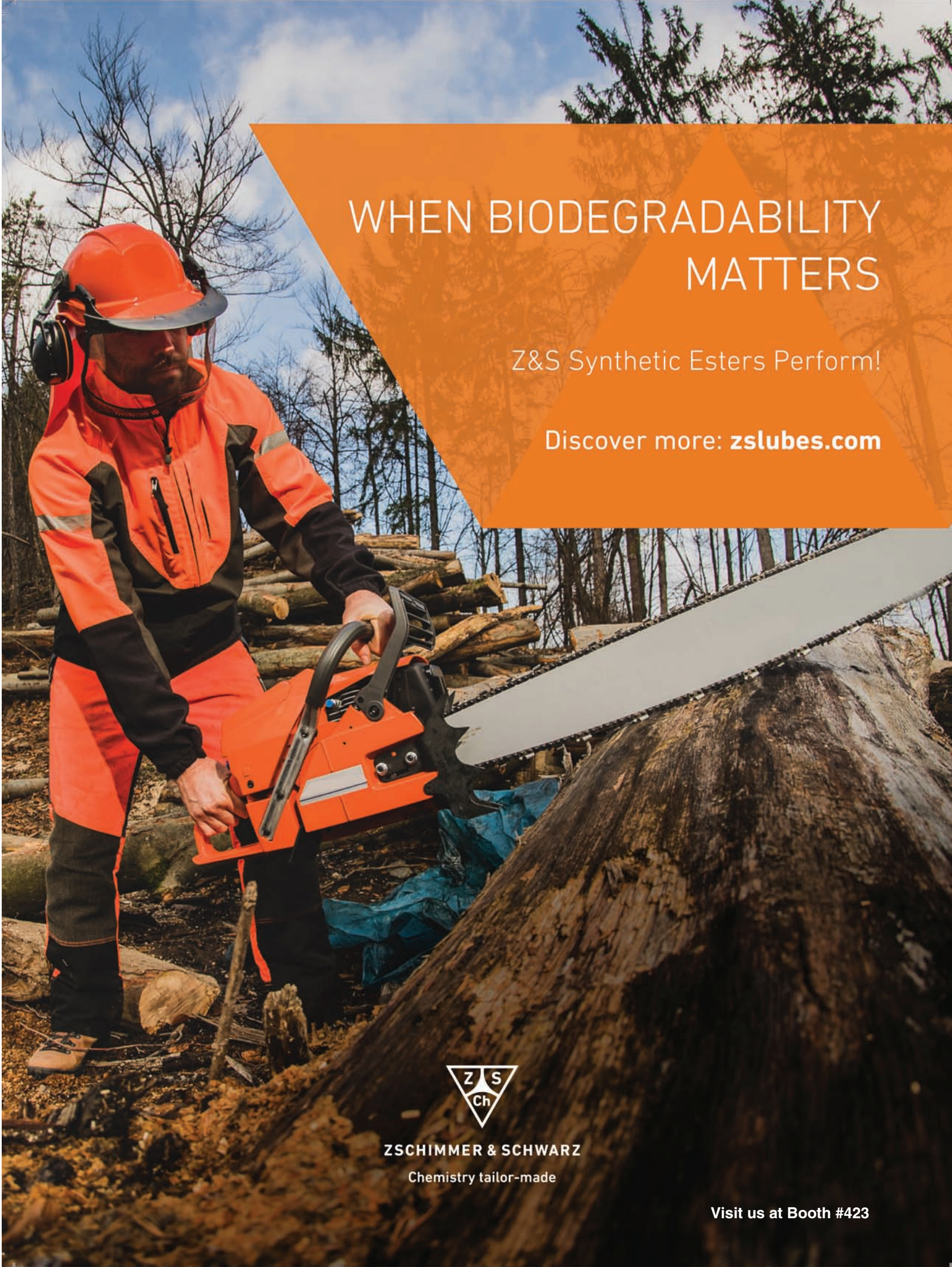
Ionic liquids have gained significant attention as promising lubricant additives due to their unique physicochemical properties. Despite the advantages that it will bring in terms of performance, they are known to be toxic and poorly soluble, limiting their applications. In this study, a novel, sulphur- and halogen-free ionic liquid was developed from renewable materials and designed to possess a tailored structure, enabling enhanced solubility and anti-wear characteristics. Benchmarking revealed that this novel IL demonstrates superior performance in terms of solubility, friction and wear reduction. Further, no corrosion on Cu surfaces was observed. Moreover, the biobased IL showed a substantial reduction in resistivity when used various base oils, showing the potential of minimizing the charge build-up and offering electrostatic discharge protection. Overall, this study presents a novel biobased ionic liquid that exhibits exceptional solubility, anti-wear, and conductivity characteristics

9:40 am – 10:00 am

3984321: Using Molecular Modelling to Anticipate Future Toxicity Classifications of Antioxidants and Identify Safer Compounds

Siegfried Lucazeau, NYCO, Paris, France

A recent change in the toxicity classification of a classical aminic antioxidant has raised questions on the long term innocuity of other aminic antioxidants. Should we expect more classifications in the near or remote future? Do phenolics represent a safer alternative in the long run? How can we anticipate the toxicity features of other antioxidants? Computational chemistry and molecular modelling have been used to estimate the probability of a compound to show toxic features like reprotoxicity, carcinogenicity, mutagenicity or even neurotoxicity. The results of extensive evaluation work tend to show that there may not be safe, long-term solutions in the realm of classical aminic or even phenolic antioxidants. However, it appears like some specific oligomeric compounds do show a favorable toxicity profile. Supporting data from in-vitro and in-vivo testing confirm such observations, giving a high level of confidence in this new, future proof antioxidant species.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10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4004954: Synthesis and Lubricant Properties of Isostearic and Isooleic Based Biolubricants

Brajendra Sharma, Majher Sarker, Helen Ngo, Michael Powell, USDA/ARS/NEA/ERRC, Wyndmoor, PA

The structure of biolubricants impacts physicochemical and tribological properties. Trimethylolpropane (TMP) esters of isostearic and isooleic acids have been synthesized via esterification reactions and characterized using FTIR, NMR, GC-MS, and LC-MS. The presentation will also discuss the lubricant properties including physicochemical and tribological properties. These TMP esters were found to have higher oxidative stability, better antiwear properties, and improved cold flow performance compared to high-oleic sunflower oil (HOSUN) and polyalphaolefins (PAO). These are also miscible with HOSUN and PAO, therefore can be blended to formulate biolubricants.

11:00 am – 11:20 am

4002699: Evaluation of the Interaction Between Biofuels and Lubricating Oils in Achieving IMO's GHG Reduction Goals

Sara Rezaee, Ganesh Natarajan, Aparna Bala, Ramaratnam Visweswaran, Viswa Group, Houston, TX

The IMO's greenhouse gas reduction strategy sets ambitious targets, aiming for a 20% reduction by 2030 and a more aggressive 70% reduction by 2040. In the maritime sector, biodiesel and renewable diesel stand out as promising alternative fuels. They can be readily blended with marine fuels with no or minimal engine infrastructure modifications. Currently, lubricating oils used with biofuels are identical to those for residual fuels. During regular engine operations, it is common for a small volume of incompletely combusted fuel to enter the crankcase and contaminate the system oil. This leads to fuel dilution and potential degradation of lubricating oil quality. Limited information exists on the interaction between lubricants and biofuel blends. This study aims to address this gap through comprehensive testing of operational and performance properties to better understand the interaction between biofuels and lubricating oils, thus assisting informed decision-making.

Session 7F • 101 G

AI and Machine Learning I

Session Chair: Wilfred Tysoe, University of Wisconsin-Milwaukee, Milwaukee, WI

Session Vice Chair: Prathima Nalam, SUNY at Buffalo, Buffalo, NY

8:00 am – 8:40 am

4013926: From Empiricism to Strategy – Targeted Development of Hybrid Plastic-Based Tribological Materials by Combining an Interlocking Experimental Technique with Artificial Neural Networks

Alois Schlarb, RPTU, Kaiserslautern, RPL, Germany

The characterization of tribological systems involves a great deal of effort. If one wants to reproduce a realistic load spectrum to some extent during evaluation of materials, several months of test time must be planned for a single material pairing. This time and cost factor can be significantly reduced by using a new type of intelligent testing technology. However, in order to optimize the tribological pairings, the test results must be appropriately linked to the load spectra. The talk presents a systematic analysis of research results on the use of polymer-based hybrid materials based on the understanding of different wear mechanisms in sliding contact with steel. The use of artificial neural networks in combination with an intelligent experimental technique to reliably generate large amounts of data enables the step from empiricism to strategy (i.e., to systematically optimize materials for tribological applications to different load collectives by their material composition).

8:40 am – 9:00 am

3999074: Transparent Data-Driven Predictions for Formation and Friction of Tribo-Sintered Metal Oxide Antiwear Coatings

Parker LaMascus, Daniel Delghandi, Andrew Jackson, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Marjeta Fusha, Lei Zhang, Robert Wiacek, Pixelligent Technologies, LLC, Baltimore, MD

We utilize machine learning techniques to investigate the key drivers of metal oxide tribocoating formation. Dispersed metal oxide nanocrystals will undergo tribosintering for a variety of tribological conditions, creating durable surface-bound layers that prevent failure. Despite the benefits of metal oxide tribocoatings being seen in a huge diversity of experimental conditions and lubricant formulations, the underlying mechanism of tribosintering is not well understood. We synthesize 6 years' worth of experimental data on metal oxide tribocoatings using machine learning techniques and principles of FAIR (Findable, Accessible, Interoperable, Reusable) data management. We discuss the interpretability and transparency of data-driven predictions, and use these techniques to move toward more rigorous models for the friction and formation of tribosintered metal oxide coatings.

9:00 am – 9:20 am

4002132: Unlocking the Potential of Ensemble Machine Learning in Tribology

Max Marian, Sangharatna Ramteke, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile; Naveen Venkatesh S., Sugumaran Vaithiyanathan, Vellore Institute of Technology, Chennai, India

Ensemble Machine Learning (ML) methods combine the predictions of multiple ML models to enhance overall performance. The presentation will discuss two exemplary cases in the context of tribological applications and condition monitoring. In the first use case, we explore the application of ensemble deep learning methods to extract features from scanning electron microscopy images of wear particles obtained from engine oil. In the second case, we focus on intelligent fault diagnosis from vibration data of dry friction clutch systems. In both cases, we demonstrate how ensemble ML can extract nuanced patterns and relationships in either image or vibration data, leading to more accurate and reliable and robust predictions compared to conventional, individually trained ML algorithms.

9:20 am – 9:40 am

3979196: Machine Learning Assisted Condition Monitoring Using Acoustic Emission Technology on Rotating Mechanical Components

Nikhil Murthy, Vincent Coburn, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Reece Teramoto, Mathworks, Natick, MA

The capability to detect and classify faults in rotating mechanical components would allow for more reliable and less wasteful maintenance practices for many systems. One method of detection is the use of high frequency acoustic emission sensors which has been proven to be a useful method for detecting tribological phenomena however classification of faults with these sensors are difficult and require the interpretation of many complex features within the signal. This study explores machine learning techniques as a method to classify mechanical faults base on the acoustic emission signal. We use acoustic emission data from seeded fault and full life durability experiments performed on a high-pressure fuel pump to train and validate several models. We will discuss the merits of different machine learning methods, the intricacies of training the models, and their applicability in different experimental scenarios.

9:40 am – 10:00 am

4004342: Grinding the Gears of Knowledge – and End-to-End Framework for Tribological Data

Ilia T. Bagov, Christian Greiner, Nikolay Garabedian, Karlsruhe Institute of Technology, Karlsruhe, Germany

Tribological systems are influenced by an enormous number of external factors. That's one of the major reasons why reproducibility of tribological results has been a long-standing challenge. Data science and computational statistics offer a way to handle this complexity. For the success of such approach data quality and the digitalization strategy play key roles. We use the FAIR (Findable, Accessible, Interoperable, and Reusable) data principles as a guide for how to approach the challenges of R&D data. We present an end-to-end solution which enables researchers to describe, store, and connect their datasets. Our suite consists of a terminology service for metadata definition, as well as a module which automatically annotates tribological experiments using these schemas. Additionally, we provide a ready-to-use suite of analytical solutions, which creates reports about the data sets' contents or applies advanced analytical methods such as machine learning to provide additional insights.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

3980467: Gaussian Processes Regression – A Powerful Machine Learning Tool for Elastohydrodynamic Film Thickness Predictions

Wassim Habchi, Lebanese American University, Byblos, Lebanon

A general Machine Learning (ML) framework is presented here for lubricant film thickness predictions in elliptical elastohydrodynamic (EHD) contacts. Finite element (FEM) simulations are used to generate substantial training and testing datasets that are used within the proposed ML framework. The proposed ML model consists of a pre-processing stage in which conventional EHD dimensionless groups are used to minimize the number of inputs to the model. The core of the model is based on Gaussian Process Regression (GPR); a powerful ML regression tool, well-suited for small-sized datasets. The last stage is a post-processing one, in which the output film thicknesses are retrieved. The results reveal the capabilities and potential of ML; producing quasi-instantaneous predictions, that are far more accurate than conventional film thickness analytical formulae. Produced central and minimum film thickness predictions are on average within 0.3% and 1.0% of the FEM results, respectively.

