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WEDNESDAY

Exhibitor Appreciation Hours

Monday and Tuesday, May 20 & 21, 3-4 pm both days

Minneapolis Convention Center | Minneapolis, Minnesota (USA)

Refreshments will be served!

The trade show is a major component of STLE's Annual Meeting. In 2024 STLE is making it even easier for you to fit a visit to the exhibition into your personal itinerary with two hours of dedicated exhibit time—no need to worry about missing a Commercial Marketing Forum presentation, education course or technical session!

Come view the newest products and services from the lubricant industry's leading companies. More than 100 companies from every corner of the industry will be represented and looking to do business with you.

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

2024 Exhibit Schedule

Monday: Noon–5 pm (Exhibitor Appreciation Hour 3–4 pm)

Tuesday: 9:30 am–Noon & 2–5:30 pm (closed for President's Luncheon - Noon–2 pm. Exhibitor Appreciation Hour 3–4 pm)

Wednesday: 9:30 am–Noon

78th STLE Annual Meeting & Exhibition

MINNEAPOLIS

Minneapolis

May 20 & 21, 2024

Exhibitors: To reserve a spot at the 2025 STLE exhibition at the Hyatt Regency Hotel in Atlanta, Ga., contact Tracy Nicholas VanEe at (847) 430-6767, ***emeraldcomminc@yahoo.com.***

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Overview

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

Wednesday, May 22

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

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

Commercial Exhibits and Posters
9:30 am – 12:00 pm – **Exhibit Hall B**

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

- Advanced Lubrication 302: Advanced Lubrication Regimes – **200 F**
- **NEW!** Auto/Diesel, Gasoline, Hydrogen and Ammonia – **200 J**
- Metalworking Fluids 240: Metalworking Fluid Formulation Concepts – **200 H**
- Sustainability: Biolubricants and Biofuels – **200 G**

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

5A • Materials Tribology III – **101 B**
5B • Condition Monitoring I – **101 C**
5C • Lubrication Fundamentals III: Sustainable Lubrication – **101 D**
5D • Gears I – **101 E**
5E • Tribology of Biomaterials I – **101 F**
5F • Sustainable Power Generation I – **101 G**
5G • Fluid Film Bearings I – **101 H**
5I • Commercial Marketing Forum V – **101 J**
5J • Electric Vehicles V – **200 DE**

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

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

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

6A • Materials Tribology IV – **101 B**
6B • Condition Monitoring II – **101 C**
6C • Lubrication Fundamentals IV: Oil Degradation – **101 D**
6D • Rolling Element Bearings I – **101 E**
6E • Environmentally Friendly Fluids I – **101 F**
6F • Sustainable Power Generation II – **101 G**
6G • Tribochemistry III– **101 H**
6I • Commercial Marketing Forum VI – **101 J**
6J • Electric Vehicles VI – **200 DE**

Networking/Refreshment Break
3:00 – 3:40 pm – **Convention Center Foyer**

Worldwide Surface Topography Challenge
5:00 pm – 6:00pm – **101 G**

Exhibition hours

- **Wednesday, May 22** (9:30 am – 12:00 pm)

TIME	SESSION 5A Materials Tribology III Room 101 B	SESSION 5B Condition Monitoring I Room 101 C	SESSION 5C Lubrication Fundamentals III Room 101 D
8:00 am – 8:40 am	Crystal Rotation Kinematics and the Activation of Different Twinning Systems Due to Tribological Loading, C. Greiner, p. 86	Taking a Holistic Approach to Fluid Analysis, R. Clark, p. 88	Lubricant Inerting – A New Route to Sustainability, H. Spikes, p. 92
8:40 am – 9:00 am	Synchrotron In-Situ Study of Scuffing Evolution, C. Lorenzo Martin, p. 86	Oil Condition Monitoring Based on Diagnostic Evaluation Using an RGB Sensor, T. Hiraoka, p. 88	Flows Around a Contacting Asperity Modeled in the Micro and Nanometer Scales, N. Dorcy, p. 92
9:00 am – 9:20 am	Microstructure of Self-Mated Steels Before and After Severe Wear Due to Scuffing, S. Berkebile, p. 86	Chemical Cleaners for Varnish Removal from Component Surfaces, J. Morales, p. 90	Lubrication Using Hydrogen, J. Zhang, p. 92
9:20 am – 9:40 am	Experimental Investigations of Scuffing Initiation and Coatings for Scuffing Prevention, K. Jacques, p. 86	The Critical Role of Hydraulic Oil in Keeping System Clean, L. Wang, p. 90	The Fast Response Regulation Mechanism of Friction Coefficient Induced by Microviscosity in the Contact Region,C. Zhang, p. 92
9:40 am – 10:00 am	High Temperature Tribology of Inconel Alloy B4C Reinforcement, A. Maria Fuentes Caparros, p. 86	Lubrication Condition Monitoring via Ultrasonic Reflection Technique, P. Dou, p. 90	Understanding the Growth Dynamics of Capillary Bridges . . . Grease Lubrication, V. Siekman, p. 94
10:00 am – 10:40 am	Break	Break	Break
10:40 am – 11:00 am		Experimental Investigation of an In-Situ, Temperature-Based Lubrication Gap Height Determination for Plain Bearings, T. Baszenski, p. 90	Controlling Friction with an Electric Field, J. Wong, p. 94
11:00 am – 11:20 am	Thermal Modeling of Shear Localization & Stick-Slip in High-Speed Machining of Metals, R. Narasimhan, p. 88	Sensors for Wind Turbine Main Sliding Bearings, G. Nicholas, p. 90	Ion-Specific Ice Provides a Facile Approach for Reducing Ice Friction, C. Dong, p. 94
11:20 am – 11:40 am	Tribological Performance of MoS_2 Coating Enhanced by Ti_3AlC_2 MAX Phases, S. Ghosh, p. 88	. . . Analyzing Surface Wear Mechanisms in Sliding Contacts Using Acoustic Emission, R. Gutierrez, p. 90	
11:40 am – 12:00 pm	Achieving Superlubricity and High Adhesion Strength of Hydrogenated Amorphous Carbon Film with Al/Cr/Si-Doping, Q. Ma, p 88	Reactive, Preventive, Predictive, Corrective Maintenance, and a Proactive Plan – Where Does It All Fit?, M. Holloway, p. 92	

TIME	SESSION 6A Materials Tribology IV Room 101 B	SESSION 6B Condition Monitoring II Room 101 C	SESSION 6C Lubrication Fundamentals IV Room 101 D
1:40 pm – 2:20 pm	Robust Superlubricity in Mo_2TiC_2 MXenes Facilitated by Tribocatalytic Reaction at the Sliding Interfaces, A. Sumant, p. 105	Comparing New ASTM Methods for FTIR Analysis of Fluid Condition, D. Swanson, p. 108	Stop Over-heating (Killing) your Bearings with Poor Lubrication Practices, A, Rienstra, p. 109
2:20 pm –2:40 pm	Room Temperature Sintering of TiO_2 Nanoparticles – Exploiting Friction to Manufacture Wear-Resistant Coatings, P. Nautiyal, p. 105	Extended Lubricant Analysis Using Nuclear Magnetic Resonance (NMR), C. Rohbogner, p. 108	Development of a Lifetime Model for the Oxidation Stability of Lubricating Greases, N. Dörr, p. 109
2:40 pm – 3:00 pm	Novel Organic Friction Modifiers with Extended Performance Durability, M. Lee, p. 105	Oil, Fuel, and Coolant Analysis – How Each Can Dramatically Extend Equipment Life, M. Holloway, p. 108	Investigating the Oil Aeration Performance of Lubricants, T. Fang, p. 109
3:00 pm – 3:40 pm	Break	Break	Break
3:40 pm – 4:00 pm	Influence of Contact Temperature for Tribology in Polymer Contacts & Models to Quantify It, M. Kalin, p. 106	Application of EIS to Lubricating Oil Condition Monitoring, T. Fang, p. 108	Influence of a Transmission Oil Degradation on System-Level Behavior, B. Duran, p. 109
4:00 pm – 4:20 pm	Influence of Polymer Morphology on the Ultralow Wear Behavior PTFE Composites, K. Van Meter, p. 106	Combining Oil Analysis Tests to Identify the Root Cause of Machine Failures, R.Master, p. 108	The Evaluation of Ti_3C_2Tz MXene Nanofluid for Balanced Lubrication and Thermal Management, K. Arole, p. 109
4:20 pm – 4:40 pm	Performance of Experimentally Developed 3D Printed High-Performance Polymer Composites, N. Dhakal, p. 106	Quantifying Severity of Wear and Contamination with a Filtergram, D. Walsh, p. 108	Lubrication Fundamentals Business Meeting
4:40 pm – 5:00 pm	Investigating the Friction and Wear Properties of Polymer Laser Sintered Components, K. Nar, p. 106	Condition Monitoring Business Meeting	
5:00 pm – 6:00 pm	Materials Tribology Business Meeting		

SESSION 5D Gears I Room 101 E	SESSION 5E Tribology of Biomaterials I Room 101 F	SESSION 5F Sustainable Power Generation I Room 101 G	
Oxide Formation During Loss of Lubrication and the Effect on Friction, A. Isaacson, p. 94		Assessing the Potential for Improved Lubricants to Reduce Wind Operations and Maintenance Costs, M. Blumenfeld, p. 98	**8:00 am – 8:40 am**
Investigations on the Influence of Synthetic Lubricants on the Pitting Load Carrying Capacity of Cylindrical Gears, M. Brummer, p. 94		Empowering the World's Lower Carbon Ambitions Through Metallocene Base Stock Technology in Industrial Lubricant Solutions, L. Bunting, p. 98	**8:40 am – 9:00 am**
Optimization of Gear Oil Formulation for Achieving Energy Efficiency & Long Life, K. Rai, p. 95	Polyamide with Nanocellulose and Carbonaceous Reinforcements … Tribomaterials, L. Kneissl, p. 96	Wind to Wheels – Efficiency of the All-Electric Powertrain, R. Dwyer-Joyce, p. 99	**9:00 am – 9:20 am**
Improving the Tribological and NVH Properties of Sintered Gears by Mechanochemical Surface Finishing, D. Chobany, p. 95	Morphological Characteristics of Biomass Materials as Supercapacitors, M. Velhal, p. 96	Foaming in Wind Turbine Gearboxes: Causes, Impacts and Treatment – Part III, M. Blumenfeld, p. 99	**9:20 am – 9:40 am**
The Behavior of Tribofilms Under Realistic Gearbox Conditions, M. Ingram, p. 95	Instantaneous Frictional Behavior of Corn Stover Biomass Particles, C. Lorenzo Martin, p. 96	Screener Test Development for Wind Turbine Gearbox Journal Bearings, A. Gant, p. 99	**9:40 am – 10:00 am**
Break	**Break**	**Break**	**10:00 am – 10:40 am**
The Importance of Multi-Metal Compatibility in Modern Industrial Gearboxes, P. Norris, p. 95	Rate-Dependent Detachment Dynamics from Gradient-Stiffness Hydrogels Using AFM Nano-Indentation, M. Hasan, p. 96x		**10:40 am – 11:00 am**
Experimental Investigations on Spin Power Losses Generated in a Planetary Gear Set, M. Winger, p. 95	Examining Stopper-Syringe Contact in Freeze-Thaw Cycling of Prefilled Syringes, C. Fidd, p. 96		**11:00 am – 11:20 am**
Varnish Detection in Gear Systems by Microscopy, B. Van Horn, p. 95	Exploring Structure-Property Relationships in 3D-Printed Polymeric Biomaterials, S. Lazarte, p. 98		**11:20 am – 11:40 am**
Gears Business Meeting	A Nature-Inspired Lubricant-Infused Surface for Drag Reduction Prepared Using Porous Polydimethylsiloxane, X. Sang, p. 98		**11:40 am – 12:00 pm**

SESSION 6D Rolling Element Bearings I Room 101 E	SESSION 6E Environmentally Friendly Fluids I Room 101 F	SESSION 6F Sustainable Power Generation II Room 101 G	
Comparison of Fatigue Performance of Different Aerospace Rolling Element Bearing Materials, N. Londhe, p. 110	How Ester Technology Contributes to Technical and Sustainability Targets, M. Hof, p. 112	Effects of Tribology on CO_2 – Emissions in the Use Phase of Products – Contributions of Tribology to Defossilization, V. Bakolas, p. 113	**1:40 pm – 2:20 pm**
Effect of Operation Temperature & Lubrication Regime on Bearing RCF Life Using Computational Modeling Tool, B. Jalalahmadi, p. 110	A Brief History of Refrigeration Lubricants, M. Costello, p. 112	Evaluation of Experimentally Developed High-Performance Polymer Composites for Hydropower Bearings, N. Emami, p. 113	**2:20 pm –2:40 pm**
Prediction of Bearing Damage Beyond Rolling Contact Fatigue, P. Wingertszahn, p. 110	Meeting Sustainability Standards in Industrial Lubricants Using Specialty Additives, S. Velez, p. 112	… Characterization of Carbon Composites for High Temp. Gas-Cooled Pebble Bed Reactor, T. Grejtak, p. 114	**2:40 pm – 3:00 pm**
Break	**Break**	**Break**	**3:00 pm – 3:40 pm**
Linkage Between Structural Fatigue and Rolling Contact Fatigue …, S. Shimizu, p. 110	… Compatibility and Tribological Behavior of Regular and High Oleic Soybean Oil, P. Bhowmik, p. 112	Understanding the Biomass Fouling Process on the Screw Feeder for Pyrolysis Reactors, J. Qu, p. 114	**3:40 pm – 4:00 pm**
The Effect of Current and Lambda on White-Etch-Crack Failures, N. Demas, p. 110	Environmentally Friendly Base Oils From Upcycled Plastic Waste, R. Kennedy, p. 113	Lubricant Chemistry Management – The Proactive Solution to Turbine Oil Problems, M. Hobbs, p. 114	**4:00 pm – 4:20 pm**
Particular WEC Triggers and Their Failure Risk – It's All a Question of How Long They Last?, D. Merk, p. 110	Candidate Marine Turbine Lubricant Additives – Liquids with High Lubricity & Eco-Friendliness, W. Wang, p. 113	Impact of the Lubricant Chemistry on Knock Sensitivity of a Gas Engine Running on Hydrogen, Z. Fard, p. 114	**4:20 pm – 4:40 pm**
Mechanistic Study of White Etching Area Development in Butterflies … Roller Bearings, M. El Laithy, p. 112	Investigation of Film Formation and Pressure Viscosity Relation of Water-Based Lubricants …, M. Hasan, p. 113	Sustainable Power Generation Business Meeting	**4:40 pm – 5:00 pm**
Rolling Element Bearings Business Meeting	Environmentally Friendly Fluids Business Meeting		**5:00 pm – 5:30 pm**