11:00 am – 11:20 am

4005195: Prediction of Slender-like Elastohydrodynamic Contacts by Machine Learning Methods

Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile; Marko Tosic, Thomas Lohner, Technical University of Munich, Garching, Bavaria, Germany

Slender-like elastohydrodynamically lubricated (EHL) contacts are characterized by a small angle between the main lubricant entrainment direction and the major axis of the elliptical contact. In this work, we introduce Machine Learning (ML) approaches, including artificial neural networks, which have been trained using a large dataset obtained from numerical EHL simulations. These ML models were designed to predict the behavior of slender-like EHL contacts with varying directions of lubricant entrainment, along with several other stress-related parameters, such as external load conditions, materials, etc. Thereby, we not only focus on the overall prediction performance and optimizing the ML hyperparameters, but also on achieving highly accurate local predictions within the parameter space and explore approaches to systematically expand and refine the existing dataset with the aim of improving model generalization and local accuracy.

11:20 am – 11:40 am

4000228: Artificial Intelligence in Simulation and Model Generation

Hannes Grillenberger, Andrei Degtiarev, Schaeffler Technologies, Herzogenaurach, Germany

Methods of Artificial Intelligence are increasingly introduced in our daily life of app and internet use. This presentation shows possibilities on the usage of some of these methods in the workflow of CAE tools. Simulation is becoming more and more important and are thus its usage needs to be re-invented in the age of AI. Simulations are crucial in the current design process as they can reduce time and costs. For example, the Bearinx Simulation Suite or the FVA Workbench are tool packages that focus on simulations of bearings in systems. These programs are constantly expanded to better predict bearing performance – like friction, NVH, dynamics, rating life. However, many people need to perform simulations and build simulation chains to fully use this potential. This process should be accelerated and simplified in usage. This could result in faster results, more simulations and possibly higher design quality. AI can make an important contribution to accelerate and simplify this process.

Session 7J • 200 DE

Electric Vehicles VII

Session Chair: Peter Lee, Southwest Research Institute, San Antonio, TX

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

8:00 am – 8:40 am

4036435: Synergies of Surface Finish, Coatings & Additive Chemistry on Friction and Wear at the Piston Ring and Cylinder Liner Interface

Lake Speed, Total Seal, Phoenix, AZ

Utilizing Formula 1 and NASCAR piston ring technology, SwRI and Total Seal tested various piston ring face coatings (5), cylinder liner surface finishes (5) and engine oil additive chemistries (5) to evaluate the impact of each variable on the friction and wear of the piston ring and cylinder liner interface. A Plint TE-77 reciprocating rig was used to test the various piston ring and cylinder liner sections as well as different oils. SEM, EDX and ICP testing were also completed on the used liner sections and used oil samples respectively. Whilst the amount of data generated from these tests was immense, distinct patterns did emerge and certain synergies between variables became clear. By utilizing these synergies, the rate of wear was reduced by over 80% and Friction could be reduced by more than 50%. This presentation will cover the details of which coatings, surface finishes and additive chemistries were evaluated.

8:40 am – 9:00 am

4045651: Lubricants for Electrified Commercial Vehicle (Part I) Benchmarking Transmission Efficiency – An Investigation and Correlation of Bench Tests and Axle Efficiency Rig Test

Hyeok Hahn, Kuldeep Mistry, Chevron Lubricants, Richmond, CA

The shift to electric vehicles demands a complete rethink of driveline hardware. Moreover, electrification is transforming driveline architecture in iterations by different OEMs, as commercial vehicle electrification expands, the performance demands on lubricants increase for this new paradigm of electrified trucks, especially on axle efficiency is critical. Traditional axles prefer higher viscosity fluids (SAE 75W-80 and above) for extended component durability, whereas the oil-cooled e-motor prefers low viscosity fluids (kinematic viscosity at or below 6 centistokes at 100°C) to minimize power loss. Thus, understanding fluid propertiesin both systems is crucial. This study aims to align axle oil and e-motor coolant by screening lubricant formulation with different additives, optimizing composition, and correlating bench and axle efficiency rig tests. The goal is to develop formulations meeting the specific needs of electrified drivetrains for superior performance and efficiency.

9:00 am – 9:20 am

4077174: Lubricant Durability Evaluation in a 15L Hydrogen Internal Combustion Engine

Vickey Kalaskar, Southwest Research Institute, San Antonio, TX

This study implemented an SI, 15L Daimler H2-ICE engine based on their diesel engine platform. This study aimed to understand the lubricant durability aspect. Lubricant durability in H2 ICEs is a novel topic and has not been studied primarily due to continual fueling supply challenges for such extended hours. Nonetheless, SwRI has recently installed a liquid H2 facility capable of supplying H2 without disruptions and is currently running an extended test on the engine to understand the long-term test impacts on lubricant properties. The engine is operated over a modified RMC-SET cycle that is repeated multiple times over the 500-hour timeframe and intermittent oil samples are captured to track lubricant properties as a function of time. Several ASTM methods are used to assess the lubricant samples. The test method development, approach, and generalized test sample results are presented in this presentation.

9:20 am – 9:40 am

4070788: Design and Characterization of Environmentally-Friendly Heat Transfer Liquids for Electric-Vehicle Battery Packs

Ioannis Karathanassis, City, University of London, London, United Kingdom

Electric vehicle battery thermal management systems typically comprise indirect cooling using air or water-glycol configurations. High battery discharge rates can generate sufficient heat to overwhelm indirect cooling necessitating a direct cooling strategy that removes the need for heat transfer across a solid interface. In addition, regulations for reducing use of fluorocarbons, often used as coolants, requires consideration of environmentally friendly fluids with low global warming potential. Herein we report methodologies implemented for the design and assessment of novel oil-based viscoelastic heat-transfer liquids in battery immersion cooling concepts. The correlation of liquid chemistry to the desired rheological and thermal behavior is accomplished utilizing a range of numerical and experimental techniques, ranging from molecular dynamics at atomistic scales validated by rheology measurements to computational fluid mechanics and particle image velocimetry at engineering scales.

9:40 am – 10:00 am

4067009: Investigation of the Discharge Voltage in EV Motor Bearings

Liang Guo, Henk Mol, Thijs Nijdam, Lieuwe de Vries, SKF BV, Houten, Netherlands

As the automotive industry shifts towards electric vehicles (EV), the issue of electric discharge in motor bearings is increasingly gaining attention due to its potential to cause damage on bearing surfaces and even lead to premature failures. The level of discharge damage is directly influenced by the discharge energy, which is dependent on the bearing capacitance and discharge voltages. To gain insights into the discharge voltage within EV motor bearings, electric discharge tests were conducted using in-house developed Tractor equipment, which enables the accurate reproduction of real-world application conditions. The test findings confirm that the discharge voltage follows a probabilistic distribution and is contingent upon the working conditions. The presentation will cover essential aspects, including the design of the test rig, the acquisition and extraction of the discharge signal, the analysis of damaged surfaces and a model explaining the distribution of discharge voltage.

10:00 – 10:40 am – Break

10:40 am – 11:20 am

4090927: A Comprehensive Study Comparing Several Fluids Heat Transfer Performance in an E-Machine

Vickey Kalaskar, Southwest Research Institute, San Antonio, TX

With the advent of electrified vehicles and applications, understanding and improving the heat transfer in e-machines is necessary for efficient operation and to reduce losses. Often, e-machines employ lubricating oils as heat transfer fluids. SwRI used an instrumented e-machine from a renowned heavy-duty manufacturer in this study to understand and compare the heat transfer performance of several fluids. The fluids consisted of a range of market, group III, group IV PAOs, and group V esters. Five unique test conditions were chosen at a fixed shaft power of 75 kW and ranging motor speeds. The heat transfer results were correlated with the fluid's properties such as density, viscosity, specific heat capacity, and thermal conductivity.

11:20 am – 11:40 am

4103987: Innovating Aeration Measurement for Enhanced Vehicle Lubrication Systems

Anthony Khoraych, Advanced Test and Automation Inc., Milton, Ontario, Canada

This presentation introduces an innovative method for measuring lubrication aeration, crucial for optimizing vehicle hydraulic performance and reliability. Traditional methods fail to accurately measure aeration levels, affecting system efficiency and component longevity. A new approach is introduced that uses active flow regulation to maintain constant pressure and flow, enabling precise measurement of undissolvable gases. By overcoming challenges of varying conditions that impact aeration, this research promises improved testing tailored to real-world applications. It aims to make aeration measurement as routine as checking pressure and temperature, enhancing vehicle safety and efficiency. Join us in advancing transportation through pioneering aeration measurement techniques.

Session 7K • 200 B

Wear I

Session Chair: Xue Han, Cummins, Inc., Columbus, IN

Session Vice Chair: Kora Farokhzadeh, DSM Engineering Materials, San Jose, CA

8:00 am – 8:40 am

4002592: PQ versus FerroQ: Understanding In-Service Lubricant Ferrous Debris Quantification

David Swanson, POLARIS Laboratories®, Indianapolis, IN

The venerable kittiwake pQ first saw the light of day back in 1985, invented by the Swansea Tribology Group, and since then, has become an essential component of condition monitoring. One of the more modern developments has been the FerroQ device. How do they compare? In this session, we'll cover the differences, benefits, and limitations when analyzing ferrous content to understand best and obtain valuable data to meet your lubricant analysis objectives.

8:40 am – 9:00 am

4025908: A Digital Twin Approach for Evaluating the Real-Time impact of Ice Collision Loads on Wear Development in Ship's Stern Tube Bearings

Ahmed Saleh, Markus Gilges, Benjamin Lehmann, Georg Jacobs, Dhawal Katre, MSE – Institut für Maschinenelemente und Systementwicklung, RWTH Aachen University, Aachen, Germany

Climate change has led to new shipping routes in polar waters, increasing touristic and commercial traffic in these regions. Subsequently, collisions between ship propellers and sea ice become more frequent. Such collisions subject the propellers to extreme impulse loads, which are then transferred through the propeller shaft to the sliding bearings of the stern tube, particularly to the sliding bearing mounted directly next to the propeller. Extreme bearing loads can lead to mixed friction conditions that cause wear in these sliding bearings and eventually cause them to fail. To prevent damage to sliding bearings, the digital twin is a promising solution that is proving effective in the intelligent maintenance and predictive operation for propulsion systems. Thus, this study aims to establish a digital twin approach based on high-fidelity models. Its primary objective is to evaluate the real-time impact of ice collision loads on the wear development in ship's stern tube bearings.

9:00 am – 9:20 am

3976527: Measuring Wear the Right Way

Mark Malburg, Digital Metrology Solutions, Columbus, IN

The measurement of wear is essential in tribological testing and research. However, the methods commonly used are not well defined and bad practices can lead to costly errors in decision making. In this case study-based talk, we will present modern tools and methods for assessing macro and micro wear based on recent ISO standards for surface analysis.

9:20 am – 9:40 am

4004540: Utilizing Vibration Analysis for Friction Prediction and Scuffing Prevention

Jeng-Haur Horng, Jin-Long Lin, Thi-Na Ta, National Formosa University, Huwei, Yunlin, Taiwan

This study presents a new approach for indirectly predicting friction between machine parts when direct measurement is challenging. Through the analysis of vibration signals, a regression equation is developed to estimate friction coefficients. The results reveal that the friction coefficient increases with the ratio of vibration velocity to sliding velocity (Vv/Vs). Furthermore, this study investigates the influence of different factors, such as the running-in process, vibration, and operating conditions on the occurrence of scuffing failure. Both the experimentally measured friction coefficient and the calculated friction coefficient based on Vv/Vs are employed in the friction power intensity (FPI) criterion to predict the initiation of scuffing. The FPI values obtained using both approaches exhibit similar results, thereby validating the reliability of the proposed methodology.

7K

9:40 am – 10:00 am

4023248: Surface Integrity, Microstructural Evolution and High Temperature Fretting Wear of Wrought and Additively Manufactured Inconel 625 Superalloy

Ali Beheshti, Manisha Tripathy, George Mason University, Fairfax, VA; Lloyd Hackel, Curtiss Wright Surface Technology, Livermore, CA

This presentation covers a microstructural and fretting wear study of LPBF printed and wrought Inconel 625. The wear behavior is evaluated up to 700°C. The samples are studied through advanced surface and material characterization techniques. In addition, samples are subjected to shot peening and laser peening processes to measure the extent of tribological enhancements. Results show that the coefficient of friction of all the samples decreases with an increase in temperature whereas the wear volume is found to increase with temperature. Additively manufactured samples exhibited higher wear at room temperature while showing significantly less wear at elevated temperatures than the wrought samples. Compared to shot peening process, laser peening effect penetrates deeper to the surface with refined microstructures where only laser peened samples show improved tribological properties. Some suggestions to make laser peening effective at elevated temperatures will be also discussed.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4005334: A Quantitative Study of the Galling Resistance of Superalloys Based on Nickel and Cobalt

Michael Fahrmann, Ramanathan Krishnamurthy, Paul Crook, Haynes International, Kokomo, IN

Several Ni-/Co-based superalloys, strengthened via solid solution strengthening (alloys HAYNES 230, 625, HAYNES 25) or via 2nd phase precipitation (alloys HAYNES 282, 718 and Waspaloy) were tested for galling resistance using a variation of the ASTM G98 standard test developed at Haynes International that facilitates comparatively better differentiation in the galling response of superalloys. Wear surface roughness measurements obtained following LASER scanning of the galling wear scars show that the Co-based 25 alloy suffered less galling damage compared to Ni-based alloys. SEM & optical microscopy analysis of wear samples reveal considerable plastic flow/shear localization underneath the surface of the galled Ni-based superalloys compared to the limited deformation suffered by the Co-based 25 alloy, indicating the extent to which a cobalt base benefits the resistance to galling of such materials.

11:00 am – 11:20 am

3979656: Influence of White Etching Layer on Rail Surface to Rail Wear Behavior and Microstructural Transformations with an Attempt to Generate WEL with Laser Beams

Yue Yang, Roger Lewis, The University of Sheffield, Sheffield, United Kingdom; Klaus Six, Virtual Vehicle Research GmbH, Graz, Austria

Hard white etching layers (WEL) that form in wheels and rail due to high temperatures and pressures during a wheel slides, for example, can cause several types of failures during subsequent wheel passage over rail. This research focused on investigating crack initiation and growth at the WEL/substrate boundary and within the WEL. Different formations of WEL were created artificially by controlling modes, energy densities, and operational time of laser treatment on R260 rail material disc samples before they were tested in a rolling/sliding condition against wheel material in twin disc testing. The material surface and microstructure were analyzed post laser treatment and after the twin-disc tests using optical and scanning electron microscopy as well as using nano-hardness measurements. The WEL formation due to the laser treatment was compared with field examples of WEL and damage formation characteristics were analyzed.

11:20 am – 11:40 am

4001910: The Multifunctional Properties of Amine-Neutralized Phosphate Esters Antiwear Additives

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

The friction and wear properties of a new class of amine-neutralized phosphate esters were investigated under different contact conditions. The results in base oils indicate that excellent wear protection can be achieved at a relatively low treat rate and P-content compared to ZDDPs in a wide temperature range. Moreover, the selection of specific amine moieties enables independent optimization of wear and friction performances, while also providing access to multifunctional additives. Furthermore, the amine counterion chemistry influences the compatibility with MoDTC and ZDDP, resulting in some cases in synergistic effects. This combination of attributes makes the investigated additives interesting candidates for a range of lubricant applications. This study further highlights the potential of optimal additive combinations to achieve low ash (or low SAPS) formulations while reducing friction and wear, especially in components that operate across different tribological regimes.

11:40 am – 12:00 pm

Wear Business Meeting

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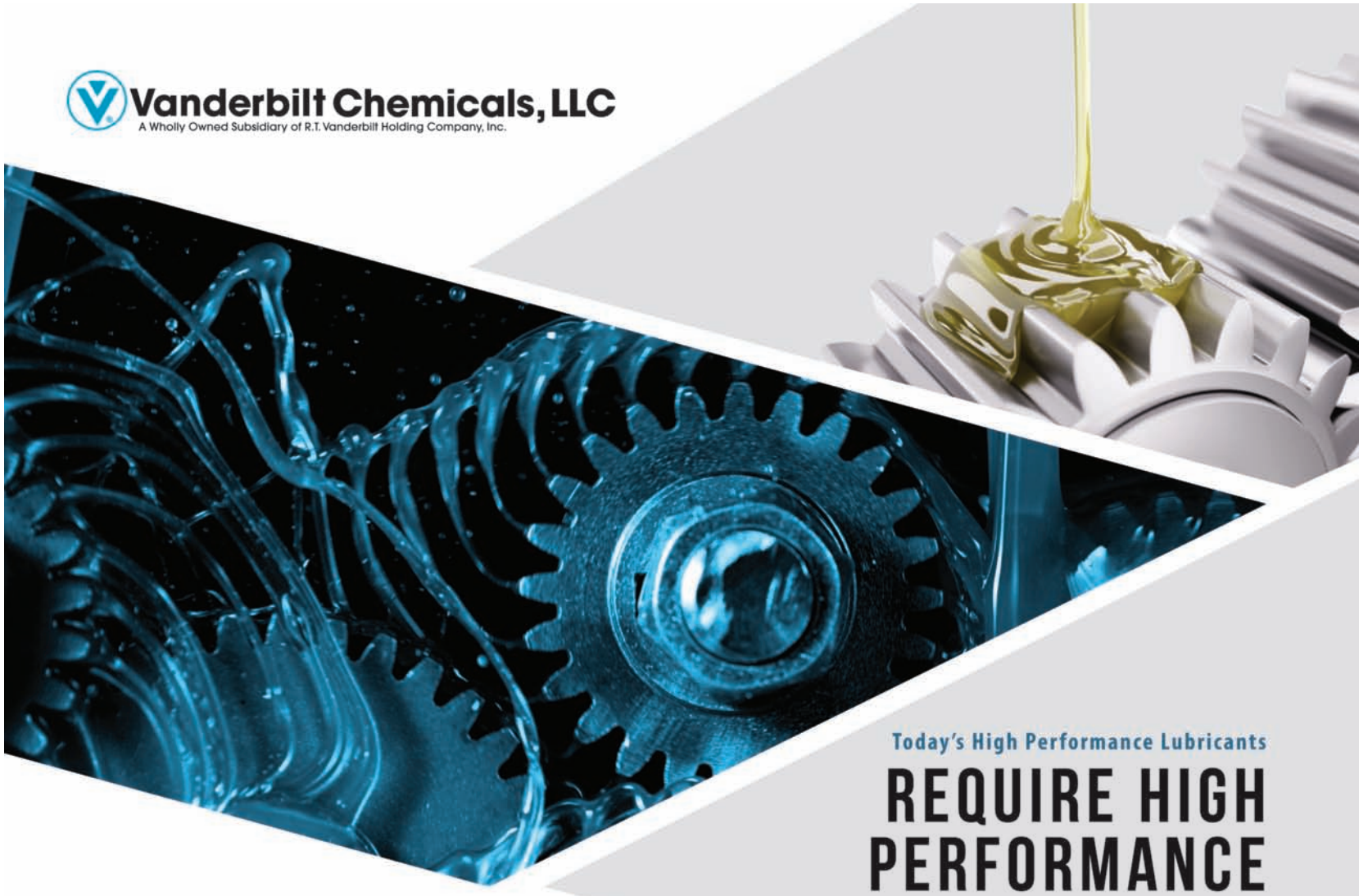

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Session 7L • 200 A

Nonferrous Metals I

Session Chair: Ariane Viat, Constellium Technology Center, Voreppe Cedex, France

Session Vice Chair: Tom Oleksiak, Quaker Houghton, Oswego, IL

8:00 am – 8:40 am

3982448: Simulating Friction in Aluminum Hot Rolling Emulsions on the Lab Scale

Pablo Bakermans, Yao Lu, Bas Smeulders, Quaker Houghton, Uithoorn, Netherlands; Tom Oleksiak, Quaker Houghton, Oswego, IL

Simulating lubrication performance in aluminum hot rolling is a unique challenge. Not only does the process have varying temperatures, reductions and speeds but also the application of the lubricant as an emulsion provides further complications. A roll bite mimicking test approach has been developed which translates field conditions to a lab scale test. The methods have been optimized to differentiate the lubrication challenges in the process. Data has been found to correlate well with pilot mill and field results.

8:40 am – 9:00 am

3985744: Hot Rolling Emulsions and the Importance of Antioxidant Additives

Bill Poynor, Kaiser Aluminum, Spokane Valley, WA; Annie King, Wayne Jenkins, Total Energies, Rockingham, NC

Emulsions are a type of coolant commonly used throughout the aluminum manufacturing process. This presentation will specifically review emulsions used in the Hot Rolling of aluminum and the importance of antioxidant additives. In many hot rolling applications, the emulsion is heated either directly or indirectly to elevated temperatures. In this presentation I will focus on the chemical and physical effects on the in-use emulsion if emulsion chemistry isn't maintained and antioxidants are not managed at an appropriate level.

9:00 am – 9:20 am

4002029: How Metalworking Emulsions Evolve During Usage – The Effects of High Temperatures and Contamination

Ariane Viat, Constellium Technology Center, Voreppe Cedex, France

The aluminum hot rolling process is usually cooled down and lubricated thanks to oil emulsified in water. To both control oil consumption and ensure enough cooling capacity, the emulsion is in a closed circuit and is dimensioned with a large volume. While circulating, the emulsion evolves. Therefore, the emulsion in use has very different properties compared to the fresh emulsion prepared in the lab: firstly, the rolling process generates wear particles that can react at the oil-water interfaces. Secondly, even if the average temperature of the emulsion circuit is kept constant, the emulsion suffers from periodic "heat strokes" during the contact with the hot metallic surfaces. These two phenomena affect the emulsion: enhancing stability through the Pickering effect of the metallic particles, but also destabilizing when the emulsion is subjected to a temperature at which its surfactants are less effective. This paper investigates the balance between these two opposite effects.

9:20 am – 9:40 am

4005002: Lubricity Additives for Fully Synthetic, Nonferrous Formulations

Bradley Arnold, Tiffany Meyers, Clariant, Mont Holly, NC

Metalworking fluid chemistry is ever evolving and changing due to the operation severity, increased nonferrous metal production, and the need for sustainable additives. Metalworking fluid is exposed to various conditions and must withstand harsh conditions during the manufacturing and processing of these nonferrous materials (e.g., rolling, cutting, forming, grinding). Lubricity additives can vary with shape, size, and solubility, contributing to the overall fluid performance. Formulators are looking for additives that simultaneously deliver additional functionalities that help metalworking fluid address today's formulation challenges. This paper will focus on several polyalkylene glycol chemistries as lubricity improvers specific for water-based, oil-free metalworking formulations, and how they perform on nonferrous alloys.

9:40 am – 10:00 am

4005225: The Effects of High Magnesium Metallic Debris on the Lubrication Fluid From Condition Monitoring Testing

Steven Wheeler, Kimberly Williams, Total Energies, Rockingham, NC

Lubricating fluids are formulated to perform at a specific range of physical properties depending on the specific need of the fluid. During the lubricating process, frictional wear introduces metallic debris into the lubricant. Condition monitoring tests can show the effects metallic debris has on the in-use lubricating fluid. This work will add high levels of magnesium to a lubricating fluid and perform condition monitoring tests to show how increased contact with high magnesium alloy over time effects the in-use lubricating fluid.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4025237: Oxidation of Aluminum Hot Rolling Oils – A Case Study

Josef Leimhofer, AMAG Rolling GmbH, Ranshofen, Austria

Oils for the hot rolling of aluminum are complex mixtures of several raw materials. They are used as emulsions for hot rolling, and their composition and properties, which are crucial for their use, are constantly monitored, as they permanently change due to their use: the emulsions are stored at elevated temperature and are exposed to much higher temperatures during hot rolling (i.e., thermally stressed). Due to this thermal stress, the oil phase is prone to oxidation. To prevent oxidation, the rolling oil contains antioxidants. In case the antioxidant function is insufficient, oxidation of the hot rolling oil may start. In this work, the course of an oxidation of a hot rolling oil is shown; the emulsion is investigated with standard analytical techniques as well as with IR- and NMR-spectroscopy. The results given show, which analysis parameters are sensitive for oxidation, which components of the formulation are most prone to oxidation, and which countermeasures can be taken.

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11:00 am – 11:20 am

3988984: New Polymeric Antiwear Additives for Non-Ferrous Metalworking Fluids

Lucas Luz, Solvay, Paulínia, São Paulo, Brazil

The increasing usage of lighter alloys for weight reduction, and more regulations leading towards less phosphorus containing additives are important drivers to develop new additives to enable fluid formulators to overcome some of today's and future most pressing challenges. Polymeric additives containing phosphorus are a great strategy to provide the ideal lubricity and stain protection over the substrate while reducing the phosphorus content of the formulation. This presentation is going to introduce polymeric additives under development and some data to demonstrate how they can be incorporated into metalworking fluids formulation as an option of the classical phosphate ester technology.

11:20 am – 11:40 am

4002579: Bio Source Oil for Aluminum Cold Rolling

Gautier Burette, TotalEnergies, Nanterre, France; Annie King, Total Energies, Linden, NJ

Cold rolling of aluminum sheets requires a lubricant based on highly purified mineral oil. This kind of oil has a low viscosity and a high volatility, which leads to a high consumption by evaporation. This poses an environmental problem because the mineral oil comes from a fossil feed stock. To reduce CO2 emissions in industry, a non-fossil alternative can be used. This is the case with Lubrilam Bio, a base oil technology 100% bio sourced from used cooking oil or vegetable oil. Lubrilam Bio allows reducing the carbon footprint and the energy consumption of the rolling process, without compromising the performance and the specifications. The presentation will make a comparison between the physical properties and tribology measurement that can mimic the aluminum rolling process of Lubrilam Bio versus the mineral oil.