WEDNESDAY >>

TIME	SESSION 5G Fluid Film Bearings I Room 101 H	SESSION 5I Commercial Marketing Forum V Room 101 J	SESSION 5J Electric Vehicles V Room 200 DE
8:00 am – 8:20 am	Elasto-Hydrodynamic Lubrication Analysis of a Porous Misaligned Crankshaft Bearing Operating with Nanolubricants, B. Bou-Saïd, p. 99	Chemours – Auto Noise, Vibration and Harshness (NVH) Lubrication and the use of Perfluoropolyether (PFPE) Oils and Greases, R. Vieira, p. 101	Alternates to Fluorosilicone Based Antifoams for Electric Vehicle Driveline Fluids Due to PFAS Regulations, S. Peerzada, p. 104
8:20 am – 8:40 am		Simerics CFD Software, R. Ranganathan, p. 101	
8:40 am – 9:00 am	Performance of Orifice Compensated Hole-Entry Hybrid Spherical Thrust Bearing Operating with ER Lubricant, S. Sharma, p. 99	ExxonMobil – EHC 340 MAX™: Above and Beyond Group I Bright Stock, T. Aridi, p. 101	Combination Effects of Phosphate and Sulfur Additives on Anti-Wear/Anti-Pitting Properties and Tribofilm Formation in Rolling-Sliding Contacts, Y. Jeung, p. 104
9:00 am – 9:20 am	Exploring the Impact of Non-Newtonian Oils on Refrigerator Compressor's Journal Bearing – A Thermo-Hydrodynamic Investigation, M. da Silva Cardoso, p. 99	Afton Chemical's Key Driver Seminar – Re-think, Re-define, Re-refine: Formulating Solutions for the Future, J. Garrett, p. 101	Molybdenum Compounds as Additives in Future PCMO and EV Applications – A Comparative Study, D. Boudreau, p. 104
9:20 am – 9:40 am	Comparison Between Prediction and Measurement of Start-Up Torque Reduction by Hydrostatic Lift Recess in Tilting Pad Journal Bearings, H. Hatori, p. 100		Advanced Rheo-Tribological Testing of Greases for Electric Vehicles, P. Staudinger, p. 104
9:40 am – 10:00 am	Cryogenic Hydrostatic Bearing Failure from Pneumatic Hammer Instability During Liquid Nitrogen Supply, K. Ryu, p. 100	Evonik – Collaborative R&D for Next-Gen Electric Vehicle Chemistries, A. Rice, p. 102	How Can We Measure the Performance of Greases for Connectors? A Hands-On Tribo-Method, L. Lopes, p. 104
10:00 am – 10:40 am	**Break**	**Break**	**Break**
10:40 am – 11:00 am	A Triangle Based Finite Volume Approach Applied to the Analysis of a Hydrodynamic Bearing Operating with Two-Phase Lubricant, M. Arghir, p. 100	Cargill – Achieving Low Traction and Low Wear in EV transmission Fluids, S. Davis, p. 102	Electrical, Mechanical, and Performance Properties of Electric Vehicle Motor Greases with Silver Nano-Particle Additives, J. Janik, p. 105
11:00 am – 11:20 am	Nonlinear Bump Foil Stiffness Model in Foil Bearings – Experimental Measurements, Analytical Models, and Stability Characteristics, W. Lee, p. 100	SEQENS Program for More Sustainability in the Lubricant Industry, X. Semery, p. 102	Dedicated e-Fluids for Energy Efficiency, H. Thaker, p. 105
11:20 am – 11:40 am	Performance Evaluation and Comparison of Hybrid Rigid and Hybrid Foil Thrust Bearings, E. Ebewele, p. 100	BASF Corporation – The Future of Sustainability with BASF Fuel and Lubricants, D. Niedzwiecki, p. 102	
11:40 am – 12:00 pm	Effects of Top Foil Thickness on Dynamic Characteristics of Hybrid Foil-Magnetic Bearing Systems, Y. Ha, p. 101	Emery Oleochemicals DEHYLUB® Esters Engineered for EV Fluid Performance, J. Sliner, p. 102	
12:00 pm – 12:30 pm	Fluid Film Bearings Business Meeting		

TIME	SESSION 6G Tribochemistry III Room 101 H	SESSION 6I Commercial Marketing Forum VI Room 101 J	SESSION 6J Electric Vehicles VI Room 200 DE
1:40 pm – 2:20 pm	Tribological Performance and Durability of an In-Situ-Deposited Carbon Tribofilm Derived from Cycloalkane Molecules, Z. Al Hassan, p. 115	ADEKA Corporation – Advancing Carbon Neutrality in Lubricant Additives, ADEKA's Innovations with MoDTC and Other Functional Materials, J. Shim, p. 115	Electric Vehicle Testing – Correlation of Benchtop and Rig Tests Using Ester Containing Fluids, A. Kurchan, p. 115
2:00 pm – 2:20 pm	Ultrafast Phonon Energy Dissipation at Multi-layer Graphene Interfaces, H. Dai, p. 115		
2:20 pm –2:40 pm			High Speed E-Motor Bearings for Electric Vehicles, J. Modi, p. 116
2:40 pm – 3:00 pm			Plastic Thrust Washers Enable Space Savings, Efficiency in Electric Drive Units, G. Poterala, p. 116
3:00 pm – 3:40 pm	**Break**	**Break**	**Break**
3:40 pm – 4:00 pm			Influence of Ionic Liquids as Lubricant Additives on Electrically-Induced Bearing Damage, S. Saha, p. 116
4:00 pm – 4:20 pm			Electrification Effects on Oxidation Performance … Drivetrain Lubricants, J. Conner, p. 116
4:20 pm – 4:40 pm			Shear Stability and Thermal Performance Analysis of Engine Oils for Electric Vehicles, D. Veeregowda, p. 116
			4:40 pm – Engine & Drivetrain Business Meeting

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5A • 101 B

Materials Tribology III

Session Chair: Tomas Grejtak, Oak Ridge National Laboratory, Oak Ridge, TN

Session Vice Chair: Nicolas Molina Vergara, The University of Texas at Austin, Austin, TX

8:00 am – 8:40 am

3998720: Crystal Rotation Kinematics and the Activation of Different Twinning Systems Due to Tribological Loading

Christian Greiner, Karlsruhe Institute of Technology, Karlsruhe, Baden-Württemberg, Germany

In 1950, Bowden and Tabor pointed out that in metallic tribological contacts the majority of the dissipated energy is spent to change the contacting materials' microstructures. This, in part, explains why most metals show a highly dynamic subsurface microstructure under the shear load imposed by a sliding contact. One key process involved therein is the reorientation of the crystal lattice. Model experiments performed with high-purity copper bicrystals shed light on the early stage, fundamental mechanisms of tribologically induced lattice rotation kinematics. Electron backscatter diffraction (EBSD) performed directly on the wear track reveals a crystal rotation process around the transverse direction, irrespective of sliding direction, grain orientation and normal load. By making use of CoCrFeMnNi single crystals, we could identify that depending on the friction coefficient, different deformation mechanisms like dislocated mediated plasticity and twinning are being activated.

8:40 am – 9:00 am

3981220: Synchrotron In-Situ Study of Scuffing Evolution

Cinta Lorenzo Martin, Dawid Bachnacki, Athena Butler-Christodoulou, Harvey Campos-Chavez, Oyelayo Ajayi, Argonne National Laboratory, Lemont, IL; Jun-Sang Park, Peter Kenesei, APS, Lemont, IL; Farida Koly, David Burris, University of Delaware, Newark, DE; Nikhil Murthy, Scott Walck, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Scuffing, a type of surface damage in highly stressed and poorly lubricated sliding contacts, is characterized by a rapid increase in friction and severe plastic deformation of the near surface material. Scuffing is difficult to study directly due to a lack of access to the contact interface and the speed of failure. This talk presents real-time characterization of scuffing failure of lubricated steel in a reciprocating contact using high-energy, high-speed synchrotron X-ray diffractometry. In-situ XRD of the contact interface during scuffing showed a sharp increase in the peak FWHM, which is attributed to grain refinement and increase in dislocation density. Additionally, ex-situ experiments consisting of 1-micron step XRD depth profile before and after scuffing showed a reversal and enhancement of a sinusoidal strain pattern of the near-surface region with localized tension in the loading and compression in the sliding directions after scuffing.

9:00 am – 9:20 am

3998829: Microstructure of Self-Mated Steels Before and After Severe Wear Due to Scuffing

Stephen Berkebile, Nikhil Murthy, Scott Walck, Dawid Bachnacki, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Cinta Lorenzo Martin, Oyelayo Ajayi, Argonne National Laboratory, Lemont, IL; Jun-Sang Park, Peter Kenesei, APS, Argonne National Laboratory, Lemont, IL; Farida Koly, David Burris, University of Delaware, Newark, DE

A type of severe wear called "scuffing" occurs when materials in sliding mechanical contacts undergo significant adhesive and plastic deformation that propagates quickly through the contact area. Scuffing is proceeded by microstructural changes in the material during sliding. Further, plastic deformation during scuffing alters the material structure significantly. Using Scanning Electron, Focused Ion Beam, and Transition Electron Microscopies, we have studied the microstructure of steel at different stages of sliding and scuffing in reciprocating contacts. During sliding, a small layer of grain refinement occurs at the surface and small areas of oxide are formed. The layer of grain refinement deepens significantly during scuffing to several micrometers. We also observed elongation of the grains in the direction of sliding but not in the transverse direction. We will discuss the relationship between areas of plastic deformation and grain refinement.

9:20 am – 9:40 am

4002756: Experimental Investigations of Scuffing Initiation and Coatings for Scuffing Prevention

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

To improve high-pressure fuel injection system operation in low-viscosity fuel environments and expand compatibility to different fuel chemistries, further examination of state-of-the art materials and their resistance to scuffing is needed. In this work, a high-frequency reciprocating tribometer was used to perform pin-on-flat load-progression experiments on hardened 52100 steel, additively manufactured steels, and several coating candidates in multiple fuel environments. These experiments were followed by microscopy/spectroscopy to characterize the friction coefficients, wear, and chemical alterations of the material surfaces. It was found that the ability of the surfaces to prevent scuffing largely depends on the characteristics of the materials, such as hardness, surface energy, and corrosion resistance. The use of multi-layer coatings with each layer optimized for different fuel chemistries inhibits the onset of scuffing when applied to steel surfaces otherwise prone to wear.

9:40 am – 10:00 am

4011602: High Temperature Tribology of Inconel Alloy B4C Reinforcement

Ana Maria Fuentes Caparros, Anton Paar TriTec, Corcelles-Cormondreche, Switzerland

Inconel 625 and similar alloys have excellent thermal stability and are therefore often used in high temperature applications. These alloys are also used for surface protection of less wear resistant load-bearing structures. However, protective layers from pure HT alloys usually suffer from low wear resistance; this is why they are generally reinforced with ceramic particles. The goal of our work was to investigate the wear and mechanical properties of Nibasit 625 (similar to Inconel 625) layer with B4C particles as well as the effects of the B4C particle size and heat treatment. The CoF of all samples were studied at different temperatures, between 25°C and 750 °C. The smaller B4C grain size resulted in much

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lower (~3x) wear rate at 750°C compared to pure Nibasit and the large grain size samples. SEM observations of the wear tracks on all samples revealed that the improved wear resistance was due to re-deposition of the Nibasit matrix on the B4C particles

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

Open Slot

11:00 am – 11:20 am

4004898: Thermal Modeling of Shear Localization and Stick-Slip in High-Speed Machining of Metals

Ravi Srivatsa Bindiganavile Narasimhan, Dinakar Sagapuram, Texas A&M University, College Station, TX

We present an analytical framework for modeling heat generation and non-steady temperature fields underlying shear-localized chip formation in high-speed machining of metals. This chip formation mode is characterized by periodic localization of flow (shear bands) in the plastic deformation zone, and concurrent stick-slip motion at the tool-chip contact. In this study, analytical methods based on planar heat sources (stationary and moving type) and the heat partitioning principle are developed to model both the transient and long-time (quasi-steady-state) characteristics of the shear-localized zone and tool-chip contact temperatures. Quantitative temperature predictions are made for the case of orthogonal machining of Ti-6Al-4V alloy and good agreement with the experimental data from the literature is found. The description of stick-slip, time-dependent heat sources, and related temperature effects should be of more general interest than their particular application to machining.

11:20 am – 11:40 am

3983882: Tribological Performance of MoS_2 Coating Enhanced by Ti_3AlC_2 MAX Phases

Sujan Ghosh, Nihal Ahmed, Joshua Manley, University of Arkansas at Little Rock, Little Rock, AR; Bo Shen, Wan Shou, University of Arkansas at Fayetteville, Fayetteville, AR

This study aimed to develop a novel, multi-functional coating with enhanced oxidation resistance and durability. The coating consists of MoS2 with a composition of 10% Ti_3AlC_2 nanoparticles on a 6061-T6 aluminum substrate. The results demonstrated a significant improvement in the coefficient of friction (COF) and durability of the MoS_2 + MAX phase coatings compared to the bare Al and MoS2 coatings. The optimized coating with two sintering cycles exhibited a 72% increas in durability from 1,173 cycles (for pure MoS_2) to 3,193 cycles and maintained a COF of 0.32. The better oxidation resistance and higher mechanical strength of the MoS_2+MAX phases coating were responsible for the superior tribological behavior of these coatings. This novel MoS_2 + MAX phase coating has potential applications in various industries requiring stable, low-friction, and durable lubrication solutions.

11:40 am – 12:00 pm

4003493: Achieving Superlubricity and High Adhesion Strength of Hydrogenated Amorphous Carbon Film with Al/Cr/Si-Doping

Quansheng Ma, Tsinghua University, Beijing, China

Excellent tribological properties of hydrogenated amorphous carbon films make it an important candidate for friction reduction in industry. In this work, a novel Al, Cr and Si co-doped hydrogenated amorphous carbon film was prepared by high-power impulse magnetron sputtering method. The AlCrSi/a-C:H film showed favorable mechanical performance and high adhesion (~80 N), which was attributed to the controlled elements doping and special transition layers produced by HiPIMS method. Meanwhile, superlubricity was obtained with coefficient of friction 0.0014. Detailed characterizations suggested that doping elements played significant roles in tribo-chemical reactions during friction. On one hand, doping elements can promote shear-induced graphitization and formation of graphite-like layers at the friction interface. On the other hand, the preferential oxidation of doping elements can protect the formed graphite-like layers from oxidation.