11:40 am – 12:00 pm

3987935: Phosphonate from Used Cooking Oil as Biobased Lubricant

Grigor Bantchev, USDA-ARS, Peoria, IL

Used cooking oil was collected form a local pizza restaurant and reacted with dibutyl phosphite to generate phosphonated used cooking oil. GC-MS, NMR and FTIR confirmed that the radical-initiated reaction run to a high degree of completion (no residual double bonds detected). The phosphonate was tested as an additive in polyalphaolefin (PAO6) in 1 to 5 wt.%. It improved the antiwear performance in both 4-Ball (ASTM D4172) and high-frequency reciprocating rig (modified ASTM D6079, HFRR) tests. In the 4-Ball test, the phosphonate additive resulted in an increase of the coefficient of friction (COF), in the HFRR th COF decreased 20% to 50%. The cloud point and pour points were acceptable at low levels. The results suggest that the phosphonate has a good potential to be used as additive up to 3 wt. %

12:00 pm – 12:30 pm

Nonferrous Metals Business Meeting

Session 8A • 101 B

Materials Tribology VI

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

Session Vice Chair: TBD

1:40 pm – 2:20 pm

4043046: Do Oxide Coatings Strengthen Metal Nanoparticles?

Tevis Jacobs, Ruikang Ding, University of Pittsburgh, Pittsburgh, PA; Ashlie Martini, University of California, Merced, Merced, CA

Technology-relevant nanoparticles deform at low loads, impairing their use in industrial applications. While much is known about the effect of particle size on strength, relatively little is known about the effect of coatings. Prior work has suggested that oxide coatings on the surface could impede deformation mechanisms (dislocation nucleation and surface diffusion), thus strengthening nanoparticles. In this investigation, we coated platinum nanoparticles in silicon oxide and compressed them inside of a transmission electron microscope. We coupled the instantaneous stress and strain measurements to real-time high-resolution video of the shape and structure of the particle. The results reveal the separate but interacting influences of size and surface coating.

2:20 pm – 2:40 pm

4065221: Tribological Performance of ATSP Composites in Simulated Lunar Environments for Sealing Applications

M. Akif Rahman, Andreas Polycarpou, The University of Tulsa, Tulsa, OK

In this study, the tribological performance of advanced Aromatic Thermosetting Copolyester (ATSP) composites as potential sealing materials in extreme lunar environments are investigated. Lunar dust abrasive and temperature variable conditions are applied. We focused on frictional and wear characteristics of ATSP composites against bare steel disks of 52100 and 440c steels under a temperature range of -180°C to 150°C and nitrogen environment. The results show ATSP composites exhibit exceptional wear resistance and low coefficient of friction under extreme conditions. Morphological analysis of the worn surfaces of the steel disks were carried out by Scanning Electron Microscopy (SEM) and 3D laser microscopic scanning. The results provided valuable insight into the wear mechanisms and effectiveness of the sealing applications against dust intrusion and will act as a guideline for developing bearings with long lifetime and desired performance for other extreme condition applications.

2:40 pm – 3:00 pm

4077561: Study of Cast Iron Piston Ring Tribology for Aerospace Application and Discussion of Lessons Learned During Testing

Mary Makowiec, Pratt & Whitney, East Hartford, CT

This presentation will discuss why cast iron piston rings are still used in jet engines and discuss some of the lab-scale testing that was used to understand the wear performance of cast iron in different engine interfaces. In addition, it will review some of the results that were identified during testing that can provide some interesting insight into lightly lubricated surfaces that may cause adhesive wear depending on the surface finish of the parts. Finally, another lesson learned that will be discussed is the sensitivity of the testing results to plate geometry and coating related features.

3:00 pm – 3:20 pm – Break

3:20 pm – 3:40 pm

4014563: Tribological Performance of Advanced Polymers for Hydrogen Environment Applications

Ajinkya Raut, Texas A&M University, College Station, TX; Andreas Polycarpou, The University of Tulsa, Tulsa, OK

The global demand for clean hydrogen energy has increased due to the necessity for sustainable energy sources. To meet this demand, it's crucial to minimize hydrogen loss during production and transportation. Polymers are replacing metals in components with sliding contacts such as valves, bearings, and seals. This shift is driven by their excellent tribological performance, resistance to corrosion, and ability to function without external lubrication. Despite their impressive performance in the air, these polymers haven't undergone sufficient testing in hydrogen environments. In this research, we produce multiple composites using ATSP and PTFE matrices and assess their tribological behavior in a specially designed tribometer within a hydrogen atmosphere. The study reports on friction, wear, and durability of these polymer coatings, and it identifies the most effective tribopairs suitable for bearing materials in hydrogen-related applications.

3:40 pm – 4:00 pm

4000592: The Droplet-Luminescence Excited by Contact Electrification on Polymer Surface

Shicai Zhu, Changhui Song, Yu Tian, Liran Ma, Tsinghua University, Beijing, China

Due to the direct conversion of mechanical force into light, Mechanoluminescence (ML) has been widely investigated in sensors, displays, anticounterfeiting and artificial skin. However, since the duration of luminescence is very short, this presents a great challenge for the visualization of trajectory generated by the motion, resulting in existing trajectory visualization applications frequently require an auxiliary device and extra power supply. With the ML material ZnS:Cu, which also has electroluminescent properties, we have found the interesting luminescence from water droplets flowing through scratches on the surface of a flexible ML composite film, which is called as droplet-luminescence. Contact trajectory visualization can be directly realized by the electric field between polar-liquid droplets and residual triboelectric charges on a rubbed surface without an auxiliary device. This provides an extremely simple but efficient way to store and display motion trajectories.

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Session 8C • 101 D

Metalworking Fluids II

Session Chair: Stephanie Cole, Münzing North America, LP, Bloomfield, NJ

Session Vice Chairs: Nicole Clarkson, Barentz North America LLC, Lisle, IL & Stefanie Velez, Münzing Chemie GmbH, Bloomfield, NJ

1:40 pm – 2:00 pm

4000605: Investigation of Tribological Properties of Metalworking Fluid Lubricity Additives on Different Metals

Yixing Philip Zhao, Quaker Houghton, Conshohocken, PA

The major driver of new product development in MWF is the sustainability and green chemistry. The important attributes of sustainability are high productivity, energy efficiency, and good tool life, which require formulators to use proper lubricity additives for machining efficiency. The trend is also going towards using additives from renewable sources. Thus, MWF formulators need more understanding of vegetable-based additives. In this presentation, we will report some tribology test results with different types of EP and non-EP lubricity additives on four common metals. We have found that the lubricity can have big changes not only with the additive chemistries, but also on different metal types. The surface roughness values (Sa and Sz) of metal scares from testing were also obtained by profilometer measurements. It is very interesting to see some additives may have low friction forces, but not necessarily generate good finish.

2:00 pm – 2:20 pm

4002646: The Role of Polymers in Quenching Fluids

Jacob Scherger, Functional Products Inc., Macedonia, OH

Quenching fluids are very important in the metal forming process. They control the speed at which a formed metal part is cooled, which in turn helps to control properties and performance of the finished part. Polymer additives play a crucial role in determining the quench rate provided by a fluid and thereby the hardness and ductility of the metal part. Polymers act by altering the rheology and wetting properties of a fluid to encourage heat transfer from a surface. Here the effect of polymer additives and polymer accelerators are examined in straight oil quenching fluid formulations. Different polymer molecular weights and chemistries are compared in terms of the cooling rates they provide.

2:20 pm – 2:40 pm

4002677: Mapping Extreme Pressure Additive Activation from Lathe Machining on High Strength Steel

Ryan Weber, Gabe Kirsch, Britt Minch, John Hogan, Jeanne Petko, Glenn Black, Johnnie Thomlison, The Lubrizol Corporation, Wickliffe, OH

Various industries, including automotive and aerospace, require the use of high strength alloys that are more difficult to machine. Metalworking fluids designed for such alloys require a wide range of lubricity additives including boundary lubricants, antiwear, and extreme pressure (EP) additives to extend tool life and achieve superior surface finish. In this talk, we explore the surface chemistry of metal chips and machined workpieces from a lathe facing operation on high strength steel utilizing three fluids containing a polymeric ester boundary lubricant used in tandem with either phosphate ester or sulfurized olefin EP additives. Chips and workpiece surfaces are imaged using scanning electron

microscopy with energy-dispersive x-ray (SEM-EDX) analysis, demonstrating evidence of effective thermal activation of the EP additives during cutting.

2:40 pm – 3:00 pm

4002705: Boundary Lubricant Additive Multimetal Optimization for AISI 1018 Steel, Aluminum, and Copper Alloys Using Twist Compression Tests (TCT) and DOE

Ted McClure, Alexes Morgan, Sea-Land Chemical Company, Cleveland, OH

Electric vehicles (EV) require changes in the way vehicles are manufactured. Materials and manufacturing processes continue to evolve in response to these changing requirements. Electric current and thermal management are important considerations, contributing to increasing use of copper and aluminum. Metalworking fluid end users require fluids performing with multiple metals, for improved efficiency and inventory control. The Twist Compression Test (TCT) is used to evaluate the boundary lubrication performance and galling resistance of material couples. Previous work, comparing boundary additive responses, using TCT with AA5182-0 and C110 HO2, is extended to include AISI 1018 steel. High performing additives are identified, and combinations evaluated using mixture DOE. Boundary additives evaluated include polymers, esters, fatty acids, alcohols, and amines. The aim is to provide useful data and processes for formulation of lubricants in applications involving multiple metals.

3:00 pm – 3:20 pm – Break

3:20 pm – 3:40 pm

4005611: Increasing Metalworking Fluid Performance with Amino Alcohols and Alkanolamides

Kathleen Havelka, Andrew Schiffer, Maxwell Petit, Advancion Corporation, Buffalo Grove, IL

Through covalent coupling of a fatty acid with an amino alcohol, a fatty acid AMP alkanolamide emulsifier with high bio-content was developed, expanding the formulating options for water dispersible fluids containing carboxylic acids and amino alcohols. Formulations that contain both ionic and covalent coupling of carboxylic acids and amino alcohols show excellent heat removal and good lubrication properties. A systematic study will be presented demonstrating the use of fatty acid AMP alkanolamide, conventional emulsifiers and other fatty acid alkanolamides. The structure-property relationships developed will explain the benefits seen with AMP alkanolamide and serve as a formulating model to develop high-performing and sustainable metal - working fluids. The unique multifunctionality of AMP alkanolamide in combination with amino alcohols offers new potential in optimizing next-generation metalworking fluids to produce defect-free parts while minimizing operating costs and reducing waste.

3:40 pm – 4:00 pm

4004910: MWF Formulations and Performance Testing Using Estolides

Marlon Lutz, Biosynthetic Technologies, Indianapolis, IN

Metalworking fluids are required to enable specific metalworking operations on many types of metal workpieces. MWF formulations need to be specifically designed for a given metalworking operation such as cutting/grinding, drawing/stamping, tapping, milling, drilling, and cleaning. Biobased ingredients are typically added to formulations to provide additional lubrication during the metalworking operation, enhance the tool life and efficiency, and improve surface finish. Estolides serve as an exceptional biobased choice for delivering high performance, improved worker health and safety and increased sustainability efforts for the formulator. We have demonstrated the use of estolides in metalworking fluid protype formulations geared toward cutting and grinding, drawing and stamping, and general machining operations. We'll discuss the performance testing results of estolide containing formulations versus conventional base fluid formulations used in metalworking operations.

4:00 pm – 4:20 pm

4014426: Overview on Tribometric Screening Methods for Forming and Metalworking

Ameneh Schneider, Optimol Instruments, München, Germany

The increase in range of materials used in forming technology needs consequently tribological optimization in the forming processes and this called for new tribometric methodologies. This presentation will provide an overview of the possibilities of tribological testing of materials and lubricant in lab scale by choosing the test condition and geometries close to the chosen metal-forming process with SRV tribometer. These methodologies illuminate test conditions from cold to hot forming (up to 700°C) as well as for testing with water-based metalworking fluids. Finally, it will discuss how the new tribological methodologies supported the industry to optimize the formulation of MWFs as well as made it possible to form high strength materials that are difficult to form. This will help to cope with the upcoming challenges such as lightweight design and improved fuel economy.