Session 5B • 101 C

Condition Monitoring I

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

4000850: Taking a Holistic Approach to Fluid Analysis

Randy Clark, POLARIS Laboratories®, Indianapolis, IN

Fluid analysis plays a significant role in condition monitoring and is crucial for achieving our reliability objectives. However, we often tend to be reactive and only act when we receive a high-severity report. While this approach may help prevent catastrophic failures, it also results in reactive maintenance. This course will adopt a more comprehensive approach to fluid analysis, use historical trends to identify the causes of high-severity fluid analysis reports and learn ways to prevent these high-severity reports from reoccurring.

8:40 am – 9:00 am

4000240: Oil Condition Monitoring Based on Diagnostic Evaluation Using an RGB Sensor

Takeshi Hiraoka, Takashi Honda, Makoto Miyajima, Noriko Ayame, Tadashi Oshio, ENEOS Corporation, Yokohama, Japan

Proper management of lubricants is important for extending the lifetime of machinery. Conventional diagnosis methods often require periodic analysis to evaluate the degree of lubricant deterioration, leading to time-consuming operations which need much manpower. Under the circumstances, our group has developed a method to monitor the condition of industrial lubricating oils easily and quickly by tracking their color changes resulting from deterioration or abnormality of them. In this report, we introduce a method for detecting water contamination and estimating the residual rates of various antioxidants by quantifying the oil color using an RGB sensor. This makes it possible to properly determine the timing to replace the oil, and greatly reduces the effort to maintain the lubricating oils.

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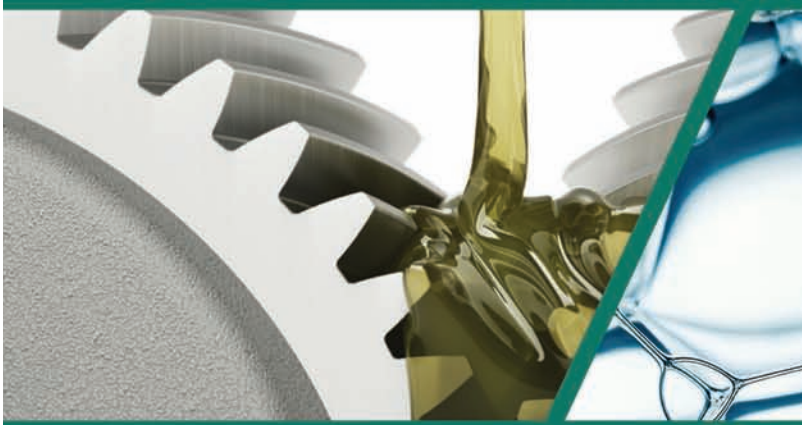

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5B

9:00 am – 9:20 am

3999491: Chemical Cleaners for Varnish Removal from Component Surfaces

Jose Morales, Ashlie Martini, University of California, Merced, Merced, CA; Zhen Zhou, Jason Bahora, Zefu Zhang, Nathan Knotts, Chevron Lubricants, Richmond, CA

Varnish that forms on metal surface due to oil degradation is detrimental to the function and operational life of mechanical components. Here, we used a custom test rig to evaluate the varnish removal characteristics of chemical cleaners under different conditions. The method enables varnish removal from real mechanical components to be directly observed and quantified. Particularly, a series of tests was performed to quantify varnish removal from heat exchanger surfaces, demonstrating the utility of the test method for comparing chemical cleaner performance under application-relevant conditions. The results of this testing contribute to enabling heat exchangers to have a longer lifespan, proper functionality, and better performance.

9:20 am – 9:40 am

4005086: The Critical Role of Hydraulic Oil in Keeping System Clean

Lin Wang, James Hannon, ExxonMobil, Annandale, NJ

The most common failure mechanism of a hydraulic oil in service is contamination which can be generated through oil aging, leakage, wearing or condensations. Contamination control is typically considered mainly a maintenance issue. Few have recognized that hydraulic oil formulation can play a critical role in resisting contamination. Given the same equipment conditions, a hydraulic oil formulated specifically to control contamination can last three times longer than a basic hydraulic oil. The mechanism and benefits of keep-clean hydraulic oil to reliably extend oil and equipment lives, will be discussed in detail in this presentation.

9:40 am – 10:00 am

4001416: Lubrication Condition Monitoring via Ultrasonic Reflection Technique

Pan Dou, Min Yu, Tom Reddyhoff, Imperial College London, London, United Kingdom

Lubrication-related parameters, such as film thickness, viscosity, and temperature, are important indicators that reflect lubrication conditions and transmission efficiency in mechanical equipment, therefore their monitoring is highly important. Recently, ultrasonic-based measurement has been widely studied, showing promising potential in the practical industry owing to its non-destructive characteristics. This paper develops an ultrasonic reflection technique to monitor these lubrication-related parameters simultaneously. The echo amplitude information is used to obtain the film thickness and viscosity by combining EHL theory and acoustic simulation. The time difference of adjacent echoes is used to reverse the oil film temperature based on the acoustic speed-temperature relationship. To assess the efficacy and reliability of the proposed method, a reciprocating rig, specifically designed to emulate line-contact tribopair scenarios, is employed for the experimental verification.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

3998352: Experimental Investigation of an In-Situ, Temperature-Based Lubrication Gap Height Determination for Plain Bearings

Thao Baszenski, Georg Jacobs, Tobias Gemmeke, Kevin Kauth, Karl-Heinz Kratz, Benjamin Lehmann, RWTH Aachen University, Aachen, Germany

Plain bearings are increasingly being used in areas of mixed friction, which causes an increased damage risk. A relevant criterion for the detection of mixed friction in plain bearings is the lubrication gap height. The concept of the DIN-standardized Gümbel curve provides a relationship between the lubrication gap height and the shaft displacement angle for hydrodynamic radial plain bearings solving the Reynolds' differential equation. The shaft displacement angle, in turn, can be determined from the temperature field on the bearings running surface. In this work, the development and experimental testing of a temperature-based condition monitoring system (CMS), which is based on the Gümbel curve relationship is developed. The CMS is fully integrated into the bearing. Experimental investigations of the CMS for the calculation of gap height determination, which are derived from the temperature map using the Gümbel curve relationship, are presented and are validated by simulative results.

11:00 am – 11:20 am

3988395: Sensors for Wind Turbine Main Sliding Bearings

Gary Nicholas, Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

Sliding bearings, typical in hydroelectric plants and marine propellers, are becoming increasingly prevalent in wind turbine (WT) drivetrain applications. They are replacing conventional roller bearings due to their reduced maintenance and failure rate potential. This reduces operational costs and the initial investment capital for large WTs (10MW+). However, little is known of their field operational performance (failure mechanisms, service life) under the slow and transient loading conditions of WT drivetrains. There is also no field experience for their operation in the wind sector. This project intends to address the knowledge gap by providing the underpinning data through development of a multi-sensor measurement suite for WT sliding bearings. The sensing system will comprise of thermocouples, capacitance, strain, ultrasonic and acoustic emission sensors intended for measuring bearing temperature, oil film thickness, pad loading, touchdown and wear.

11:20 am – 11:40 am

4006600: Predicting Friction and Analyzing Surface Wear Mechanisms in Sliding Contacts Using Acoustic Emission

Robert Gutierrez, Imperial College London, London, United Kingdom

There is a keen interest in developing acoustic emission (AE) methods in the machine condition monitoring market, as it is proving to be an effective method of monitoring contact properties such as friction and wear. Herein, AE and coefficient of friction (CoF) have been recorded from HFRR sliding tests. AE data is used to train machine learning (ML) models to predict CoF from new tests. Strong predictions are given for tests done at different conditions. However, the mechanisms relating asperity interactions to AE are still not fully understood. To address this, scratch tests were done using aluminum specimens with different oxide coating

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thicknesses while recording AE. The scratch images show wear mechanisms involving surface crack initiation and propagation. Correlations of AE with scratch image features can then be investigated. Overall, the sliding test ML models allow for AE measurements of friction, while the scratch tests provide an insight into how wear mechanisms produce AE.

11:40 am – 12:00 pm

4002576: Reactive, Preventive, Predictive, Corrective Maintenance, and a Proactive Plan — Where Does It All Fit?

Michael Holloway, SGS, Highland Village, TX

Work performed that is planned versus work done due to failure requires different procedures and protocols. The delineation of duties and tasks are outlined for predictive maintenance vs corrective maintenance. By implementing the appropriate strategy can increase equipment availability and increase staff utilization. In this session, attendees will learn how to establish safe work practices, preserve, and optimize the reliability and safety requirements while satisfying the operational requirements. Attendees will be able to establish lubrication tasks, set task intervals, and develop clearly worded procedures. This session will also cover how to execute periodic, nonrecurring lubrication tasks and how to convey the difference to staff.

Session 5C • 101 D

Lubrication Fundamentals III: Sustainable Lubrication

Session Chair: Ashish Jha, Chevron, Richmond, CA

Session Vice Chair: Chanaka Kumara, Oak Ridge National Laboratory, Oak Ridge, TN

8:00 am – 8:40 am

4000339: Lubricant Inerting – A New Route to Sustainability

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

The recent availability of portable nitrogen concentrators that filter O_2 from an air flow to provide an almost pure N2 stream now makes it feasible to blanket closed lubrication systems in inert gas. This offers enormous potential benefits in terms of preventing lubricant oxidative degradation in operating components; promising increased lubricant life, higher lubricant operating temperatures and a much wider range of applications of bio-based lubricants that are especially susceptible to oxidation. This presentation describes research both to identify lubricant formulations that can provide low friction and protection against wear, scuffing and rolling contact fatigue in zero or very low oxygen atmospheres and to quantify the potential benefits in terms of lubricant life and operating window provided by a very low oxygen-containing environment

8:40 am – 9:00 am

3981034: Flows Around a Contacting Asperity Modeled in the Micro and Nanometer Scales

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

Mixed lubrication conditions can often arise around asperity contacts. Understanding how the flow is interrupted at such points is crucial at the molecular scale where the flow is dominated by intermolecular forces. Using molecular dynamics simulations, this work studies a shear-driven wedge flow approaching a fixed incline narrowing and ultimately blocking the exit gap. Attention is paid particularly to the narrowest point of the wedge and boundary layer of the flow. Approaching a blockage, the flow is interrupted and deviates from the otherwise no-slip boundary condition. This deviation is quantified by calculating the boundary-layer velocity along the channel length. Simulations were run to explore the impact of key factors such as incline steepness, wall speed, and intermolecular properties with the goal of producing an equation to describe wall slip and the flow around a fully blocked asperity contact.

9:00 am – 9:20 am

3987063: Lubrication Using Hydrogen

Jie Zhang, Janet Wong, Hugh Spikes, Imperial College London, London, United Kingdom; Tushar Bera, Shell Global Solutions (US) Inc., Houston, TX

There is growing interest in using hydrogen as a carbon-free gaseous fuel to replace liquid hydrocarbons in crankcase and turbine engines. This gas must be pumped and injected into a combustion chamber, and both pump and injector require effective lubrication to limit friction, wear and seizure of rubbing surfaces. Unfortunately, hydrogen gas is a poor lubricant for most engineering metals, so additional lubrication must be provided, for example as an oil or grease or employing coatings on rubbing parts. This presentation describes the use of a sealed tribometer to study the friction and wear properties of hydrogen and how these may be improved via lubrication.

9:20 am – 9:40 am

3985385: The Fast Response Regulation Mechanism of Friction Coefficient Induced by Microviscosity in the Contact Region

Caixia Zhang, Lihui Wang, Beijing University of Technology, Beijing, China; Zhifeng Liu, Jilin University, Changchun, China

The friction coefficient control is important in intelligent manufacturing. This study found that the microviscosity is a key factor influencing the fast response of the friction coefficient variation. The friction contact region of polymer coatings is creatively subdivided into core, corona, and blank regions according to functional specificity to investigate microviscosity. The synergism of the three areas were explored. The high microviscosity core region of the polymer coating is the basis for keeping the friction coefficient at a low level. The microviscosity exhibited by ions that are more readily adsorbed in the corona region is the key to determining changes in the friction coefficient. The blank region ensures low shear viscosity during friction. Regulation of the friction coefficient can be achieved by controlling the microviscosity in each region. This study provides a theoretical basis for the intelligent regulation of friction.

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9:40 am – 10:00 am

3998464: Understanding the Growth Dynamics of Capillary Bridges for Enhanced Grease Lubrication

Vincent Siekman, Dirk Van Den Ende, Frieder Mugele, University of Twente, Enschede, Overrijsel, Netherlands; Piet Lugt, SKF Research and Technology Development, Houten, Netherlands

In this study we (experimentally and numerically) explore the dynamic growth of a capillary bridge formed when a bearing ball gently touches an approximately 100-micron thin film of silicon oil on a glass substrate. Fluorescence microscopy measurements reveal the formation of a dimple, i.e. a local minimum in the height profile, near the oil-ball contact, resulting in a large resistance to oil flow towards the oil bridge. Describing the flow in the thin film with lubrication theory, while the driving pressure is predicted by the momentary curvature of the liquid bridge, we calculate the height profile as a function of time. These profiles match, for a wide variety of initial film thicknesses, very well with the experimentally observed evolution of the capillary bridge and with the dimple profiles obtained from the fluorescence measurements. To reduce the large flow resistance, further research will focus on the effects of coating the substrate with a polymer brush or grease thickener.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4001256: Controlling Friction with an Electric Field

Janet Wong, Yun Zhao, Hugh Spikes, Imperial College London, London, United Kingdom

Lubrication by demand can be achieved if the properties of our lubricants can respond to changes in operating conditions. Active control is achieved if we can regular these conditions at our will. Many potential regulators exist, one of which is via applied electric field. Using surfactant aqueous solutions as our model lubricants, we examine how an applied electric field can regulate the friction of a steel-steel conduct in a range of lubricating conditions. The effects of concentrations, molecular structures and addition of salt on the response of the lubricants will be explored.

11:00 am – 11:20 am

4004481: Ion-Specific Ice Provides a Facile Approach for Reducing Ice Friction

Chang Dong, Liran Ma, Tsinghua University, Beijing, China

Ice friction plays a vital role in both fundamental research and practical applications. Here, we report the discovery of an ion-specific effect of hydrated ions on ice friction. By simply changing the initial type and concentration of ions in ice-making solution, the ice friction coefficient can be reduced by 75 percent. The direct link was revealed between ion charge density and the ice friction coefficients by analyzing experimental spectra and molecular simulation results. Part structure of ice was destroyed and turned from ice-like water structure to liquid-like water structure by adding ion. Moreover, lower charge density ions lead to weaker ionic force with water molecules in bound layer and perform greater ability of turning ice-like water structure to liquid-like water structure. This work serves to provide guidance for the design of low friction coefficient ice-making solution and deeper understanding of the molecular structure of ion-containing water at low temperature.