4:20 pm – 4:40 pm

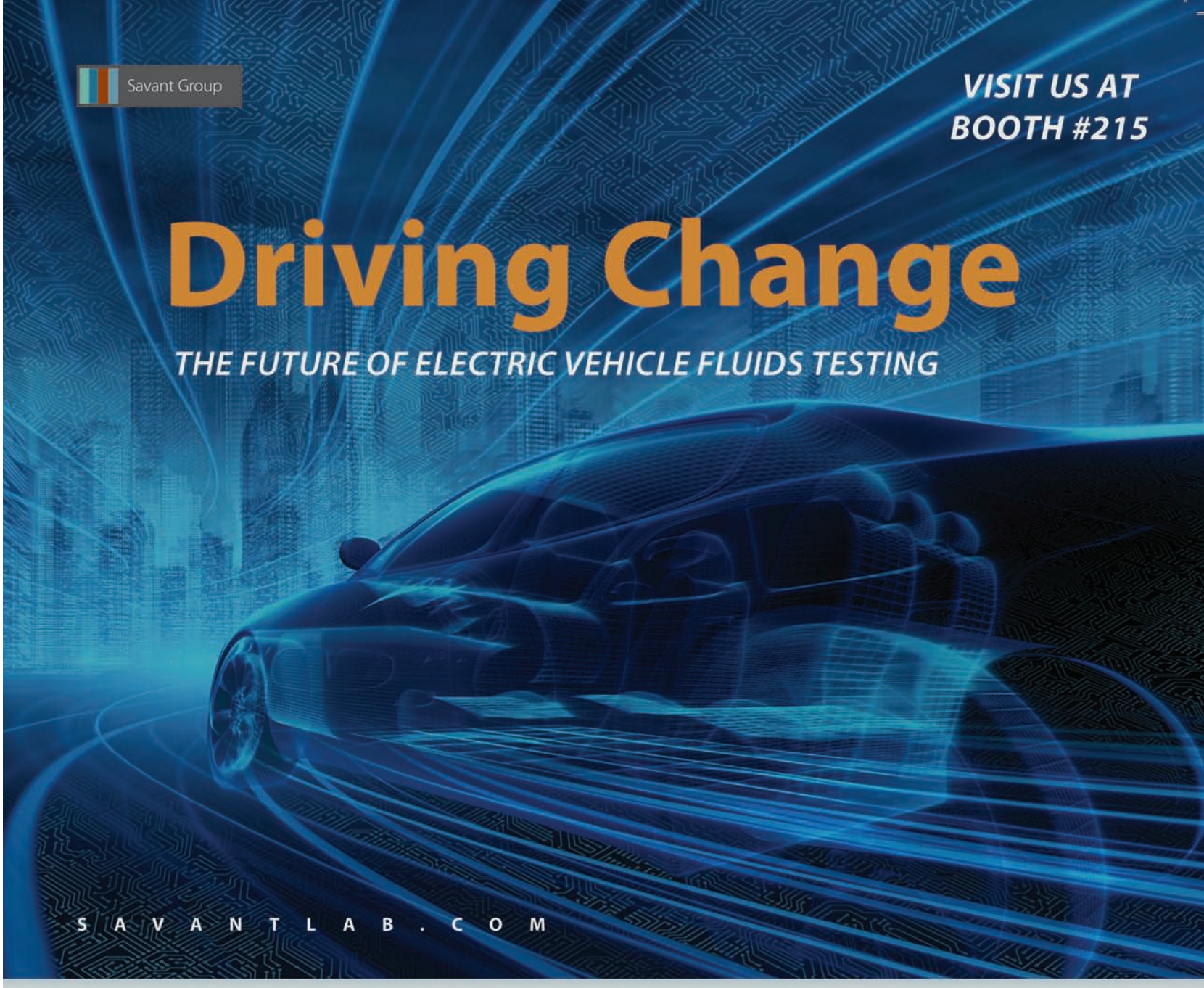
4094439: Fluid Fusion- Enhancing Performance and Longevity with Hybridization Sustainable Metalworking Fluids

Jesse Ziobro, Stockton University, Houston, TX

This presentation outlines the forefront of sustainable metalworking utilizing modern hybridized formulary. The focus is on enhancing performance, stability and longevity of a metalworking fluid utilizing hybrid formulations. By merging traditional and sustainable technologies hybridized formulations mark a significant advancement in high performance machining. Through in-depth examination of key performance properties (e.g., 4 Ball EP and AW, Falex Pin and V block (elliptical), RTech cutting tribometer, PDSC, etc.) we will reveal the transformative new sustainable hybrid technology. The presentation will shed light on the impact sustainable formulations provide in advancing innovative and sustainable metalworking fluids.

4:40 pm – 5:00 pm

Metalworking Fluids Business Meeting



The transportation industry and its fluids are evolving, and Savant Labs are at the forefront of electric vehicle drivetrain fluids testing. Developing and testing fluids engineered to meet the specific requirements for electric vehicles is critical to providing protection and assurance. The lubrication and cooling demands of electrical systems present new challenges to fluid formulations, primarily copper corrosion and potential for conductive deposit formation in EV powertrains. Savant Labs run a full slate of fluid property testing and can perform two crucial tests that have been uniquely developed to address these emerging concerns:

Conductive Deposit Test (CDT) per ASTM D8544: Reveals destructive conductive deposits forming from the chemical reaction of the lubricating fluid and copper at elevated temperatures under low voltage, electrified conditions, both in the fluid and vapor state.

Wire Corrosion Test (WCT): Identifies the rate of corrosion and depletion of copper on the test wire in both fluid and vapor states.

As leaders in lubrication testing and research, Savant Labs can help you prepare for the future as you develop fluids that meet the expanding EV industry requirements.

Visit **SavantLab.com** to learn more.

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WCT : Savant Labs, in partnership with Lubrizol, is exclusive test provider in North America ■ CDT: Equipment developed and patented by Tannas

A WORLD OF LUBRICATION UNDERSTANDING

Session 8D • 101 E

Rolling Element Bearings III

Session Chair: Travis Shive, SKF USA Inc., Lansdale, PA

Session Vice Chair: Kushagra Singh, Purdue University, West Lafayette, IN

1:40 pm – 2:20 pm

4005653: Propagation of Surface-Initiated Fatigue Cracks and its Significance to Fatigue Life Predictions

Amir Kadiric, Pawel Rycerz, Bjoern Kunzelmann, Imperial College London, London, United Kingdom

This talk explores the propagation behavior of surface-initiated contact fatigue cracks using recent experimental and numerical results and discusses the significance of this in terms of our ability to better predict contact fatigue lifetimes. A method employing a triple disc fatigue machine in combination with a novel crack sensor, which allows us to generate and grow surface fatigue cracks and quantify their propagation rates, is first described. The results are shown to explore the influence of several parameters, including surface roughness, friction, type of steel and Hertz pressure on crack propagation rates. An accompanying LEFM crack model is used to study the evolution of stress intensity factors during crack over-rolling. The trends in crack propagation rates are then discussed in terms of our ability to predict the crack growth, and hence eventual failure, starting from an initial fault, in a manner that is commonly employed in structural fatigue.

2:20 pm – 2:40 pm

4000229: Automated Cage Optimization Using Machine Learning

Hannes Grillenberger, Schaeffler Technologies, Herzogenaurach, Germany

Cages are important components of rolling element bearings. Due to their high degree of freedom, they are subjected to dynamics which are influenced by many factors. Some simulation programs can capture the complex movements and effects, but typically they take a long time or use too many empirical assumptions to find a proper physical based design. To find an optimum design for all operation conditions is too extensive by these physical simulations only. The presentation shows a workflow how to automatically optimize a cage design on the robustness against cage instability. By switching between physical and data driven machine learning models the optimization task can be fulfilled not only for one operating condition, but for all operating condition of the bearing. The approach reduces the simulation time needed by more than three orders of magnitude compared to a purely physical simulation – without essentially loosing quality and thus can be used in the design process.

2:40 pm – 3:00 pm

4002170: Bearing Rotor Housing System Modelling

Abbas Shafiee, Farshid Sadeghi, Purdue University, West Lafayette, IN; Matthew G. Wilmer, The Timken Company, North Canton, OH

Most traditional bearing models have conventionally assumed that the bearing inner race is fixed to a rigid shaft and the outer race is fixed to a rigid ground. In practical applications, bearings are often integral parts of rotating machinery, where the flexibility of rotor and housing components can introduce displacements and misalignments that exert a substantial impact on bearing performance. In order to address these shortcomings and improve on the versatility of bearing simulations, the previously developed ADAMS dynamic bearing model was integrated with flexible rotor and housing models. This combined bearing-rotor-housing system enables the exploration of how the housing and rotor flexibility influence bearing dynamics and provides valuable insights into the operation of the bearing and can lead to optimizing bearing system designs.

3:00 pm – 3:20 pm – Break

3:20 pm – 3:40 pm

4005450: Modeling Raw Material CO_2 Emissions to Reduce the Bearing Industry Carbon Footprint

Samantha Melnik, Bryan Allison, SKF, Falconer, NY; Paul Lynch, Penn State Behrend, Erie, PA

194 countries signed the Paris Agreement to make a concerted global effort to reduce climate change. Iron and steelmaking contribute approximately 7% of the worldwide CO2 emissions. Rolling element bearings are primarily composed of high strength steel and a substantial portion of the emissions attributable to bearings are due to the manufacture of bearing steel including mining, ironmaking, and steelmaking operations. There are varying paths to producing steel, thus leading to varying emissions factors associated to the final product. Through the informed selection of raw materials and processes, the total emissions attributed to bearing manufacturing can be greatly decreased. In this presentation, a new method to estimate the emissions generated during steelmaking will be discussed.

3:40 pm – 4:00 pm

3980974: A Fast and Efficient Calculation Method for Pitch Bearing – Blade Assembly Subjected to External Loads

Rémy Duquesne, Daniel Nelias, Sébastien Morterolle, Contact and Structural Mechanics Laboratory (LaMCoS), Lyon, France

Pitch bearings are components used in wind turbines or airplane propellers to make the link between the hub and the blade. The excentric aerodynamic forces lead to high loads and overturning moments on the bearings. It is therefore important to use tools that can predict the level of stress that each rolling element will have to withstand. In our work, we propose an efficient bearing calculation method adapted to pitch bearings that will solve the equilibrium of a bearing assembly supporting a flexible blade. The interest of our method is that the external loads due to aerodynamic and centrifugal effects are prescribed on the blade, and then distributed between the bearings. In our approach, we suggest considering the governing equation of the blade bending, which will allow us to establish additional relations between the unknowns and then further solve the initially statically indeterminate problem with a classical Newton-Raphson algorithm.

4:00 pm – 4:20 pm

4001192: Frictional Torque Investigations of Radially Preloaded Cylindrical Roller Bearings

Tom Wittek, Leibniz University Hannover, Garbsen, Germany

By distributing the external load over a higher number of rolling elements, the maximum rolling element force can be reduced and thus the fatigue life increased. In addition, the unloaded zone is reduced, which reduces slip damage. The increase of the load zone can be realized by reducing the bearing clearance to negative values. Each additionally loaded rolling element worsens the efficiency due to additional frictional losses. The balance between maximum fatigue life and friction

minimization can thus be adjusted as a function of the mounting clearance. To detect an ideal mounting clearance, the operating behavior of test bearings with different bearing clearances was reproduced theoretically and experimentally. Using the calculation model developed, it was found that an optimum mounting clearance exists. With the aid of this calculation method, bearing arrangements can be designed in a resource-efficient manner and thus contribute to the sustainable design of technical systems.

4:20 pm – 4:40 pm

4003498: Effect of Cage Wear on Lifetime of Cryogenic Bearing Under Various Load Conditions

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

Cryogenic ball bearings are used in LNG pumps, and rocket turbopumps is a self-lubricating bearing. The appropriate thickness of transfer film on the ball and raceway surfaces is important for adequate lubrication and stable operation of the bearing. Excessive or too little cage wear can cause premature failure. However, the appropriate cage wear to ensure long life is unknown. In this research, accelerated life tests (ALT) of ball bearings were performed with 4 different stress levels. We analyzed the correlation between the cage wear and the life of cryogenic ball bearing. The analysis showed that the life of the bearing decreased as the wear of the cage increased. Test bearings with relatively long lives had a wear rate below a certain level. Additionally, it was found that the wear rate decreases as the dimensionless internal clearance increases.

Session 8E • 101 F

Environmentally Friendly Fluids III

Session Chair: Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA

Session Vice Chair: Selim Erhan, Process Oils, Inc., Trout Valley, IL

1:40 pm – 2:20 pm

3987440: Sustainable High-Performance Lubricants & Greases – Eliminating Hazards and Enhancing Performance Using New Technologies of Non-Hazardous Antiwear and Antioxidant Additives

Gregoire Herve, NYCO, Paris, France

Sustainability is increasingly vital in technological developments, with final users seeking nonhazardous materials that pose minimal environmental and safety risks. Evolving regulations are unveiling the true toxicity of various chemicals, particularly affecting performance additives, transcending industries. The quest for effective and safer additive chemistries remains a big challenge for the industry. Our work tackles this challenge head-on through an innovative approach: a holistic assessment integrating modeling and practical experiments on anti-wear and antioxidant additives. The result? Lubricants, greases included, that not only excel in performance but are also safer and risk-free. Finally, our thermal and tribological evaluations demonstrate superiority over existing market lubricants. This research demonstrates the harmonious coexistence of sustainability and performance, aligning with industry and environmental needs.

2:20 pm – 2:40 pm

4026812: Lubricant Requirements for Low GWP Refrigerants in HVAC&R Applications.

Wasim Akram, Morgan Leehey, Trane Technologies, Bloomington, MN

Due to environmental regulations, HVAC&R (heating, ventilation, air conditioning, and refrigeration) equipment manufacturers are required to transition products to lower global warming potential (GWP) fluids. In general, HVAC&R systems have unique lubricant requirements, however new refrigerant chemistries are posing additional challenges. Hydrofluoroolefin (HFO) chemistries interact with existing lubricant chemistries differently than traditional hydrofluorocarbon (HFC) refrigerants, leading to lubrication challenges as well as potential concerns with chemical stability and material compatibility. As applications of these systems are expanded to higher temperature ranges, these challenges become more significant. This presentation will explore the requirements and test methods utilized to evaluate a lubricant for use in these systems.

2:40 pm – 3:00 pm

4002561: Sustainable Sourcing and Traceable Mass Balance – Unveiling the Path to Environmentally Friendly Fluids

Shubhamita Basu, Alisha Bloodworth, Dominic Petruccio, Perstorp Polyols, Toledo, OH; Elisa Swanson-Parbäck, Valentina Serra-Holm, Perstorp AB, Malmö, Sweden, Sweden

The industry is experiencing a transformation driven by a shared commitment to high-performing lubricants and eco-conscious practices, leading to an increasing demand for environmentally friendly fluids. This paper explores the multifaceted concept, encompassing in-use performance and environmental attributes, with a particular focus on the selection of raw materials. In this context, transparency plays a pivotal role and is crucial to avoid 'greenwashing' and to establish trust in value chains. This paper underscores how the procurement of lubricant raw materials from recycled and renewable sources can profoundly influence sustainability metrics, aligning with environmental stewardship and substantiating a reduced carbon footprint. As environmental regulations evolve and consumer expectations rise, this paper emphasizes the importance of the adoption of certified traceable mass balance as a globally recognized approach that serves as the linchpin for a sustainable transition.

3:00 pm – 3:20 pm – Break

Session 8F • 101 G

AI and Machine Learning II

Session Chair: Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile

Session Vice Chair: Nikolay Garabedian, Karlsruhe Institute of Technology, Karlsruhe, Germany

1:40 pm – 2:20 pm

4027551: Navigating the Microscopic World – Autonomous Measurements Powered by Machine Learning

Yongtao Liu, Rama Vasudevan, Maxim Ziatdinov, Oak Ridge National Laboratory, Oak Ridge, TN; Sergei Kalinin, The University of Tennessee, Knoxville, TN

Here we developed ML-driven automated and autonomous scanning probe microscopy (SPM), enabling the automatic discovery of material functionalities and mechanisms. We demonstrate the application of active learning and hypothesis learning-driven SPM by investigating ferroelectric materials, including studies of domain wall dynamics, domain switching mechanisms, and the relationship between domain structure and local properties. Hypothesis learning empowers the microscope to autonomously deduce the physical laws governing material responses. While we applied these methodologies in a specific class of materials, they hold potential for broader applications across various characterization approaches and techniques, such as characterizing stiffness and adhesions via force-distance curves in SPM.

Acknowledgments: This work was performed at the Center for Nanophase Materials Sciences, a US Department of Energy Office of Science User Facility.

2:20 pm – 2:40 pm

4004369: Application of Machine Learning to Pour Point Prediction of Transesterified Bio-oils for Biolubricant Production

Guillermo Díez Valbuena, Alejandro García Tuero, Jorge Díez Peláez, Eduardo Rodríguez Ordóñez, Antolín Hernández Battez, University of Oviedo, Gijón, Asturias, Spain

The Sustainable Development Goals have raised awareness of the climatological situation of our planet, so a decarbonization process has begun to reduce the carbon impact of products such as fuels or lubricants. Some of the most demanding tribological properties for new biofuels and biolubricants are those that affect the cold flow of fluids. Pour point is the minimum temperature at which a fluid can flow and predicting this property can be used as a pre-screening step to filter out bio-oils as candidates for the biolubricant production. Machine learning techniques can help find complex correlations between feedstock composition and final product pour point. This work presents models for predicting pour point from the fatty acid methyl ester distribution of the feedstock oil, a study of the performance of the models using metrics such as mean absolute error and coefficient of determination, and a study of the importance of the different attributes in making the prediction.

3:00 pm – 3:20 pm – Break

Session 8K • 200 B

Wear II

Session Chair: Kora Farokhzadeh, DSM Engineering Materials, San Jose, CA

Session Vice Chair: Xue Han, Cummins, Inc., Columbus, IN

1:40 pm – 2:00 pm

4002989: Tribological Properties of Lubricating Oils Derived From Plastic Wastes Under Electrified Conditions

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

Plastic pollution is a significant environmental issue that has led to global efforts to reduce its harmful effects. Here we present the tribological properties of a high-quality lubricant upcycled from plastic wastes. More specifically, using a ball on disk tribometer and a variety of surface and structure analytical techniques, we elucidate the friction and wear characteristics of such oil under normal and electrified conditions. The results confirmed that lubricant derived from plastic oil showed much superior wear performances than conventional oils due to the formation of a carbon-rich tribofilm. We also observed a very unique wear transition taking place with respect to the extent of electrical current passing through the contact interface suggesting that electricity can be used to control or manipulate the mode or mechanism of wear.

2:00 pm – 2:20 pm

4004031: Effect of High-Pressure Hydrogen Gas on the Friction and Wear of PTFE Composite

Kotaro Ishii, Hironori Shinmori, Yoshinori Sawae, Takehiro Morita, Kyushu University, Fukuoka, Japan; Hikaru Hashimoto, Ayako Aoyagi, Shigenobu Honda, NOK Corporation, Fujisawa, Kanagawa, Japan

In this study, a friction and wear test was conducted to evaluate the tribological property of PTFE composite under different hydrogen gas pressures. Pin-on-disk tribometers were installed into a high-purity hydrogen gas chamber and a high-pressure hydrogen gas environment chamber, and gas pressures were 0.1 and 40 MPa, respectively. PTFE composite containing bronze and carbon fiber was prepared as the pin, and SUS 316L was prepared as a disk. From the results, the constant friction coefficient was observed at 40 MPa gas pressure, while the friction coefficient gradually decreased and reached 0.05 at 0.1 MPa gas pressure. Raman and XPS analysis indicated carbon-based transfer film formed on the disk surface at 0.1 MPa. On the other hand, PTFE-based transfer film was formed on the disk at 40 MPa. Analysis data revealed that differences in the composition of the transfer film led to the difference in friction and wear behavior.

2:20 pm – 2:40 pm

4004248: Effects of Trace Moisture on Tribo-Film Formation, Friction and Wear of CF-filled PTFE in Hydrogen Under High Contact Pressure Condition

Qian Chen, Takehiro Morita, Yoshinori Sawae, Kyushu University, Fukuoka, Fukuoka, Japan; Kanao Fukuda, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

Carbon fiber (CF) filled polytetrafluoroethylene (PTFE) composites are widely used as sealing material for reciprocating gas compressors. This study aims to investigate the effects of trace moisture content in hydrogen gas on tribological behavior of CF-filled PTFE composites under high contact pressure condition. Sliding tests were carried out on pin-on-disk tribometer installed within an atmosphere-controlled chamber using a composite pin and a stainless-steel disk. The moisture content of the hydrogen gas environment was controlled from 200 to 1000 ppb while the contact pressure and sliding speed were set at 7 MPa and 2 m/s, respectively. The results showed tribological behavior was significantly affected by trace moisture content. Both specific wear rates of the composite pin and coefficient of friction tended to increase as the water content increased. Furthermore, transfer films with different chemical composition were observed atop the disk surfaces at different moisture levels.

2:40 pm – 3:00 pm

4004395: Effect of the Accelerated Cryogenic Ageing on Mechanical and Tribological Properties of PEEK and PI Composites

Nazanin Emami, Maksim Nikonovich, Luleå University of Technology, Luleå, Sweden; Amilcar Ramalho, University of Coimbra, Coimbra, Portugal

Recent advances in energy and transport industries have increased the demand on extreme working environments like low-temperature vacuum and exposure to cryogenic liquids such as liquid nitrogen and hydrogen, increasing the need for materials capable to perform under extreme conditions. In this study, the mechanical and tribological behavior of commercial PEEK and PI composites was examined after cycling-aging in liquid nitrogen and at 40oC in air. Results indicate that aging impacts mechanical and tribological performance of the tested composites. Samples weight, stiffness, and friction coefficients slightly changed. With increased number of cycles, fracture toughness and wear resistance of some materials showed significant decrease, 100% and 400%, respectively, caused by matrix embrittlement and/or thermal stresses at filler/matrix interface. While wear mechanisms were not significantly altered compared to non-aged materials, abrasive and fatigue wear became more pronounced.

3:00 pm – 3:20 pm – Break

3:20 pm – 3:40 pm

4000684: Study on the Friction Temperature Field and Wear Characteristics of Polymer Materials

Yichun Xia, Tsinghua University, Beijing, China

The friction and wear characteristics of polymer materials are significantly affected by the friction temperature. This study focuses on the surface contact friction process between three polymer materials and steel. Firstly, friction and wear experiments under different conditions were designed and the friction temperature was measured. Secondly, two models for simulating friction temperature have been developed: the constant heat partitioning model and the total heat flux model. Comparing the simulation and experimental results, it was found that the friction temperature and heat partitioning coefficient obtained by the total heat flux method are more consistent with the experimental results, and the heat partitioning coefficient is not a constant value during the friction process. Under different experimental conditions, the wear characteristics of the three polymer materials are different, and the friction temperature significantly affects the wear form of the polymer.

3:40 pm – 4:00 pm

4000274: A Strategy to Enhance the Wear Resistance of PTFE/Kevlar Fabric Liner via Oil-Containing Microcapsules

Weitang Xiong, Tsinghua University, Beijing, China

It has been an everlasting challenge to enhance the wear resistance of PTFE/Kevlar fabrics, facing demanding service conditions and reliability requirement of self-lubricating spherical plain bearings. Utilizing microcapsule technology, the liquid lubricants encapsulated by solid materials can be dispersed into fabric matrix, so a better lubricating effect is expected to achieve. In this work, an innovative strategy to prepare oil-containing microcapsules was reported. The prepared oil-containing hollow silicon microcapsules (Oil@SiO2) and oil-containing hollow carbon nanocapsules (Oil@C) were used as additives to enhance the wear resistance of PTFE/Kevlar fabrics, respectively. The friction coefficient of modified fabrics decreased by 24%, while the service life increased by 127%, compared with that of pure fabrics. Besides, the transfer film on friction counterpart and morphology of wear scar were analyzed to reveal the enhancement mechanism and self-lubricating mechanism.

4:00 pm – 4:20 pm

3998295: The Impact Corrosion Has on the Particle Wear Emissions Generated From Different Brake Rotor Material

Ishmaeel Ghouri, University of Leeds, Rochdale, United Kingdom

The new Euro 7 standard is set to be in place by 2025, which will be the first legislation that will cap the emissions produced by a brake system. This has caused brake manufacturers to find alternative solutions to reduce the emissions generated from the conventional grey cast iron (GCI) friction brake system. With electric vehicles (EVs) becoming the future of the modern vehicle, their regenerative braking system will cause the friction brakes not to be used as frequently as for an internal engine combustion vehicle. This may lead to a build-up of corrosion on the brake rotor that may not only affect the performance and service life of the brakes but also increase particle wear emission when braking. Aluminum metal matrix composite (Al-MMC) and plasma electrolytic oxidation (PEO) coated rotors could be an alternative solution to reduce the risk of corrosion failure, possibly produce lower brake emissions and also improve the efficiency of the EV by reducing its un-sprung mass.

2024 STLE Annual Meeting Posters

Exhibit Hall B

Early career posters

4004752: Effectiveness of India's Bharat Stage Mitigation Measures in Reducing Vehicular Emissions – Bharat State -IV and Beyond

Kamaraj Duraisamy, Adipro USA, New York, NY

In an effort to reduce the impact of vehicular emissions on air quality, India has set Bharat Stage emission standards since 2000 and the country has now shifted to BS-VI norms from April 2020 onwards. The impacts of different stages of BS emission standards in controlling pollutant emissions are analyzed. The results show that the CO, NMVOC, OC, and BC emissions have reduced by 7%, 9.7%, 20%, and 5%, respectively in 2021 when compared to 2017. The NOx emission levels have increased by 4.9% in 2021 with reference to 2017. The NOx emissions show a positive correlation with vehicular population under BS-VI norms. The findings indicate that though the advanced emission control measures are expected to effectively reduce the emissions, the penalty of emitting new pollutant species and increasing NOx levels. This paper will detail of review of the requirements in Bharat Stage IV identify the gaps in curtailing emissions and suggest future courses of action.