Session 5D • 101 E

Gears I

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

Session Vice Chair: Chengjiao Yu, Hebei University of Technology, Tianjin, China

8:00 am – 8:40 am

4000448: Oxide Formation During Loss of Lubrication and the Effect on Friction

Aaron Isaacson, Todd Palmer, Penn State University, University Park, PA

The mechanisms governing loss of lubrication gear failure in rotorcraft gearboxes are not well understood. Industry convention suggests that better material hot hardness leads to longer gear life without lubrication. It is well documented that mesh friction increases as scuffing occurs during loss of lubrication induced gear failure. Changes in the coefficient of friction due to oxide film formation at high temperatures are studied using the ball on disk test for four carburized aerospace gear steels (SAE/AISI 9310, Pyrowear 53, Ferrium C-64, and Pyrowear 675). Results show that formation and destruction of the surface oxide layer affects the friction behavior of these alloys. Finally, gear tests performed in an inert atmosphere provide validation that the presence of surface oxides can improve gear performance during significantly reduced lubrication.

8:40 am – 9:00 am

3985183: Investigations on the Influence of Synthetic Lubricants on the Pitting Load Carrying Capacity of Cylindrical Gears

Markus Brummer, Thomas Tobie, Karsten Stahl, Gear Research Center (FZG), Technical University of Munich (TUM), Garching near Munich, Germany; Johannes König, ZF Group, Friedrichshafen, Germany

Synthetic lubricants show advantageous properties compared to mineral oils. In gearboxes, a higher pitting load carrying capacity can be achieved, enhancing the power density. ISO 6336-2 is a well-known standard for calculating the safety factor against pitting for gears. The standard was mainly developed based on test results with mineral oils, giving limited assessment on the pitting load carrying capacity for synthetic lubricants. In this research, pitting load carrying capacity tests were conducted on an FZG back-to-back gear test rig with different lubricants based on mineral oil, polyalphaolefine and polyglycole, each of ISO VG 100. The results are analyzed with the standard ISO 6336-2 and an alternative approach according to Knauer (1988), which addresses lubricating properties more in-depth. The analysis of the test results shows the limitations of the standard and further need for research to adequately quantify the pitting load carrying capacity of synthetic lubricants.

9:00 am – 9:20 am

3998690: Optimization of Gear Oil Formulation for Achieving Energy Efficiency & Long Life

Kavita Rai, Chanakya Tripathi, Sumit Bhaskaran, Rahul Meshram, Ajay Harinarain, Mukul Maheshwari, Indian Oil Corporation Ltd., Faridabad, India

The power losses in gear systems are mainly caused by friction. The gear box efficiency can be improved by reducing the friction. The carefully designed lubricants not only improve gear transmission performance but also helps to reduce the friction coefficient between the mating surfaces through the use of special additive chemistry & base oils. The present paper highlights the importance of gear oil chemistries to achieve higher oxidation stability, better EP properties and energy efficiency. A systematic study for developing a novel formulation of an energy efficient gear oil meeting all the national and international specifications with energy saving characteristics has been taken. The present paper discusses the methodologies used for development of high-performance gear oils and its comparison with conventional gear oil chemistry w.r.t physico-chemical properties, viscosity temperature behavior and tribological test properties viz. frictional and load bearing properties.

9:20 am – 9:40 am

4000249: Improving the Tribological and NVH Properties of Sintered Gears by Mechanochemical Surface Finishing

David Chobany, Boris Zhmud, Linus Everlid, Tribonex AB, Uppsala, Sweden

In recent years, there has been a growing interest to manufacture gears using the powder metallurgy (PM) process that provides a cost-effective alternative to conventional gear cutting. Surface specifications and tooth microgeometry of PM gears have a big impact on their efficiency and noise characteristics. In the present communication, the application of a novel mechanochemical surface finishing method – Triboconditioning CG – for improving the tribological and NVH characteristics of PM gears is described. Mechanochemical surface finishing combines elements of mechanical burnishing with a tribochemical deposition of a solid lubricant tribofim. This allows one to obtain, via a single finishing operation, a smoother surface with a significantly reduced coefficient of boundary friction and improved wear-resistance and load-carrying capacity. Triboconditioned gears reveal better efficiency, higher resistance to micropitting and scuffing, and lower noise.

9:40 am – 10:00 am

4000269: The Behavior of Tribofilms Under Realistic Gearbox Conditions

Marc Ingram, Thomas Baldwin, Ingram Tribology Ltd., Carmarthen, United Kingdom

Tribofilms are formed on steel surfaces under mixed, boundary or high shear EHD conditions. It is common to study the formation of the tribofilm under short (sub 3-hour) tests equating to a few thousand contact cycles. It is less common to study the effect of these tribofilms under realist conditions of lambda ratio, contact pressure and contact cycles, effectively stimulating the contact conditions of a gearbox. This is important to observe the tribofilm formation of oils under realistic conditions and the longevity of the film over an extended period of operation. Here we study the effect of different lubricants and different steels used in gear manufacture. We use a sliding/rolling contact of 2 GPa, and custom finished surfaces to achieve the require lambda ratios. We find the growth of the tribofilm to be rapid at lambda ratios of 0.4 and 0.05. Then the thickness of the tribofilm decreases slowly between 5 M and 30 M contact cycles.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4002020: The Importance of Multi-Metal Compatibility in Modern Industrial Gearboxes

Paul Norris, Helen Dyer, Afton Chemical Ltd., UK, Bracknell, United Kingdom; Andrew Gant, Afton Chemical Ltd., Bracknell, Berkshire, United Kingdom

Multi-metal compatibility has been a discussion topic in Industrial Gear and Wind turbine applications for several years now, mainly due to the increasing use of journal bearings in some applications. Deployment of bearings containing bronze alloys raises a number of concerns over the compatibility of the lubricant with copper and the impact this may have in terms of both corrosion concerns and on system cleanliness through the lifetime of the oil. Compatibility of typical gear chemistry with other metal options such as aluminum and tin has also been considered. Interactions of the lubricant with potential bearing metallurgies has been at the forefront of recent development efforts in both synthetic Industrial Gear and Wind Turbine lubricants. Strategies to limit interactions have been deployed and this in turn has provided additional cleanliness benefits. Data will be shared comparing recent developments to existing commercial technologies and the potential benefits will be explored.

11:00 am – 11:20 am

4002476: Experimental Investigations on Spin Power Losses Generated in a Planetary Gear Set

Marie Winger, Fabrice Ville, INSA Lyon, Villeurbanne, France; Yann Marchesse, Christophe Changenet, ECAM LaSalle, Lyon, France; Patrice Gédin, Safran Transmission Systems, Colombes, France

Planetary gear sets are widely used for to their compact size and high gear ratio. It is of the utmost importance that their efficiency is as high as possible. To achieve this, it is necessary to understand and analyze the sources of energy dissipation. The aim of this study is to determine and investigate the spin losses generated in a planetary gear set, namely the drag and the pocketing losses. The gearbox configuration studied features a rotating ring gear and is oil-jet lubricated. The analysis is based on experiments carried out on a specific test rig composed of a reduced-scale planetary gear set. On this test rig, gearbox losses are measured under different operating conditions (mainly oil flow rate, oil temperature, rotational speed). A thermal network is used to determine the losses distribution. In this way, each individual energy dissipation is studied, and the impact of different operating conditions is highlighted.

11:20 am – 11:40 am

4002907: Varnish Detection in Gear Systems by Microscopy

Brandon Van Horn, POLARIS Laboratories®, Indianapolis, IN

Analyzing wear and contaminant particles in in-service lubricants is essential for identifying the root cause and severity of potential damage in various mechanical systems. However, conventional lubricant analysis methods may fail to detect the presence and extent of harmful varnish deposits, especially in gear systems where they can cause serious problems. Join us in this session, where we will demonstrate how applying ASTM D7684 and qualitative microscopic techniques helps to identify damaging varnish particles (and the resulting wear) in a variety of affected gear systems. Don't miss this opportunity to learn how to protect gear systems using this approach to investigate and eliminate the source of the problem before a major failure occurs.

5D

11:40 am – 12:00 pm

Gears Business Meeting

Session 5E • 101 F

Tribology of Biomaterials I

Session Chair: Tomas Babuska, Sandia National Laboratories, Albuquerque, NM

Session Vice Chair: Quentin Allen, Brigham Young University, Provo, UT

Session Starts at 9:00 am

9:00 am – 9:20 am

4004743: Polyamide with Nanocellulose and Carbonaceous Reinforcements – Sustainable and Functional Tribomaterials

Lucas Kneissl, Roberts Joffe, Nazanin Emami, Luleå University of Technology, Luleå, Norrbotten, Sweden; Mitjan Kalin, University of Ljubljana, Ljubljana, Slovenia

Polyamides (PAs) are widely used in various applications, including tribological, due to their good friction and wear properties, favorable strength-to-weight ratio and chemical resistance. Moreover, their hydrophilicity benefits compatibility with cellulosic reinforcements to create sustainable composites without fossil-based reinforcement. In this work, bio-based PAs were reinforced with nanocellulose to produce functional tribomaterials. To add further functionality, carbonaceous materials were employed. A higher wear resistance was obtained in dry conditions, while the frictional performance was mainly influenced by the secondary filler. The testing conditions clearly influenced the friction and wear mechanisms. Morphological and microstructural features further showed a notable dependence. Therefore, novel, sustainable tribomaterials with additional functionality can be produced for e.g. the automotive industry to be used in gears, steering systems or bearing cages.

9:20 am – 9:40 am

4017800: Morphological Characteristics of Biomass Materials as Supercapacitors

Mrudul Velhal, Kailash Arole, Hong Liang, Siddhi Mehta, Texas A&M University, College Station, TX

Morphology of materials in supercapacitors is one of the important parameters for their performance. In this work, we studied the morphology and density of biomass material lignin on the electrochemical performance as a supercapacitor. Synthesis, material characterization, charge–discharge performance was conducted and data was analyzed. Results showed that porous material provided networks that enabled an electrolyte to penetrate resulting desirable electrochemical performance. This presentation will discuss about the development of biomass electrochemical devices and the role of their morphological performance.

9:40 am – 10:00 am

3998077: Instantaneous Frictional Behavior of Corn Stover Biomass Particles

Cinta Lorenzo Martin, Oyelayo Ajayi, George Fenske, Jacob Lasso Garifalis, Argonne National Laboratory, Lemont, IL; Jordan Klinger, Yidong Xia, INL, Idaho Falls, ID; Benjamin Davis, Ricardo Navar, Los Alamos National Lab, Los Alamos, NM

Controlled and reliable flow of solid particulate biomass materials from bins, hoppers, etc. is essential for successful operation of bio-refineries making bio derived fuel (such as SAF) and chemicals. Friction is one of the critical material properties governing the flow of biomass materials and an important input into material handling equipment design. A bench top tribometer was adapted to measure instantaneous friction of biomass materials by attaching copious amount of biomass particles unto sliding surfaces. This paper presents results of instantaneous friction measured for whole corn stover particles of 2 mm and 4 mm size at different loads (pressure) and speeds (shear rate). In general, the particle-particle friction coefficient decreases with increasing normal pressure, while the wall-particle friction is nearly independent or a very small increase with the normal pressure. There was minimal effect of sliding speed (shear rate) on average friction.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4005801: Rate-Dependent Detachment Dynamics from Gradient-Stiffness Hydrogels Using AFM Nano-Indentation

Md Mahmudul Hasan, Alison Dunn, University of Illinois at Urbana-Champaign, Urbana, IL

Crosslinked hydrogels with intentional softer surface layers have vanishing stiffness. Our previous research revealed that these layers control contact mechanics and display strong relative adhesion when fewer polymer chains come in contact. This finding provides opportunity to study the detachment dynamics of hydrogel chains from glass probe over varying depths(range:0.3-1.2 µm) and retraction rates(range:0.1-10 µm/s).Here, the force response in unloading phase of nanoindentation on polyacrylamide hydrogel was analyzed using Discrete Fourier Transform (DFT).DFT frequency spectrum showed discrete, hierarchical detachment events at various length scales only after maximum adhesion point. Furthermore, we found unloading rate-dependent adhesion behavior, even though apriori negligible viscoelastic effect was reported in literature. This in-depth dynamic analysis provides a deeper understanding of the interactions between gradient-stiffness hydrogels and other analogous surfaces at nanoscale.

11:00 am – 11:20 am

3986778: Examining Stopper-Syringe Contact in Freeze-Thaw Cycling of Prefilled Syringes

Catherine Fidd, Kylie Van Meter, Adam DeLong, Santiago Lazarte, Grace Lin, Brandon Krick, Florida State University, Tallahassee, FL; Nestor Rodriguez, Ludovic Gil, William Leverd, Becton Dickinson, Le Pont-de-Claix, France

Deep cold storage of prefilled syringes down to a range of cold temperatures, some less than -80°C, is often required to ensure the stability of biologics and drugs like mRNA vaccines. Thermal expansion and compression combined with mismatch of material CTE, and phase changes of syringe materials, lubricants and contents during freeze/thaw cycling can impact the integrity of the stopper-syringe seal and the sterile barrier between syringe contents and outside environment. This

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UNDERSTANDING FRICTION

presentation studies the stopper-syringe interface using a custom cryostat to thermally cycle prefilled syringes combined with in situ optical microscopy. Optical methods are used to visualize and measure the real contact area and the position of the stopper as a function of temperature. The optically determined contact/loss of contact is compared to an annular flow model developed to correlate differential pressure measurements of the system to measure at stopper-syringe barrel separation or leakage temperature.

11:20 am – 11:40 am

4005726: Exploring Structure-Property Relationships in 3D-Printed Polymeric Biomaterials

Santiago Lazarte, Brandon Krick, Florida State University, Tallahassee, FL; John Tolbert, Diana Hammerstone, Juan Mendoza, Lesley Chow, Lehigh University, Bethlehem, PA; Tomas Babuska, Sandia National Laboratories, Albuquerque, NM

Interactions between cells and biomaterials are essential to regenerate functional tissue. Cells are affected by chemical and physical cues in their microenvironment. These cues can be functionally embedded in 3D-printed scaffolds to direct human mesenchymal stromal cell (hMSC). By controlling the cues embedded in the 3D-printed scaffolds, hMSCs differentiation can be spatially directed. In many load-bearing tissue regeneration applications, including osteochondral tissues, the mechanical properties of the scaffold must be locally tuned to perform a physiological function while new tissue is forming. This work investigates how changing the scaffold architecture correlates with the mechanical properties. Scaffolds with matching compressive moduli but different material properties and programmed filament spacing were printed and characterized. This approach enables us to design scaffolds with properties that match and support the native tissue and its function.