4000420: Tribological Behavior of Recycled Polyvinyl Butyral (rPVB) and Glass Fiber Reinforced Polyamide 6 (PAGF) Blends in Dry and Micro-Abrasive Contacts

Leonardo Farfan-Cabrera, Andys Hernandez Peña, Andrea Guevara Morales, Ulises Figueroa Lopez, Ariadna Carmona-Cervantes, Tecnologico de Monterrey, Monterrey, Nuevo Leon, Mexico; Juan Pascual-Francisco, Universidad Politecnica de Pachuca, Zempoala, Hidalgo, Mexico

Contributing with recycling of polymers in automotive industry, recycled polyvinyl butyral (rPVB) from automotive windshields is being explored as a solid lubricant reinforcement for improving lubricity of other engineering polymers. This work aims to evaluate the tribological behavior of recycled polyvinyl butyral (rPVB) and glass fiber reinforced polyamide 6 blends in two-body and three-body abrasion by dry and micro-abrasive wear tests. Different polymer blends were produced by adding recycled polyvinyl butyral (rPVB) into a matrix of either a commercial polyamide 6 (PA6) Ultramid B3S, and a commercial 30% glass-fiber reinforced polyamide 6 (PAGF) Ultramid B3ZG6 from BASF. The tribological tests were conducted in an instrumented micro-abrasion tester for generating wear and measuring friction coefficient. Overall, rPVB was found to be effective to reduce CoF up to 10% and 50% for both PA6 and PAGF in dry condition.

4091228: Effect of Commercial Tackifiers on Adhesion and Tackiness of Calcium Soap Grease

Taylor Hudson, Jacob Bonta, Valvoline Global Operations, Lexington, KY

The objective of this study aims to quantify how different concentrations of commercial tackifiers affect the inherent tackiness and adhesion of a calcium soap grease at room temperature. This was studied by employing indention-retraction sequences, which were measured with a Tackiness Adhesion Analyzer based on the ASTM Method currently under development.

Graduate posters

4088419: Frictional Properties of Catheters and the Implications for Medical Procedure Safety

Kevin Moreno-Ruiz, Samuel Leventini, Ashlie Martini, University of California, Merced, Merced, CA; Andrei Cumpanas, Brandon Camp, Ralph Clayman, University of California, Irvine, Irvine, CA

The frictional properties of catheters determine their effectiveness in medical procedures. This study focuses on the tribological interactions between catheters and tissues, particularly examining the coefficient of friction (CoF). A series of catheters were ex-vivo tested to simulate insertion and retraction cycles in ureter tissues. With this approach, the catheters could be ranked based on their CoF, revealing significant differences in their performance. The results demonstrate that certain catheters reduce tissue trauma due to their frictional performance. The insights gained from this research are pivotal in guiding the development of catheters that are safer, potentially leading to reduced complications in ureteral catheterization.

4096599: Urea-functionalized Hydrophilic MoS_2 Particles as Potential Additives for Grease

Mohammad Humaun Kabir, Darrius Dias, Kailash Arole, Hong Liang, Texas A&M University, College Station, TX

Molybdenum disulfide (MoS_2) is favored in lubricant formulations for its versatile surface chemistry, yet it lags in performance relative to alternative antiwear agents. This research studies the effects of MoS_2 on tribological performance of a lithium grease. The MoS_2 particles were functionalized with hydrophilic urea molecules. Tribotesting showed that urea-modified MoS_2 enabled 22% reduction in friction and an 85% decrease in wear. Analysis indicated that urea's presence on MoS_2 surfaces and between layers resulting hydrophilicity on the surface and reducing van der Waals forces between the layers. This work suggests using functionalized hydrophilic molecules for advanced lubricant additives.

4096756: Annealing Ti_3C_2Tz MXenes to Control Surface Chemistry and Friction

Kailash Arole, Micah Green, Hong Liang, Texas A&M University, College Station, Bryan, TX

Although surface terminations on MXene nanosheets strongly influence their functional properties, synthesis of MXenes with desired types & distribution of those terminations is still challenging. Here, it is demonstrated that thermal annealing helps in removing much of the terminal groups of molten salt-etched MXenes. The chloride terminations of ML-Ti_3C_2Tz were removed via thermal annealing & which created some bare sites available for further functionalization of Ti_3C_2Tz. The annealed ML-Ti_3C_2Tz was refunctionalized by –OH groups and 3-aminopropyl triethoxysilane (APTES). The –OH and APTES surface-modified ML-Ti_3C_2Tz are evaluated as a solid lubricant, exhibiting a 70.1 & 66.7% reduction in friction. This enhanced performance is attributed to the improved interaction or adhesion of functionalized ML-Ti_3C_2Tz with the substrate material. This approach allows for the effective surface modification of MXenes and control of their functional properties.

4088769: Synergetic Tribological and Electrical Performance of Lubricants with Ti_3C_2Tz MXene as Additives

Mohsen Tajedini, Kailash Arole, Micah Green, Hong Liang, Texas A&M University, College Station, TX

This research explores the impact of incorporating Multi-Layer (ML)-Ti_3C_2Tz MXene into lubricants on their frictional performance and electrical properties. Through electrochemical impedance analysis, we studied the effects of concentrations of ML-Ti_3C_2Tz MXene in light mineral oil on friction and electrical conductivity. Results revealed that the addition of ML-Ti_3C_2Tz MXene reduced friction by up to 60% while simultaneously enhancing electrical conductivity. The outcome of this research opened opportunities for improving lubricants tailored for electric vehicles.

4089596: Advancements in Lubrication Systems – Gadolinium-Doped DLC Coatings and Phosphorus-Containing Ionic Liquids for Enhanced Wear Resistance and Friction Reduction

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

Enhanced techniques in managing friction and wear could significantly lower greenhouse gas emissions. Diamond-like carbon (DLC) coatings are noted for their durability, while phosphorus-containing ionic liquids (ILs) are recognized for their ability to reduce friction. This research focuses on DLC coatings enhanced with gadolinium (Gd-DLC) through high-power impulse magnetron sputtering. The study examined the effectiveness of these coatings in conjunction with two distinct phosphorus-containing ILs, noting an 80% reduction in wear when gadolinium was incorporated. Further analysis of the wear tracks post-experiment was conducted using sophisticated instruments like XPS and ToF-SIMS, providing insights into the interactions between the ILs and Gd-DLC coatings. These findings pave the way for advancements in lubrication system designs.

4090127: Enhancing Tribological Properties of MoS_2 Using a Chromium Underlayer

Nihal Ahmed, Sujan Ghosh, University of Arkansas at Little Rock, Little Rock, AR

Lightweight metals like Aluminum are highly sought after in the vehicle and aviation sectors due to their impressive strength-to-weight ratio. Despite its favorable strength-to-weight ratio, Aluminum has high COF and wear rate, limiting its use in vehicles and aviation industry. MoS_2 coatings are examined to improve these properties but face challenges like low adhesion to Aluminum and oxidation in air. By integrating a chromium underlayer known for its corrosion resistance and adhesive qualities, this research aims to overcome these drawbacks. The layers were applied using Physical Vapor Deposition (Sputtering). Results showed a substantial COF reduction from 0.7 to 0.28 and a doubled lifespan of the MoS_2 coating, indicating the chromium's significant role in enhancing durability and adhesion without impacting the low COF. However, adding a chromium top layer did not improve the coating's durability or COF, highlighting the complexity of optimizing such composite coatings.

4093793: Computational Analysis of Low-Speed, High-Load Journal Bearing

Asmita Schinde, Nicholas Garafolo, The University of Akron, Akron, OH

A computational analysis is presented addressing the performance and reliability of a large, low-speed, high-load journal bearing for the rolling mills industry. A multiphysics model has been developed utilizing EHL techniques coupled with thermal analysis and Navier Stokes in the oil supply region. A parametric study has been carried out for different load and speed. The numerical results shows that dynamic load plays significant role on the overall performance of the Hydrodynamic journal bearing. The numerical results shows good agreement with the experimental referents.

4092916: Microscale Tribochemistry of Diamond-like Carbon Coatings

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

We present 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 a quartz crystal microbalance (QCM). By resonating the QCM, we generate a 5 MHz reciprocating shear motion at the interface with track lengths of 1 to 100 nm. The QCM performs friction measurements with the normal load fixed 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 at 40 Hz. We observe a substantial reduction in friction over time as long as the track length exceeds a threshold value near 15 nm. We associate this drop in friction with the "running-in" behavior of H-DLC and its shear plane chemistry. We report measurements of sliding shear stress as a function of pressure, both before and after run-in. Finally, we explore relationships between the sliding distance, contact size, and the tribochemistry of H-DLC.

4091916: Predicting Electric Vehicle Transmission Efficiency Using a Thermally Coupled Lubrication Model

Joseph Shore, Amir Kadiric, Imperial College London, London, United Kingdom; Ning Ren, VGP Holdings, LLC (Valvoline), Lexington, KY

A model for predicting EV transmission efficiency is presented. Incorporating an iterative scheme, measured oil rheology is accounted for when predicting gear meshing friction, allowing nominally identical fluids to be compared. Gear churning losses are predicted with a newly devised expression which accounts for the non-monotonic relationship between churning torque, speed, and viscosity by considering the dynamic oil surface profile during operation. Gear meshing and churning loss predictions are complemented by an existing semi-empirical bearing loss model. Transmission temperature evolution during operation is predicted with a thermal network approach. The model is applied to the transmission of a typical passenger EV and validated with in-situ temperature measurements in real-world road tests. Finally, oil parameter studies are used to assess the influence of various properties on efficiency. One such study shows that the optimal oil viscosity strongly depends on vehicle duty.

4091717: Flow Visualization of Surface Textured Mechanical Seals by Particle Tracking Velocimetry

So Makishima, Yuichiro Tokunaga, Iwa Ou, Eagle Industry Co., Ltd., Sakado-shi, Saitama-Ken, Japan; Kazuyuki Yagi, Kyushu University, Fukuoka, Japan

A developed textured mechanical face seal, which has a Rayleigh step for dynamic pressure and a reversed Rayleigh step to cause cavitation to prevent leakage, has superior sealing and lubricating performance. It also has deep grooves, tens to hundreds of microns in depth, which has an important role in supplying fluid into the Rayleigh steps. However, there is a lack of understanding of the flow in the grooves. In this study, tracer particles were used to visualize the flow within the deep grooves to gain a better understanding of the flow. Particle Tracking Velocimetry (PTV) was used to analyze the fluid flow and velocity. Computational Fluid Dynamic (CFD) analysis was also conducted for comparison. It was found that the fluid flow in the deep grooves varied significantly with groove depth. In the experiments, the phenomenon of air bubble accumulation in the deep grooves was observed with increasing depth, and the results for this condition differed from those of the CFD analysis.

4093797: PTFE Composites: Effect of PTFE Composite Filler Materials on Dry Sliding Wear Performance

Eliot Berberich, Mark Sidebottom, Miami University, Oxford, OH

Polyfluorotetraethylene (PTFE) and a number of PTFE composites were evaluated in dry conditions in a humidity-controlled laboratory air environment. All wear and friction testing was completed using a linear reciprocating flat-on-flat tribometer for 25 km of testing at experimental conditions of 50 mm/s and 6.3 MPa of pressure against polished 304 stainless steel. The results of the testing were extremely variable, with some composite samples unable to complete testing due to excess wear, and some samples, like glass-filled PTFE, achieving ultra-low wear rates ($K \leq 5x10\text{-}7$). Results from testing resulted in groups of polymer composites with high, moderate, and low wear regimes. Additional characterization on low materials will be used to identify if mechanisms within these composite systems align with those found in previous low wear PTFE composites.

4091258: Enhancing Tribological Properties of Ni-Cr Thin Film Coatings by Incorporating MAX Phase Ceramic

Aaron McCollum, Nihal Ahmed, Sujan Ghosh, University of Arkansas at Little Rock, Little Rock, AR

Conventional Ni-Cr coatings are known for their substantial protection against wear and corrosion. However, their coefficient of friction (CoF) ranges between 0.5 and 0.55, which may not meet the requirements of applications demanding lower friction levels. The integration of MAX phase particles, celebrated for their unique blend of metallic and ceramic properties, into the Ni-Cr matrix, was aimed at overcoming this limitation. The presence of the MAX phase was confirmed using EDS. The topological study showed a very conformal Ni-Cr coating when MAX phase was added. The tribological performance was assessed using a linear ball-on-disk apparatus to mimic real-world friction scenarios. The incorporation of the MAX phase slightly reduced the CoF to 0.45-0.5. Furthermore, durability tests revealed an increase in wear life by 7 to 8 times compared to the unreinforced coatings. Findings demonstrate that including MAX phase particles in Ni-Cr coatings can effectively enhance wear resistance.