11:40 am – 12:00 pm

4004331: A Nature-Inspired Lubricant-Infused Surface for Drag Reduction Prepared Using Porous Polydimethylsiloxane

Xiao Sang, Liran Ma, Tsinghua University, Beijing, China

Lubricant-infused surfaces (LIS) inspired by Nepenthes pitcher have been found to have excellent application prospects in reducing frictional drag in recent years. However, the complicated preparation process and easy depletion of lubricant have limited their practical applications. In this paper, inspired by the mucus secreted from the fish, we propose a simple method to prepare a LIS that can be replenished with lubricant in real-time. Porous Polydimethylsiloxane (PDMS) was prepared by foaming method. Lubricant was injected and stored in the PDMS cavities, which could be released when the lubricant on the surface was depleted. The material has excellent slipping properties and high durability and achieves excellent drag reduction when water is used as the ambient liquid. This study can provide ideas for the design of new intelligent drag-reduction materials.

Session 5F • 101 G

Sustainable Power Generation I

Session Chair: Ramesh Navaratnam, Patech Fine Chemicals, Dublin, OH

Session Vice Chair: Manish Patel, ExxonMobil Chemical Company, Spring, TX

8:00 am – 8:40 am

3988918: Assessing the Potential for Improved Lubricants to Reduce Wind Operations and Maintenance Costs

Michael Blumenfeld, Kathy Cooper, ExxonMobil, Annandale, NJ; Aubryn Cooperman, Jon Keller, Matthew Prilliman, Shawn Sheng, Gabriel Zuckerman, National Renewable Energy Laboratory, Golden, CO

Currently, the US wind turbine fleet satisfies approximately 10% of the overall US electricity demand. As with any mechanical system, lubrication plays an important role in ensuring that turbines are operated in a reliable and cost-effective manner. However, there are few sources of publicly available information on the financial impact of improved lubrication on the wind turbine fleet at a national scale. In this study, open-source simulation and modeling tools developed by the National Renewable Energy Lab were used to quantify the potential for improved gearbox lubrication to reduce the levelized cost of energy of the US wind turbine fleet. Specific cases were developed for baseline, realistic and stretch goals to determine the magnitude and relative priority of key lubricant performance properties in optimizing wind turbine lubrication.

8:40 am – 9:00 am

4042610: Empowering the World's Lower Carbon Ambitions Through Metallocene Base Stock Technology in Industrial Lubricant Solutions

Lindsey Bunting, ExxonMobil, Spring, TX

For over a century, lubricants have been essential for efficient operation of machines critical for modern life. As the world pursues a lower carbon future, synthetic base stocks can play a significant role in improving energy efficiency and productivity. ExxonMobil is committed to developing solutions that enable lubricant manufacturers to produce next generation lubricants which meet society's evolving needs. In the industrial segment, lubricants based on metallocene PAO (mPAO) technology can unlock not only a reduced total cost of ownership vs. mineral-based incumbents, but also increase energy efficiency, therefore reducing energy consumption. In this presentation, we will discuss oxidation and thermal performance, as well as energy efficiency benefits for mPAO, which underpins the increased adoption of synthetic-based industrial lubricants. We will also illustrate the economic and efficiency/durability benefits of designing synthetic lubricants leveraging mPAO technology.

9:00 am – 9:20 am

3986294: Wind to Wheels – Efficiency of the All-Electric Powertrain

Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

Geo-political forces that shape our planet push us to electrification. Wind to wheel expresses how wind kinetic energy is captured, converted to electricity, transported, stored, and converted back to electric vehicle kinetic energy. There is a 'powertrain' of mechanical and electrical components to achieve this. This talk identifies from published data the energy efficiency of each stage. As an example, a 3MW turbine in the London Array wind farm charges a Tesla Model 3 EV at home in central London. Wind speed data is averaged to predict turbine loading. The grid is assumed to be functioning at a base load of half peak. The data is assembled into a Sankey diagram to identify the power flows. Whilst there are many simplifications and assumptions in the analysis it is interesting to display the data graphically in this way. It becomes possible to compare the magnitude of mechanical (tribological) losses with electrical losses, and to see how mature technologies compare with newer ones.

9:20 am – 9:40 am

4002147: Foaming in Wind Turbine Gearboxes: Causes, Impacts and Treatment – Part III

Michael Blumenfeld, ExxonMobil Research & Engineering, Annandale, NJ; Kurtis Hartlen, Imperial Oil, Brights Grove, Ontario, Canada; Marianne Rodgers, WEICan, Tignish, Prince Edward Island, Canada

Wind turbines are a demanding and cost-sensitive application where high availability and low maintenance costs are critical. One of the most frustrating issues a wind turbine operator can experience is a foaming gearbox lubricant, which can trip oil-level sensors and cause unexpected downtimes. These foaming events may result in lost revenue, messy clean-ups and difficult troubleshooting. In this presentation, we will provide an update to the case study shared at previous STLE Meetings documenting the impact of problematic gearbox foaming on the operation of a fleet of five 2MW turbines at the Wind Energy Institute of Canada. Results will be shared on identification of the proper flushing/conversion protocol for foaming gearboxes as well as converting lubricants on other oil and grease systems. Data showing the lubricant performance over time after different conversion strategies will also be presented as well as troubleshooting unusual challenges that occur post lubricant conversion.

9:40 am – 10:00 am

4001960: Screener Test Development for Wind Turbine Gearbox Journal Bearings

Andrew Gant, Afton Chemical Ltd., Bracknell, Berkshire, United Kingdom; Paul Norris, Helen Dyer, Afton Chemical Ltd., UK, Bracknell, United Kingdom

A new laboratory-based screener test to assess the compatibility of bronze journal bearing materials with lubricants specifically aimed at the wind turbine gearbox market has been developed, proven and key aspects of lubricant behavior correlated with medium term field trial performance. The work involves a rotary tribometer specifically adapted for the study of friction behaviors; both transient (full Stribeck curves) and medium duration steady state friction. Oil ageing is correlated in terms of chemical changes with tribofilm formation and compatibility between active sulfur chemistries and the tribo-pair metallurgies.

10:00 am – 10:40 am – Break

Session 5G • 101 H

Fluid Film Bearings I

Session Chair: Amruthkiran Hegde, Kingsbury, Inc., Philadelphia, PA

Session Vice Chair: TBD

8:00 am – 8:40 am

3975548: Elasto-Hydrodynamic Lubrication Analysis of a Porous Misaligned Crankshaft Bearing Operating with Nanolubricants

Benyebka Bou-Saïd, INSA Lyon, Villeurbanne , France; Mustapha Lahmar, Reda Hamel, Guelma University, Guelma, Algeria

The combined effects of the characteristic size and concentration of inorganic fullerene-like tungsten disulphide nanoparticles (IF-WS2 NPs) on the nonlinear dynamic behavior of a gasoline engine crankshaft bearing are theoretically and numerically investigated using the V. K. Stokes micro-continuum theory. It is assumed that the crankshaft is rigid, and the main bearing consists of a thin poroelastic liner. The Krieger-Dougherty law is included in the proposed EHD model to account for the viscosity variation with respect to the volume fraction of nano-particles. The Reynolds equation is derived in transient conditions and modified to account for the size of nanoparticles and the bearing-liner permeability property. According to the obtained results, the combined effects of the size and concentration of fullerene-like nanoparticles on the dynamic behavior of a compliant dynamically loaded crankshaft bearing operating with dynamic misalignment are significant and cannot be overlooked.

8:40 am – 9:00 am

3984268: Performance of Orifice Compensated Hole-Entry Hybrid Spherical Thrust Bearing Operating with ER Lubricant

Satish Sharma, Nitin Agrawal, Indian Institute of Technology, Roorkee, India

This study deals with the theoretical investigation of an orifice compensated hole-entry hybrid spherical thrust bearing system operating with ER lubricant. A mathematical model based on FEM is developed to solve the modified Reynolds equation governing the flow of lubricant in the clearance space of spherical thrust bearing together with the restrictor flow equation and appropriate boundary conditions. The influence of applied voltage on the bearing performance has been analyzed. The study reveals that ER lubrication may significantly affect the bearing performance. For a hole-entry hybrid spherical thrust bearing lubricated with ER lubricant (at V =1200, and) the value of stiffness and damping coefficients may improve by an order of 124.25 % and 128.27 %, respectively, as compared to Newtonian lubricant (at V =0, and). The numerically simulated results presented in this work are expected to be useful to bearing designers and academic community.

9:00 am – 9:20 am

3985494: Exploring the Impact of Non-Newtonian Oils on Refrigerator Compressor's Journal Bearing – A Thermo-Hydrodynamic Investigation

Mateus da Silva Cardoso, Diego Berti Salvaro, Aloisio Nelmo Klein, Álvaro Toubes Prata, Cristiano Binder, Universidade Federal de Santa Catarina, Florianópolis, Brazil

Sustainability is a pressing concern, particularly in the refrigeration industry, which accounts for ~ 20% of global electricity use.

Miniaturization while increasing rotation speeds lead to higher shear-rates. In these conditions, oils may exhibit non-Newtonian behaviors. Assessing these effects becomes essential for selecting and developing more efficient lubricants. This study delves into the impact of employing different non-Newtonian oils in a refrigerator compressor's bearing. A THD model is introduced, utilizing a power-law viscosity model. The cavitation boundary is determined using the conservation of mass equation. Parameters for the viscosity model are determined through fitting experimental data. Even slight deviations from Newtonian behavior significantly affected performance. Under identical operating conditions, using an alkylbenzene oil results in a 67% lower load capacity, a 64% lower friction force, and a 90% lower consistency parameter compared to a polyolester oil.

9:20 am – 9:40 am

4005390: Comparison Between Prediction and Measurement of Start-Up Torque Reduction by Hydrostatic Lift Recess in Tilting Pad Journal Bearings

Hiroki Hatori, Wei Li, Manish Thorat, Elliott Group, Jeannette, PA

Hydrostatic lift is applied in Tilting Pad Journal Bearings on Turbine driven equipment to provide rotor lift during turning gear application or on applications where the starting torque of the drive is lower than breakaway torque at the bearings. Torque reduction is estimated using well known correlations for hydrostatic lift available in literature. Measurements of start-up torque reduction with the assistance of hydrostatic lift on API 617 compressors are presented in this study. The influence of supply oil pressure and oil flow on start-up torque reduction is measured. The results indicate a start-up torque reduction on the order of 4% to 31% of the original torque without hydrostatic lift. The start-up torque reduction estimate using the theoretical correlations is generally conservative when compared against measurements.

9:40 am – 10:00 am

3979929: Cryogenic Hydrostatic Bearing Failure from Pneumatic Hammer Instability During Liquid Nitrogen Supply

Keun Ryu, Minsoo Wee, Hyunsung Jung, Kyuman Kim, Hanyang University, Seoul, Republic of Korea

Cryogenic turbomachinery requires reliable, low-friction, and wear-resistant support systems. Operating conditions and fluid properties have a significant impact on the performance of hydrostatic bearings and rotordynamics in cryogenic turbomachinery. Therefore, testing rotor-dynamics in a cryogenic rotor-bearing system necessitates a dependable testing environment. Depending on the ambient temperature, the phase transition of cryogenic fluids from liquid to gas can introduce inaccuracies in measurement results. This research focuses on the failure of a rotor and a liquid nitrogen-lubricated hydrostatic journal bearing caused by pneumatic hammer instability. The current study introduces a predictive model to identify the conditions that lead to pneumatic hammer instability. This work outlines the necessary conditions to avoid pneumatic hammer instability using a combination of measurements and predictions.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4000272: A Triangle Based Finite Volume Approach Applied to the Analysis of a Hydrodynamic Bearing Operating with Two-Phase Lubricant

Mihai Arghir, Anthony Voitus, Universite de Poitiers, Futuroscope Chasseneuil, France

The present work introduces a triangle based finite volume method for integrating Reynolds equation. The non-structured grid is needed for analyzing a journal bearing with inclined grooves. The paper shows how Reynolds equation can be discretized on any convex control volume, the triangles being only a particular case. The linear discretization leads to a sparse matrix that can be very efficiently solved. Two triangulation methods from open-source codes are used to generate the grids. The results show that the robustness of the finite volume algorithm is different depending on the constraints used by each open-source code. The bearing operates with a homogeneous mixture of water and air being fed by a pressure difference between its two ends. Thus, the density and the viscosity depend on the local air volume fraction. A parametric study enlighten the impact of the ingested air on the load capacity and torque of the journal bearing.

11:00 am – 11:20 am

4015302: Nonlinear Bump Foil Stiffness Model in Foil Bearings – Experimental Measurements, Analytical Models, and Stability Characteristics

Woongeon Lee, Ehiremen Ebewele, Daejong Kim, The University of Texas at Arlington, Arlington, TX

Nonlinear characteristics of the bump foil of radial foil bearings can be observed because of their inherent structural properties such as bump geometry, forming process, and complicated contact behavior with bearing housing. In this paper, the nonlinear stiffness of bump foils in flat configuration has been experimentally measured and compared with various analytical models. Also, the same bump geometry but with a curved configuration for actual radial foil bearings was used to measure the structural non-linear stiffness in the bearing level in push-pull set up and compared with analytical prediction. Finally, the non-linear bump stiffness model was adopted to the radial foil bearing to calculate overall bearing stiffness and damping coefficients, and stability characteristics through modal analysis and transient time domain orbit simulations. Lastly, the non-linear stiffness model of the bump foils will be verified by measuring bearing coefficients using shaker systems.

11:20 am – 11:40 am

4016163: Performance Evaluation and Comparison of Hybrid Rigid and Hybrid Foil Thrust Bearings

Ehiremen Ebewele, Woongeon Lee, Daejong Kim, The University of Texas at Arlington, Arlington, TX

The critical issue facing the incorporation of foil-bearing technology into high-speed turbomachinery is the low-load carrying capacity of the foil thrust bearing. Hybridization of the foil bearing has been pursued to overcome this limitation either by load sharing with a magnetic bearing or injecting externally pressurized air to provide bearing clearance. In this work, a comparison is made between a hybrid rigid thrust bearing (HRTB) and a hybrid thrust foil bearing (HTFB) with hydrostatic injection. Both bearings have the same outer diameter of 82mm, with the same taper and orifice location and sizes. The bearing performance for both bearings was evaluated at 30krpm and at 5-bar absolute hydrostatic pressure. The mass flow rate characteristics, film thickness and zero-speed performance were assessed. Power loss and

load capacity comparison between both bearings was made at zero speed and at higher speeds. Finally, the experimental results were compared with simulation.

11:40 am – 12:00 pm

4003391: Effects of Top Foil Thickness on Dynamic Characteristics of Hybrid Foil-Magnetic Bearing Systems

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

Air foil bearings (AFBs) are compliant bearings comprised of a top and bottom foil. They find widespread application in oil-free turbomachinery. However, the thickness of the AFB foil significantly impacts the bearing's stiffness and damping coefficients. Additionally, from a manufacturing perspective, excessively thin foils pose challenges in maintaining forming reliability. This paper investigates the influence of foil thickness on the dynamic characteristics of AFBs supported by hybrid foil-magnetic bearing utilizing an excitation signal generated by an active magnetic bearing (AMB). The study involved estimating the dynamic coefficients of an AFB by varying the thickness of the PTFE-coated top foil while maintaining a constant thickness for the bump foil. The least squares method (LSM) was employed to analyze the measured excitation signal and displacement data, while the invariant method (IVM) was used to reduce residuals and extract accurate dynamic characteristics.

12:00 pm – 12:30 pm

Fluid Film Bearings Business Meeting

Session 5I • 101 J

Commercial Marketing Forum V

Session Chair: TBD

Session Vice Chair: TBD

8:00 am – 8:20 am

4094847: Chemours – Automotive Noise, Vibration and Harshness (NVH) Lubrication and the use of Perfluoropolyether (PFPE) Oils and Greases

Rebecca Vieira, Derek Newbould, Chemours, Wilmington, DE

Management of Noise Vibration and Harshness (NVH) in vehicle interiors is a challenge for many automotive suppliers and OEMs. Lubrication is one tool available to engineers to solve these challenges. Understanding the lubricant performance requirements is important when considering it as an option alongside other solutions. Some desired attributes of a NVH lubricant are – low/no Volatile Organic Compounds (VOC), thermal stability, wide temperature range usability, non-migration, ability to separate surfaces, and materials of construction compatibility. Certain lubricant chemistries can only obtain some of the desired attributes and therefore are not the best choice. This presentation will outline the relevant attributes of hydrocarbon, synthetic, and Perfluoropolyether's (PFPE) based lubricants. It will then highlight several applications where PFPE chemistry has been used for NVH issues.

8:20 am – 8:40 am

4098853: Simerics CFD Software

Raj Ranganathan, Simerics, Bellevue, WA

Simerics develops and sells analysis simulation software used in the automotive, aerospace, marine and hydraulic industries. The software suite includes Simerics-CFD, Simerics-FEA and Simerics-OPT, the latter for design optimization. Key attributes of the software are fast model set-up, fast and accurate multi-node, distributed memory, parallel solver (MPI). All three software are "home grown" therefore strongly coupled within the same GUI. Fast model set-up, starting with unclean CAD geometry, is enabled by GUI based pre- and post-processors, automatic mesh generators, automatic imprinting of thousands of parts and application specific templates. Application specific templates make model setup fast and easy and manage variabilities among users and projects. Example applications include the complete engine lubrication system, complete fuel delivery system, electric motors, gears, bearings, pumps, valves, battery thermal analysis, compressors, heat exchangers, full vehicle models.

8:40 am – 9:00 am

4093439: ExxonMobil – EHC 340 MAX™: Above and Beyond Group I Bright Stock

Toufic Aridi, ExxonMobil, Sarnia, Ontario, Canada

ExxonMobil has previously announced the Singapore Resid Upgrade Project, which is scheduled for startup in 2025 and will introduce a unique high-viscosity Group II base stock – EHC 340 MAX™ – at a large scale. EHC 340 MAX can be used over the wide range of lubricants traditionally served by Group I bright stock-based formulations, with some advantages that are specific to each application allowing lubricant marketers to convert their Group I bright stock tank over to EHC 340 MAX effectively. It also serves lubricant blenders who would like to use EHC 340 MAX to achieve finished fluid differentiation, particularly in the areas of improved shear stability, improved low temperature performance, and improved oxidation stability. With EHC 340 MAX, ExxonMobil's EHC Slate of products is able to meet the broadest lubrication needs, compared to other Group II products. ExxonMobil will continue to partner with global and regional additive companies to deliver market general solutions for our customers.

9:00 am – 9:40 am

4093062: Afton Chemical's Key Driver Seminar – Re-think, Re-define, Re-refine: Formulating Solutions for the Future

Joel Garrett, Safety-Kleen, Norwell, MA; Alyson Wilson, Afton Chemical Corporation, Richmond, VA

The increasing need for support and solutions for sustainability has the industry looking for choices. The right choice for producers, blenders, and organizations starts with rethinking and redefining re-refined base oils. For Afton Chemical's 2024 Key Driver Seminar, we have invited Safety-Kleen's Senior Vice President, Dr. Joel Garrett, to share the trends and challenges faced by re-refined base oils. Dr. Garrett will also discuss the role re-refined base oils play in corporate ESG goals and how thoughtfully chosen formulations can deliver better quality, reliability, and sustainability.

9:40 am – 10:00 am

4092003: Evonik – Collaborative R&D for Next-Gen Electric Vehicle Chemistries

Adam Rice, Evonik Corporation, Richmond, VA

Get ready to embark on a journey of innovation and collaboration with Evonik's presentation on "Collaborative R&D for Next-Gen Electric Vehicle Chemistries." Join Adam Rice, Debbie Lewis, and Brigitte Sheehan as they introduce themselves and their approach to the topic. The presenters value everyone's perspectives and ideas and are committed to working collaboratively with stakeholders to achieve shared goals through open and honest discussions and feedback. Attendees will gain valuable insights into the latest advancements in the industry, and how they can incorporate them into their work to make a positive impact. The presentation will also highlight Evonik's broad portfolio, which brings new improvements to future formulations. Don't miss this opportunity to collaborate, innovate, and make a difference in the field of electric vehicle chemistries.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4089026: Cargill – Achieving Low Traction and Low Wear in EV transmission Fluids

Scott Davis, Cargill, Carmel, IN

Without globally recognized standards, there are variations in EV fluid specifications and requests to formulators are diverse, but as EVs get heavier and more powerful, transmission fluid requirements become more rigorous. Here we present an overview of the challenges faced by EV fluid formulators and where Cargill Priolube™ and Perfad™ base oils and thickeners help the formulator achieve low traction and low wear in demanding operating environments. Consideration will be given to efficiency, including full-size rig testing as well as wear, compatibility and no-harms data.

11:00 am – 11:20 am

4092643: SEQENS Program for More Sustainability in the Lubricant Industry

Xavier Semery, SEQENS, Porcheville, France

SEQENS is supporting its customers in the development of lubricants with reduced environmental impact. Being Platinum ECOVADIS certified, our French plant is fully involved in the sustainable development of SEQENS activities. To face the challenges of sustainability, SEQENS is offering a range of additives suitable for the formulation of environmentally friendly lubricants (EALs) as well as low labeled lubricants. SEQENS has developed sulfurized extreme pressure additives, that are registered on the LuSC list (Lubricant Substance Classification List) facilitating the formulation of EAL. A push for alternative technologies to lithium is rising due to several challenges in term of supply chain, price and toxicological threats and considering the need of more sustainable solutions, SEQENS is the only one to propose over based calcium sulfonate biodegradable greases with good anticorrosion and water resistance, high thermal stability, extreme pressure performance and mechanical stability.

11:20 am – 11:40 am

4089740: BASF Corporation – The Future of Sustainability with BASF Fuel and Lubricants

Daniel Niedzwiecki, BASF Corporation, Florham Park, NJ

BASF's Fuel and Lubricant Solutions is your preferred partner for sustainable high-performance lubricant components in the industrial market. Driven by the need to reduce greenhouse gas emissions and powered by our industry leading PCF methodology standard, BASF now offers the novel BMBcert™ product series. Replacing fossil-based raw materials with renewable feedstocks, our BMBcert™ products deliver significant CO_2 savings while providing the same high performance and consistent quality products you expect from BASF. This session will highlight our new portfolio of BMBcert™ products, which includes BREOX® base stocks, IRGAFLO® rheology modifiers, SYNATIVE® performance additives, and GLISSOPAL® thickener technologies, to prepare you for a sustainable future.

11:40 am – 12:00 pm

4092863: Emery Oleochemicals DEHYLUB® Esters Engineered for EV Fluid Performance

John Sliner, Emery Oleochemicals LLC, Cincinnati, OH

Emery Oleochemicals is a leading provider of high performance natural-based additives and base stocks for lubricant, metalworking fluid, and corrosion preventive formulators. Our brands include DEHYLUB® Esters, EMERSOL® Isostearic Acids, EMERY® Dimer Acids and Pelargonic Acids, and EMEROX® Azelaic Acids and Corrosion Inhibitors. Principal to our business strategy is our back-end integration to renewable feed stocks, innovative solutions, reliably consistent products, in-depth technical knowledge, and global commercial and technical support. This presentation will introduce our offering of esters that have been engineered to provide outstanding performance as base stocks or additives for fluids used in electric vehicle applications. They provide excellent low temperature properties and oxidative stability. Additionally, these products satisfy the special EV demands for properties including high thermal conductivity, specific heat capacity, breakdown voltage and dielectric constant.

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Session 5J • 200 DE

Electric Vehicles V

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

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

8:00 am – 8:40 am

4005447: Alternates to Fluorosilicone Based Antifoams for Electric Vehicle Driveline Fluids Due to PFAS Regulations

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

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

8:40 am – 9:00 am

4002326: Combination Effects of Phosphate and Sulfur Additives on Anti-Wear/Anti-Pitting Properties and Tribofilm Formation in Rolling-Sliding Contacts

Yunah Jeung, Kaito Yoshioka, Kaisei Sato, Shinya Sasaki, Tokyo University of Science, Katsushika, Tokyo, Japan; Ryotaro Ohashi, Graduate School of Tokyo University of Science, Katsushika, Japan

According to the development of lubricants, there is a growing tendency to lower viscosity oil to enhance power efficiency. This trend towards lower viscosity is increasing the risk of wear and fatigue damage on sliding components. To address these issues, lubricant additives are one of the important technologies. Our previous results have indicated that sulfur-based additives exhibited higher anti-wear properties compared to phosphorus-based additives, and a combination of sulfur-based/phosphorus-based additives showed further improvement of anti-wear performance. However, the effects of tribofilm formation on anti-wear/anti-pitting properties is not fully understood. The purpose of this study is to investigate how the combination oil of phosphorus/sulfur-based additives affects tribofilm formation, and subsequently, how it influences anti-wear and anti-pitting properties as the Sliding-Roll ratio changes using MTM-SLIM.

9:00 am – 9:20 am

4002715: Molybdenum Compounds as Additives in Future PCMO and EV Applications – A Comparative Study

David Boudreau, Vanderbilt Chemicals LLC, Norwalk, CT

In the pursuit of enhanced automotive performance and efficiency, the choice of lubricating fluids and their additives plays a critical role. This work investigates the performance profiles of various molybdenum-containing lubricant additives in PCMO and EV-based fluids. Conductivity, corrosion resistance, friction reduction, wear prevention, and their potential ability to withstand extreme pressure conditions are considered. By presenting a holistic assessment of molybdenum compound additives and their multifaceted impact on lubricating fluid performance, this research focuses on identifying sustainable, high-performance solutions for the ever-evolving automotive industry.

9:20 am – 9:40 am

4004955: Advanced Rheo-Tribological Testing of Greases for Electric Vehicles

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

Lubricants used in electric mobility applications have to cater to an additional set of criteria, beyond the existing traditional requirements. If the stray currents produced by frequency converters used to control the motor speed are discharged through the associated ball bearings, over long term, it can damage the bearings. To counter it, development of lubricants for electric vehicles must also consider electrical parameters such as permittivity, conductivity, and breakdown voltage. The primary aim of this study is to present a novel test methodology to investigate different greases at lab-scale to simultaneously characterize their frictional, and electro-tribological response. Additionally, the rheo-tribometer made it possible to measure rheological and electro-rheological properties of the greases. The sum of all these investigations can help us develop a model to understand the behavior of grease-lubricated ball-bearing systems under dynamic conditions.

9:40 am – 10:00 am

3982292: How Can We Measure the Performance of Greases for Connectors? A Hands-On Tribo-Method

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

The amount of electrical connectors in the automotive industry will likely keep increasing, many systems depend on electronic and electric connections. When disconnects occur, the consequences can range from annoying to critical. In operation in vehicles, connectors are subjected to vibrations that may induce fretting wear damage in the contacts. To extend component lifetime, electrically conductive greases can be used, but to assess their performance in a real contact, we have to test beyond standards such as the ASTM D-4170 four ball or SRV reciprocating tests. We have developed a method that uses actual USB-connector components, and recreates vibratory motions, where both friction and conductivity are used to identify 'time to failure'. This method uses real USB-connectors and can be modified for other connector types, making it a practical approach to evaluating the complete setup of USB-connector + lubricant. It is found that a specialty lubricant makes all the difference.

10:00 am – 10:40 am – Break

10:40 am – 11:00 am

4004008: Electrical, Mechanical, and Performance Properties of Electric Vehicle Motor Greases with Silver Nano-Particle Additives

Jack Janik, Sudip Saha, Samuel Bond, German Mills, Robert Jackson, Auburn University, Auburn, AL; Carlos Sanchez, Peter Lee, Southwest Research Institute, San Antonio, TX

Shaft voltages and bearing currents generated within an electric vehicle's powertrain system can accumulate near rolling element bearings, causing significant damage or mechanical failure. The incorporation of conductive lubricants is a possible solution to mitigating this damage. This work documents the properties of silver nanoparticle colloidal suspensions in polyurea greases for electrified applications. Several variations are considered, including mineral and synthetic base oils, with and without conventional additive packages. All base greases are NLGI Grade 2 consistency and ISO 100 grade viscosity. The rheological and electrical properties of the greases, such as viscosity, conductivity, and dielectric strength, are measured and used to explain the changes in performance observed in previous work.