4090898: Unveiling the Potential of PEO-Chameleon Coatings on Titanium Alloys Across Varied Environments and Temperatures

Vanessa Montoya, Ali Zayaan Macknojia, Diana Berman, Andrey Voevodin, University of North Texas, Denton, TX

Dual-phase coatings, developed by combining plasma electrolytic oxidation (PEO)-modified substrates with solid lubricants such as graphite, MoS_2, and BN, provide an efficient concept for the adaptation of materials under a wide range of conditions. The PEO layer enhances hardness and load support, while the solid lubricant powders minimize friction. Here, we evaluate the adaptation mechanism under different environments, temperature, and contact pressure conditions. In order to obtain and analyze the coating we conducted advanced characterization techniques, such as scanning electron microscopy (SEM/EDS) and Raman Spectroscopy. The ultra-low friction behavior of the composite coating was attributed to the low shear strength of solid lubricants, along with the effective adhesion and integration of the chameleon coating with the PEO sublayer under high contact pressures during sliding.

4071859: Exploring Line Contacts with Electrical Impedance Spectroscopy – A New Frontier in Film Thickness Assessment

Manjunath Manjunath, Patrick De Baets, Dieter Fauconnier, Ghent University, Ghent, Flanders, Belgium; Simon Hausner, André Heine, Flucon Fluid Control GmbH, Wistobastraße, Germany

This article focuses on utilizing electrical impedance spectroscopy (EIS) to assess global and contact impedances in roller bearings. The primary goal is to quantitatively predict lubricant film thickness in EHL and investigate impedance transitions from ohmic to capacitive behavior during the shift from boundary lubrication to EHL. Measurements of electrical impedance, bearing and oil temperature, and frictional torque are conducted on a CRT bearing under pure axial loading at various rotational speeds and supply oil temperatures. The impedance data is analyzed to measure lubricant film thickness using impedance and capacitance methods. The translation of impedance values to film thickness is compared with analytically estimated values using the Moes correlation, showing robust agreement within 2% for EHL film thickness. Monitoring bearing resistance and capacitance via EIS reveals clear transitions from boundary to mixed lubrication and from mixed lubrication to EHL.

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4078320: The Role of Tribology in the Circular Economy – Effect of Shaft Misalignment on Energy Consumption and CO_2 Emissions

Mkpe Kekung, Lulea University of Technology, Luleå, Sweden

This study investigates the impact of shaft misalignment on energy consumption and CO_2 emissions within the context of tribology and the circular economy. It aims to evaluate the energy and CO_2 emission consequences of varying degrees of misalignment in industrial machinery and to formulate practical recommendations for improvement. A combined experimental and theoretical approach was used to analyze the impact of shaft misalignment in operational inefficiency, energy loss, and increased CO_2 emissions. Key findings from the experimental study demonstrate that even minor misalignment can significantly affect energy consumption and emissions, which emphases the need for proper alignment in industrial machinery. The study highlights the necessity of incorporating tribological principles in the design and maintenance of mechanical systems to achieve better environmental outcomes, such as enhanced component longevity, decreased energy consumption, and reduced CO_2 emissions.

4082233: Evaluating Grease Behavior Under a Simulated Space Environment

Michelle Padilla, Jose Morales, Ashlie Martini, University of California, Merced, Merced, CA; Sara Cantonwine, Juan Flores Preciado, SpaceX, Hawthorne, CA

Mechanical components that operate in space need high-performance greases to decrease wear and increase operating duration. To evaluate the tribological behavior of such greases, it is necessary to test and analyze the behavior under space conditions. Here, a series of tests was conducted on various Perfluoropolyether (PFPE), Multiply alkylated cyclopentanes (MAC), and Polyalphaolefin (PAO) greases. The tests included ball-on-disk tests and four-ball tests under both typical air conditions and nitrogen conditions. Nitrogen was used to simulate space conditions as it is relatively unreactive and can create a low oxygen environment. After completing the comprehensive testing and comparisons, it was observed that environmental conditions play a significant role in the grease performance.

4083649: Improved Lubricating Performance of Nanodiamonds with Organic Friction Modifier

Afrina Khan Piya, Liuquan Yang, Ardian Morina, University of Leeds, Leeds, West Yorkshire, United Kingdom; Nazanin Emami, Lulea University of Technology, Lulea, Sweden

The frictional performance of a newly developed nano-lubricant, comprising PAO oil, GMO, ZDDP, and nanodiamonds, was analyzed using a reciprocating tribometer. The addition of 0.05 wt% nanodiamonds resulted in a 60% reduction in the coefficient of friction (COF) at 80°C. The synergistic effect of the nanolubricant significantly influenced frictional performance by facilitating the formation of chemically reactive additive layers that mechanically interlocked the nanodiamonds. From both commercial and environmental perspectives, this study offers a promising approach to reducing harmful concentrations of sulfur and phosphorus by incorporating small concentrations of nanodiamonds without compromising the protective performance level of contacting surfaces. Further exploration of the synergy between nanolubricant additives could lead to their broader application in the lubricant and automotive industries.

3981379: Decoupling Activation Volume via Dynamic Electron Transfer in Stress-Driven Chemical Reactions

Yilong Jiang, Southwest Jiaotong University, Chengdu, China

Density functional theory calculations are used to investigate the general rules of charge transfer underlying activation volume in controlling typically mechanochemical reactions process. It is found that the activation volume could be decoupled into the electronic contributions from interface chemistry and bulk physical deformation, which are commonly linear dependent with the contact pressure. Therefore, the activation volume may be indeed derived from the stress-driven charge transfer underlying cooperative competition between interfacial chemistry and bulk region. This competition is related to the stiffness change from bulk to slab. The magnitude of stiffness change represents the degree to which the interface atoms modify the bulk properties, which is directly related to the contribution of different regions to the activation volume.

3982324: Investigating the Friction and Wear Properties of Polymer Laser Sintered Components

Kieran Nar, The University of Sheffield, Sheffield, United Kingdom

Today, Additive Manufacturing (AM) is ubiquitous within industry. Laser Sintering (LS) in particular is one of the most well-established polymer AM processing techniques due its capability of producing geometrically complex and functional components. However, despite this the adoption of laser sintered components for end-use applications remains hindered due to an incomplete understanding of their in-service behaviors, particularly when subject to dynamic contact. Therefore, this work gives an overview of the pertinent sliding phenomena discovered whilst investigating the friction and wear properties of laser sintered Nylon-12 components. More specifically, ball-on-flat, pin-on-disk, dry sliding tests were performed in accordance with a design of experiments to highlight the individual and compound influence normal load, sliding velocity and contact configuration had on the coefficient of friction and wear rate of sample surfaces examined.

4000831: A Novel Multiphase CFD Model for Investigating the Flow Dynamics of Aerated Bubbles in Bearing Lubrication

Ujjawal Arya, Farshid Sadeghi, Purdue University, West Lafayette, IN

This study delves into the intricate flow dynamics of aerated bubbles within lubricating oil during bearing operation. To achieve this objective, a novel Computational Fluid Dynamics (CFD) model was prepared in Ansys Fluent, which simulates the movement of these bubbles within the bearing chamber. This model utilizes a coupled solver that incorporates a two-way transition algorithm between the Discrete Phase Model (DPM) approach, which was used to model bubble dynamics, and the Volume of Fluid (VOF) approach, which was used to depict oil starvation inside the cage pocket. Results from this CFD model were validated with the experimental observations for the bubble motion from the Counter Rotating Angular Contact ball bearing Test Rig (CRACTR). This coupled CFD model demonstrates an efficient and thoroughly validated modeling approach to examine the complex phenomenon of multiphase oil flow in bearing lubrication, adeptly accounting for the impact of both aeration and oil starvation.

4003896: Understanding the Additive Compatibility and Tribological Properties of Regular and High Oleic Soybean Oil Lubricants

Piash Bhowmik, Yachao Wang, Clement Tang, University of North Dakota, Grand Forks, ND; Brajendra Sharma, Majher Sarker, USDA/ARS/NEA/ERRC, Wyndmoor, PA; Sougata Roy, Iowa State University, Ames, IA

With the increasing demand for biobased lubricating oils in research, there's a growing emphasis on the exploration of various oil varieties. Especially there is rising interest in high oleic oils, known for their higher stability compared to conventional oils. This investigation is focused on revealing the compatibility of both regular and high oleic soybean oils with select antiwear and antioxidant additives along with a comparative performance analysis of these additives. Reciprocating friction, wear and electrical contact resistance-based analyses were conducted to evaluate additive compatibility and wear mechanisms at room temperature lubrication conditions. Interestingly, regular soybean oil with additives exhibited a 28% improvement in wear resistance, whereas high oleic soybean oil with additives demonstrated only an 8% increase. SEM-EDS analysis was conducted to uncover the underlying scientific factors responsible for the distinct properties of additized lubricants.

4005030: Exploring the Tribological Behavior of Additively Manufactured Al-6061 Alloy for Space Application

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

For a prolonged space mission, the frictional energy loss accumulates and becomes substantial with limited lubrication scope. Al6061 has been a promising candidate for space applications due to several advantages like corrosion resistance, strength-to-weight ratio, formability, and insensitivity to the extraterrestrial environment, while additive manufacturability of this alloy can give true freedom of fabrication. The tribological performance of additively manufactured Al6061 parts has yet to be widely investigated. In this study, we investigated the additive manufacturability and tribological performance of Al6061 fabricated through Wire Arc Additive Manufacturing (WAAM) and Laser-Powered Direct Energy Deposition (LP-DED). Additional investigations on TiC-reinforced Metal Matrix Composite (MMC) were also performed. Post fabrication, detailed microstructural characterization, and tribological behavior in vacuum were conducted with detailed analyses of dominant wear mechanisms.

4111141: Atomic Force Microscopy of Transfer Film Development

Kathryn Shaffer, University of California, Santa Barbara, Goleta, CA; Brandon Krick, Florida State University, Tallahassee, FL; Angela Pitenis, University of California, Santa Barbara, Santa Barbara, CA

Atomic force microscopy (AFM) provides the opportunity to perform fundamental and mechanistic observations of dynamic systems and ultimately link material microstructure and evolution during tribological interactions. This investigation focuses on evolution of tribofilm formed during sliding of polytetrafluoroethylene (PTFE) mixed with 5 wt.% - Al2O3 particles against 304L stainless steel. Sliding was periodically interrupted for AFM topography scans. The film roughness, friction coefficient, and polymer wear rate were recorded as a function of increasing sliding cycles. Topography suggested the the tribofilm nucleating in low regions in the steel, spreading, and developing a uniform film in sliding. Nanoscale domains suggesting the presence of Al2O3 particles were visible around 10,000 sliding and after. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX) showed correlations between aluminum-rich domains and similar features as those observed with AFM.

4111118: Slide-ring Hydrogel Friction

Andrew Rhode, University of California Santa Barbara, Goleta, CA; Angela Pitenis, University of California, Santa Barbara, Santa Barbara, CA; Christopher Bates, University of California Santa Barbara, Goleta, CA

Hydrogels are interconnected networks of polymer chains swollen in water. Hydrogel-like structures are employed in the body for their ability to maintain lubricious interfaces (e.g. articular cartilage). Traditionally, polymer chains in hydrogels are linked together with immobile covalent crosslinks. However, hydrogels with figure-eight sliding crosslinks were introduced by Okomura and Ito in 2001. Since then, the synthesis and bulk mechanical properties of these gels have been studied, and it has been shown that slide-ring hydrogels exhibit impressive toughness and extensibility. However, the impacts of sliding crosslinks on hydrogel tribological properties are not well understood. Here, we demonstrate how tuning the formulation of slide-ring hydrogels can be used to access a range of mechanical and interfacial properties.

4111167: Bioinspired Lubricity from Surface Gel Layers

Ahmed Al Kindi, Nemea Courelli, Kevin Ogbonna, Juan Manuel Uruena, Angela Pitenis, Allison Chau, University of California, Santa Barbara, Santa Barbara, CA

It has been demonstrated that surface gel layers can form by polymerizing hydrogels in molds of low surface energy materials near oxygen-rich interfaces. In this study, polyacrylamide hydrogel probes were polymerized in molds with decreasing surface energy and increasing oxygen permeability: borosilicate glass, polyetheretherketone (PEEK), and polytetrafluoroethylene (PTFE). Hydrogels polymerized in PEEK and PTFE molds exhibited significantly lower elastic moduli at the surface compared to glass molds (EPEEK=80±31, EPTFE=106±26 and Eglass=35,860±2,650 Pa). Biotribological experiments revealed that frictional shear stresses when sliding against human telomerase corneal epithelial cells (hTCEpi) are lower in the presence of surface gel layers (PEEK=35±15, PTFE=22±16 and glass=68±15 Pa). These findings suggest that reduced shear stresses may provide enhanced protection against cell damage during sliding, potentially preserving the integrity of mucin gel layers secreted by hTCEpi cells.

2024 STLE Annual Meeting Participants Index

Please note authors with multiple papers listed in technical sessions.

Preliminary as of April 23, 2024

Includes technical program authors, Commercial Marketing Forum (CMF) presenters, Early Career Research (ECRP) and Student Poster (SP) authors.

C

D

Participants Index

E

F

G

H

I

J

K

L

Participants Index

L

M

N

O

P

Q

R

Participants Index

S

T

U

V

W

X

Y

Z

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