11:00 am – 11:20 am

4004810: Dedicated e-Fluids for Energy Efficiency

Hitesh Thaker, Changlin Zhao, Infineum USA LP, Linden, NJ

The trends of improved fuel efficiency and CO2 emission reduction have resulted in automotive manufacturers incorporating greater levels of electrification, and developing more compact, higher voltage designs. The new hybrid and battery electic vehicle designs have led to the development of dedicated e-fluids for these applications that offer reduced energy consumption at lower viscosities while providing necessary hardware protection. Controlled testing conditions with specific electric drive unit helps provide key insights on the impact of e-fluid parameters like viscometrics and additives is key for achieving high energy efficiency.

Session 6A • 101 B

Materials Tribology IV

Session Chair: Mark Sidebottom, Miami University, Oxford, OH

Session Vice Chair: Santiago Lazarte, Florida State University, Tallahassee, FL

1:40 pm – 2:20 pm

4005662: Robust Superlubricity in Mo_2TiC_2 MXenes Facilitated by Tribocatalytic Reaction at the Sliding Interfaces

Anirudha Sumant, Sai Varun Sunkara, Yuzi Liu, Subramanian Sankaranarayanan, Argonne National Laboratory, Lemont, IL; Brian Wyatt, Babak Anasori, Purdue University, West Lafayette, IN; Andreas Rosenkranz, University of Chile, Santiago, Chile

Recent interest in exploring tribological properties of MXene is rooted in their layered structure and ability to shear easily coupled with their robust mechanical properties. However, their chemical stability a critical factor of long-term reliable lubricant has remained unproven, thereby constraining its full application potential within the lubrication industry. In this current work, we study an ordered double transition metal MXene (Mo2TiC2) and demonstrate its exceptional tribological performance in dry nitrogen atmosphere using macro-scale pin-on-disc tribo-testing. We demonstrate sustained superlubricity, with a friction coefficient as low as 0.005, persisting over the extensive course of linear sliding of 86 kilometers, with no signs of failure and minimal wear rates. We will elucidate the intricate mechanisms including the pivotal role played by tribo-catalytic reactions at the sliding interface, which yield a stable, lubricious tribolayer.

2:20 pm – 2:40 pm

3976685: Room Temperature Sintering of TiO^2 Nanoparticles – Exploiting Friction to Manufacture Wear-Resistant Coatings

Pranjal Nautiyal, Oklahoma State University, Stillwater, OK; Michael Moriarty, Parker LaMascus, Andrew Jackson, Robert Carpick, University of Pennsylvania, Philadelphia, PA; Gordon Lee, ExxonMobil Technology and Engineering Company, Clinton, NJ; Robert Wiacek, Pixelligent Technologies, LLC, Baltimore, MD

We exploit friction-assisted sintering mechanism – tribosintering – to manufacture wear-resistant coatings on steel at tribological contacts. A pressurized sliding/rolling contact is run in a processing fluid containing dispersed nanocrystals. The nanocrystals sinter on the contacting surfaces, forming robust surface-bound solid coatings. We used a ball-on-disc tribometer equipped with an optical interferometer to study the deposition and durability of TiO_2 coatings in situ. These coatings sinter at room temperature over all tested slide-roll-ratios (0 to 50%), with higher slide-roll ratios accelerating sintering. These coatings resisted wear in 10-hour durability tests in harsh boundary contact conditions in nanocrystal-free oils. In contrast, uncoated steel scuffs under these conditions. We postulate these coatings' exceptional wear resistance stems from highly effective sintering densification under combined compressive and shear stresses over tens of thousands of contact cycles.

2:40 pm – 3:00 pm

4000936: Novel Organic Friction Modifiers with Extended Performance Durability

Micky Lee, Oleon Port Klang Sdn Bhd, Port Klang Selangor, Malaysia; Pieter Struelens, Oleon NV, Evergem, Belgium

Friction modifiers keep on playing a vital role in reducing energy losses and thus improving fuel economy. However, in the light of the upcoming ILSAC GF-7 standard, the quest remains for high-performance friction modifiers maintaining their performance over an extended period of time, ensuring long-term efficiency and effectiveness. This work focuses on the design and synthesis of innovative organic friction modifiers (OFMs) with improved oxidative and hydrolytic stability allowing them to withstand harsh operating conditions and maintain their friction-reducing capabilities over extended periods of use. More specific it has been shown that the use of a specific oligomerized organic friction modifier allows to achieve a very low friction coefficient (superlubricity effect) at low speed compared to conventional organic or moly based friction modifiers even after prolonged usage and exposure to various environmental factors.

3:00 pm – 3:40 pm – Break

6A

3:40 pm – 4:00 pm

4004740: Critical Influence of Contact Temperature for Tribology in Polymer Contacts and Models to Quantify It

Mitjan Kalin, Tomaz Pozar, Shoaib Siddiqui, University of Ljubljana, Ljubljana, Slovenia

The utilization of polymer materials has seen rapid growth across various engineering applications, including gears and bearings. However, when compared to metals, polymers are considerably more sensitive to temperature fluctuations due to their inferior thermal resistance and insulating properties. Consequently, the frictional heat generated affects their tribological performance by causing softening or even melting. In this study, we present some critical parameters that cause risks of thermal degradation of polymers in such contacts. Furthermore, we developed ready-to-use models for polymer/polymer and polymer/steel contact temperatures, which effectively replicates the contact temperatures in polymer contacts in pin-disc studies. These models also aid in comprehending the tribological behavior of polymers in these contacts and enable the prediction of contact temperatures as well as to set proper tribological test conditions and test duration.

4:00 pm – 4:20 pm

4005345: Influence of Polymer Morphology on the Ultralow Wear Behavior PTFE Composites

Kylie Van Meter, Victoria Yang, Brandon Krick, Florida State University, Tallahassee, FL; Christopher Junk, Lehigh University, Bethlehem, PA

Polytetrafluoroethylene (PTFE) is commonly used as a solid lubricant in tribology applications due to its very low coefficient of friction (<0.1), thermal stability, and chemical inertness. Although PTFE has a high wear rate when used under typical engineering sliding conditions, the addition of filler materials like alumina and PEEK to PTFE have resulted n a 10,000x reduction in wear rate (K< 10-7 mm3/Nm). In recent works, polyether ketone ketone (PEKK) was used to create ultralow wear composites that are environmentally agnostic due to the abundance of ketones that accumulate at the sliding interface. It appears that the wear behavior of the composite can be further improved by altering the morphology of the polymer through composite processing control. In this study, the influence of composite processing and polymer morphology was investigated through tribological, thermal, and mechanical characterization of the composites, along with chemical analysis of the sliding interface.

4:20 pm – 4:40 pm

4004823: Tribological Performance of Experimentally Developed 3D Printed High-Performance Polymer Composites

Nayan Dhakal, Nazanin Emami, Luleå University of Technology, Luleå, Sweden; Cayetano Conesa, Ardian Morina, University of Leeds, Leeds, United Kingdom

This work investigates additive manufacturing of polyether-ether-ketone (PEEK) and polyphenylene-sulfide (PPS) composites for hydropower bearings using Fused Filament Fabrication (FFF). Composite filaments were experimentally developed, extruded, 3D-printed, and tested for their reciprocating sliding behavior. In-house developed and 3D printed parts exhibited tribological performance comparable to injection molded parts, with improved surface quality. Carbon fibers (10 wt.%) in PEEK yielded up to 37% friction reduction and a specific wear rate of 2x10-6 Nm/mm3 under dry sliding. Water lubrication reduced running-in and friction coefficients of neat PEEK up to 48% compared to dry conditions. Tribological results emphasize that material combination and sliding conditions influence running-in, friction evolution, and wear mechanism. Consequently, this research suggests that 3D printing can be a sustainable option for processing high-performance thermoplastics in tribological applications.

4:40 pm – 5:00 pm

3982319: Investigating the Friction and Wear Properties of Polymer Laser Sintered Components

Kieran Nar, 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.

5:00 pm – 6:00 pm

Materials Tribology Business Meeting

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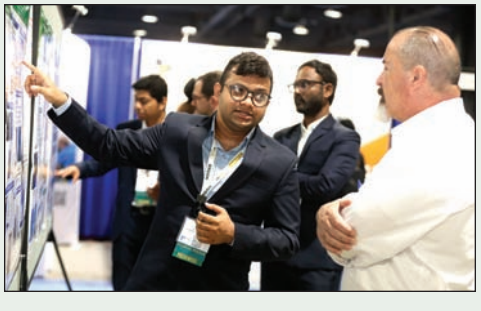

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More than 30 student and early career posters will be on display Monday through Wednesday, May 20-22 in the Minneapolis Convention Center (Exhibit Hall B) during the STLE Annual Meeting. Students and early career professionals from around the world will be participating and showcasing the latest industry research. Attendees will be able to review tomorrow's ideas and talent in the field of tribology. Posters will be judged by a conference committee, and cash stipends will be given out to the best posters. Winners will be recognized during the President's Luncheon/STLE Business Meeting on Tuesday, May 21.

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Session 6B • 101 C

Condition Monitoring II

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

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

1:40 pm – 2:20 pm

4002620: Comparing New ASTM Methods for FTIR Analysis of Fluid Condition

David Swanson, POLARIS Laboratories®, Indianapolis, IN

Condition monitoring of fluid properties by FT-IR has long been led by the ASTM method E2412. However, ASTM E2412 is a practice in itself and, as such, has no repeatability and reproducibility limits. Recently, ASTM has introduced new methods for oxidation, nitration, soot, phosphate anti-wear additives, and sulfate by-products. How do they compare, and should you challenge your laboratory to switch to them? This informative session will discuss key differences between these newly devised methods and important considerations when evaluating in-service lubricant and machine health objectives.

2:20 pm – 2:40 pm

3970806: Extended Lubricant Analysis Using Nuclear Magnetic Resonance (NMR)

Christoph Rohbogner, OELCHECK GmbH, Brannenburg, N/A, Germany

Nuclear Magnetic Resonance (NMR) is the most powerful analytical method known in organic chemistry today. As lubricants are comprised of organic and metal organic compounds it is of special interest if it can be applied in used oil analysis. NMR allows the specific observation of different elements and their neighboring structure. This may be used to observe the changes within the additive molecules in comparison with fresh oil references. It is known that AW and EP additives are structurally altered during their use. Thus, it is possible to track the concentration of the original AW/EP molecule. As AW/EP Additives are typically based on Phosphorous, the observation of the 31P isotope with NMR is preferred. The combination of already applied methods like ICP-OES analysis with the knowledge of the percentage active AW/EP Additives is an ideal tool for estimating the lifetime of the lubricant thus, leading to a sustainable lubrication strategy.

2:40 pm – 3:00 pm

4002568: Oil, Fuel, and Coolant Analysis – How Each Can Dramatically Extend Equipment Life

Michael Holloway, SGS, Highland Village, TX

Every piece of equipment has a heartbeat, blood stream, temperature and so on. Understanding the overall health and well-being of your equipment can improve your profitability and provide a competitive edge. The analysis of oil, coolant and fuel are methods being used by forward thinking companies that are focused on getting the most out of their equipment and productivity. This presentation explains the latest tools and techniques used for these practices. Whether you are looking to extend change intervals, track down the root cause for equipment breakdowns, or to use for on-going diagnostics, the practice will help drive down costs and keep the assets on the road.

3:00 pm – 3:40 pm – Break

3:40 pm – 4:00 pm

4005269: Application of Electrochemical Impedance Spectroscopy (EIS) to Lubricating Oil Condition Monitoring

Tianshi Fang, Jing Ning, Ryan Manthiri, Krystal Henry, Oluwaseyi Ogunsola, Shell Global Solutions (US) Inc., Houston, TX; Rihard Pasaribu, Shell Downstream Services International, Rotterdam, Netherlands; Robert Mainwaring, Shell Global Solutions (UK), London, United Kingdom

In-situ lubricating oil condition monitoring (OCM) has received remarkable interest from various industries, especially in applications where timely oil change is critical but inconvenient or expensive. Electrochemical Impedance Spectroscopy (EIS) has been identified as a promising technique to achieve effective and economic OCM. In this study, an in-house scientific EIS sensor along with a few commercial EIS sensors were tested to understand EIS responses to multiple parameters related to oil degradation. Mathematical models were developed to effectively analyze sensor signal. The EIS sensors responded rapidly to changes in contaminations and ageing in oils. The most indicative parameter of oil condition was identified. It was found that EIS performed differently with lubricant formulations with different levels of additization. Hence, sensor signals detecting a specific type of oil need to be interpreted with a particular model.

4:00 pm – 4:20 pm

4004685: Combining Oil Analysis Tests to Identify the Root Cause of Machine Failures (ASTM D2982-7 (2013) and ASTM D5185)

Ross Master, Bureau Veritas, Suwanee, GA

Case Comparative Study between ASTM D2982-7 (2013) Standard Method for Detection of Glycol-Base Antifreeze in Used Lubricating Oils (Qualitative) and ASTM D5185 Standard Method for Multi-element Determination of Used and Unused Lubricating Oils and Base Oils by ICP-AES (Quantitative) as a Complementary tool on O.C.M.

4:20 pm – 4:40 pm

4025260: Quantifying Severity of Wear and Contamination with a Filtergram

Daniel Walsh, Ray Garvey, Ametek, Chelmsford, MA; Kubale Shamabanse, Bryan Johnson, Palo Verde Generating Station, Tonopah, AZ

Wear debris monitoring and analysis is an extremely effective maintenance approach to ensure machine health. Rotrode filter spectroscopy (RFS), a tool used to process and measure particles greater than 5 micron to detect abnormal wear, has been discontinued. Acid digestion, another methodology used to measure larger wear particles, is cumbersome and labor intensive. Concentrating wear debris on a small footprint disposable filtergram and analyzing the debris for elemental composition by ASTM D8127 (Coupled particulate and elemental analysis using XRF) offers a new approach for wear debris monitoring. The sample preparation for this new method also becomes an ideal alternative for microscopic particle examination. This presentation will describe an overview of the challenges, and the interim results from a site-based study in a power generation facility, with data from oil and grease samples.

4:40 pm – 5:00 pm

Condition Monitoring Business Meeting

Session 6C • 101 D

Lubrication Fundamentals IV: Oil Degradation

Session Chair: Chanaka Kumara, Oak Ridge National Laboratory, Oak Ridge, TN

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

1:40 pm – 2:20 pm

4027747: Stop Over-heating (Killing) your Bearings with Poor Lubrication Practices

Allan Rienstra, Kaitlyn Dobie, SDT Ultrasound Solutions Inc, Cobourg, Ontario, Canada

The engineering that goes into manufacturing the world's best bearings makes them nearly indestructible and when they are maintained properly, they often outlast the assets they support. But many organizations use archaic, calendar-driven re-lubrication techniques that result in bearings that fall short of their engineered lifespan. New techniques use ultrasound as a guide to achieve optimal grease replenishment while reducing thermally induced degradation. The presentation will include tales of ultrasound techniques used by lubrication technicians around the world and is full of fact-filled anecdotes and case studies with before/after graphs and sound files. Join Rienstra to Hear More. Join Rienstra to grease bearings right.

2:20 pm – 2:40 pm

4004588: Development of a Lifetime Model for the Oxidation Stability of Lubricating Greases

Nicole Dörr, Christoph Schneidhofer, Michael Schandl, AC2T research GmbH, Wiener Neustadt, Austria

Thermal and oxidative stress are key influencing parameters that affect the lifetime of lubricants. By means of a modified microcoking test, 4 lubricating greases with different base oils and thickeners were exposed to temperatures from approx. 100 to 190°C in air. The oxidation stability of the greases was determined by means of an oxidation model developed from grease analytical data. This was used to rank the greases according to their oxidation stability over the temperature range investigated.

2:40 pm – 3:00 pm

3982906: Investigating the Oil Aeration Performance of Lubricants

Tianshi Fang, Eliane Gendreau, Hayley Bunce, Robert Mainwaring, Sarah Matthews, Shell, London, United Kingdom

The ability of automotive or industrial lubricants to handle air has been acknowledged for many years. Excessive foaming, associated with air release, and compromised lubrication, associated with entrained air, being of particular concern. Current hardware trends focused on increased power delivery and reduced size promote a reduction in oil volumes and oil circulation times, both of which are apt to exaggerate air handling concerns. Both trends are prevalent in modern engines and the high-speed transmissions used in e-mobility applications creating an increased interest in aeration phenomena. In these studies, we explored the impact of viscosity, temperature, flow rate and antifoam additive selection on the air entrainment behavior of a modern, high speed engine. Engine, bench top and more fundamental studies were used to create a generic understanding of aeration control that can be applied to a wide range of applications.

3:00 pm – 3:40 pm – Break

3:40 pm – 4:00 pm

4000688: Influence of a Transmission Oil Degradation on System-Level Behavior

Busra Duran, Jerome Cavoret, Fabrice Ville, David Philippon, INSA Lyon, Villeurbanne, France; Arnaud Ruellan, Frank Berens, SKF France, Saint-Cyr-sur-Loire, France

During the operation of lubricated mechanical systems, lubricant properties may change. This can influence the performance of the mechanical systems in terms of durability and efficiency, for example. This study analyzes how field operation affects system-level performance in fresh and field-collected transmission oils. Thermal and tribological tests on the FZG machine were carried out to assess the oil performance under various operating conditions by analyzing the different sources of dissipated energy (bearings, tooth friction, churning …). The dissipated energy model used for the analyses is in good agreement with the experimental results. Results reveal that, through variations in efficiency, field-collected oils behave differently from fresh oils.

4:00 pm – 4:20 pm

3999444: The Evaluation of Ti_3C_2Tz MXene Nanofluid (As a Single Fluid) for Balanced Lubrication and Thermal Management

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

Using a single fluid in vehicles for balanced lubrication and thermal management can improve fuel economy, reduce emissions, and improve performance. These fluids can be used as transmission, differential, and power steering fluids where lubrication and thermal management are essential. In this work, we evaluate the performance of Ti_3C_2Tz MXene as an additive to enhance the heat transfer, rheological properties, and tribological performance of silicone & polyalphaolefin (PAO) oils. Experimental results showed that adding MXene improved thermal conductivity by 16 % & 23 % in silicone and PAO oils, respectively. The rheological data revealed that adding Ti_3C_2Tz nanosheets reduced the viscosity by 12.3 % and 18.1 % in silicone & PAO oil, respectively. The addition of Ti_3C_2Tz reduced the friction by 23 % and 65 % in silicone & PAO oils, respectively. The improved properties & reduced fluidic drag in viscosity and friction can offer the utilization of MXene-based fluid in EV applications.

4:20 pm – 5:00 pm

Lubrication Fundamentals Business Meeting

Session 6D • 101 E

Rolling Element Bearings I

Session Chair: Ujjawal Arya, Purdue University, West Lafayette, IN
Session Vice Chair: Travis Shive, SKF USA Inc., Lansdale, PA

1:40 pm – 2:20 pm

3983543: Comparison of Fatigue Performance of Different Aerospace Rolling Element Bearing Materials

Nikhil Londhe, The Timken Company, North Canton, OH

In aerospace applications, rolling element bearings are subjected to harsh conditions of severe vibratory stresses, high rotational speeds, elevated temperatures, and aggressive lubrication conditions. To meet application needs, these bearings are made using high strength and clean bearing steels. Hybrid bearing silicon nitride rolling elements paired with steel raceways offer better tribological performance. This study offers an analysis of fatigue life data for 1185 aerospace bearings that were tested between 1995 and 2023. The relative performance of different ring materials, such as 440C SST, CSS42L, M62, 52100, M50, and M50NiL are provided. Comparisons of hybrid ball and roller bearings performance, relative to all steel variants, is also provided under identical load conditions. Bearing life predictions using an advanced stress-based fatigue life model shows good agreement with experimental data.

2:20 pm – 2:40 pm

4005361: Effect of Operation Temperature & Lubrication Regime on Bearing RCF Life Using Computational Modeling Tool

Behrooz Jalalahmadi, Nick Weinzapfel, Sentient Science, Buffalo, NY

It is widely known that operation temperature can affect rolling contact fatigue (RCF) life of bearings. We utilize our DigitalClone for Engineering (DCE) bearing modeling tool to investigate the effect of operation temperature on lubrication regime, contact pressure profile and bearing RCF life. DCE is a physics-based RCF life prediction model which has been developed considering contact stresses, material microstructure, crack initiation mechanisms, damage mechanics, and probabilistic methods. To demonstrate the validation of DCE modeling tool, two different bearing types are studied under RCF loading: a) off-the-shelf AISI 52100 cylindrical roller bearing (CRB), b) custom-made M50 angular contact ball bearing (ACBB). We perform both experimental RCF testing and computational RCF modeling using our DCE modeling tool. Due to variation of test temperature, two different lubrication regimes of mixed-EHL and boundary lubrication are created.

2:40 pm – 3:00 pm

3988753: Prediction of Bearing Damage Beyond Rolling Contact Fatigue

Patrick Wingertszahn, Oliver Koch, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany

The fatigue life calculation of rolling bearings according to DIN ISO 26281 is state of the art and is used in the design and selection of bearings. The calculations are based on the damage mechanism of material fatigue. This covers the safe design of rolling bearings for a wide range of applications. Beyond fatigue, operating conditions and environmental influences can cause other damage to the rolling bearing, such as different wear mechanisms, adhesive and abrasive, or plasticization. Among others van Lier, Wadewitz and Eglinger found critical values, for damage initialization and damage development. These values depend on local contact parameters like contact pressure, relative velocity, effective coefficient of friction, contact ratio and shear stresses. The contact parameters are strongly dependent on external loads. In this work an approach is presented with which damage characteristics for rolling bearings can be determined depending on the system loads.

3:00 pm – 3:40 pm – Break

3:40 pm – 4:00 pm

4090980: Linkage Between Structural Fatigue and Rolling Contact Fatigue – New P-F-L Curve Analysis and Evaluation Using P-S-N Curve

Shigeo Shimizu, Meiji University, Kawasaki, Kanagawa, Japan; Hiroshi Ozeki, Chiba Institute of Technology, Chiba, Japan; Tsuyoshi Shimizu, Yamanashi University, Yamanashi, Japan; Tatsuya Imai, Yoshihiro Hamada, THK Co. Ltd., Tokyo, Japan

The General Weibull Distribution (GWD) function introduced a minimum life (γ) is adopted under a fixed shape index (m) depending on the distribution shape of the iso-stressed field concerning the critical failure. The discussed items are as follows: (1) Material dependency on stress-life exponents of P-S-N curve using GWD function: (2) 2520-bearing system life distribution by Tallian (1962): (3) P-F-L curve by Lundberg and Palmgren (1947) vs. 500-bearing and 719-bearing life distributions by Snare (1970) and Okamoto et al. (1977): (4) 565-tapered roller, 596-ball and 1161-mixed bearing system lifetime data by Takata et al. (1985): (5) Life distributions of 915-ball bearing for a quarter century by Muro (1987): (6) Life distribution and load-life exponent of 3-lot, 318-ball bearing by Okamoto et al. (2005): (7) Life distributions of 6-lot, 191-ball bearing and their system data by Shimizu (2012).

4:00 pm – 4:20 pm

3986667: The Effect of Current and Lambda on White-Etch-Crack Failures

Nicholaos Demas, Cinta Lorenzo Martin, Aaron Greco, Robert Erck, Argonne National Laboratory, Lemont, IL; Ryan Luna, GE Vernova, Schenectady, NY

In this work, a benchtop test rig was used to investigate the effect of electrical current and operation in different lubricating regimes, defined by lambda (λ). It was observed that there is an inverse correlation between the magnitude of electric current applied to the ring/roller system and time-to-failure. For the same current magnitude, tests conducted in boundary and mixed lubrication regimes showed that time-to-failure increased as increased, and the tests resulted in WEC related macropits, whereas tests conducted in near-hydrodynamic regime resulted in surface damage with no macropit. It was also noted that a shift toward near-hydrodynamic lubrication resulted in a distinct surface distress on the roller surface. Sub-surface imaging revealed the presence of WECs in all cases, and broad, branching cracks that were more prevalent under the more severe boundary conditions.

4:20 pm – 4:40 pm

4000734: Particular WEC Triggers and Their Failure Risk – It's All a Question of How Long They Last?

Daniel Merk, Wolfram Kruhoeffer, Jörg Franke, Jörg Loos, Schaeffler Technologies, Schweinfurt, Bavaria, Germany

In particular cases, rolling bearings fail due to White Etching Crack (WECs) before reaching their calculated rating life. This happens if so-called additional loads, like very high friction energy, are applied on the bearing beside the Hertzian rolling contact stresses. But these WEC-critical operating conditions often do not occur over the entire operating period and are therefore not detected and not mitigated in many times. Under

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such circumstances, it is unclear whether the bearings are then already irreversibly damaged and will fail. To clarify this important question, WEC bearing tests on different WEC test stages with varied impact time of the additional load were made and will be presented.

4:40 pm – 5:00 pm

3998427: Mechanistic Study of White Etching Area Development in Butterflies Through 3D Investigations of Roller Bearings

Mostafa El Laithy, Ling Wang, Terry Harvey, University of Southampton, Southampton, Hampshire, United Kingdom; Wolfram Kruhoeffer, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany

The investigation of the development of butterflies (BFs) in bearings due to rolling contact fatigue has been a subject of intense research for decades, aimed at elucidating their underlying formation mechanisms. Majority of studies have focused on two-dimensional analysis of the BF microstructure. In this study, BFs at different stages of development, including their capsuled inclusions have been examined in three dimensions using laser-focused ion beam serial sectioning method where several BFs have been fully captured. It is revealed that the structure of fully developed BFs, contradicting to the prevailing characterization in literature, do not comprise of two separated wings, rather that, the white etching areas (WEAs) in a BF bear a closer resemblance to that of a single disc-shaped structure encapsuling an inclusion. A comparison of BFs and white etching cracks has been conducted to enhance the understanding of complex processes underlying the formation of WEAs within bearings.

5:00 pm – 5:30 pm

Rolling Element Bearings Business Meeting

Session 6E • 101F

Environmentally Friendly Fluids I

Session Chair: John Fang, Chevron Products Company, Richmond, CA

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

1:40 pm – 2:20 pm

4004294: How Ester Technology Contributes to Technical and Sustainability Targets

Matthias Hof, Emery Oleochemicals GmbH, Duesseldorf, NRW, Germany

Achieving sustainability is one of the dominating challenges in our industry today while the technical specifications continue to harshen and become more challenging. This paper will shed a view how ester products are developed now and the years to come. Innovations is constantly requested and expected while the increasing numbers of regulations, chemical listings and classification needs are leading to further challenges. Using raw materials for global products while addressing regional availabilities and supply chains needs to be addressed. Balancing cost and performance is another important factor to position new chemistries in the market. Data will be presented coming from various bench as well as tribological testing along with environmental input. It will be shown how ester technology can address these various points with existing and new products and what is already accessible to the formulating industry.

2:20 pm – 2:40 pm

3993873: A Brief History of Refrigeration Lubricants

Michael Costello, The Lubrizol Corporation, Midland, MI

Historically, chlorofluorocarbon (CFC) refrigerants were used in the HVAC industry until it was found in 1974 that the chlorine from CFC's was depleting the ozone layer in the upper atmosphere. One of the first non-ozone depleting refrigerants developed was the hydrofluorcarbons (HFC) and the new lubricants proposed were polyol ester chemistry. Subsequently additional lubricants had also been commercialized including polyalkylene glycol, polyvinyl ether, and alkyl benzene. Now that the phase down of the ODP substances is almost complete, extensions to the Montreal Protocol (Kyoto Protocol-1997 and Kigali Amendment-2016) to address the global warming potential of the new refrigerants were adopted. This paper will trace the development of lubricants used as the industry transitions from the CFC and HFC chemistry to the new Low Global Warming Potential (Low GWP) HFO and natural chemistry by focusing on the key benefits and drawbacks that each lubricant type presents.

2:40 pm – 3:00 pm

4005350: Meeting Sustainability Standards in Industrial Lubricants Using Specialty Additives

Stefanie Velez, Münzing Chemie GmbH, Bloomfield, NJ

As interest in developing sustainable industrial lubricants continues to increase, so does the number of sustainability standards and strategies in the marketplace. This is a broad topic that involves a balance between environmental impact, health and safety, and economic performance of the lubricant. A review of current sustainability initiatives along with bio-based and biodegradable specialty additives will be discussed. To further investigate the sustainability of an industrial lubricant, a comprehensive study highlighting the considerable positive impacts that high-performance defoamers have on the overall performance and lifespan of the fluid will be explored. Understanding how to balance the different aspects of sustainability using high-performance defoamers can be key in developing more sustainable industrial lubricants including metal working fluids, non-aqueous lubricants, and automotive fluids.

3:00 pm – 3:40 pm – Break

3:40 pm – 4:00 pm

4003821: Exploring the Additive Compatibility and Tribological Behavior of Regular and High Oleic Soybean Oil

Piash Bhowmik, Hyunsuk Choi, 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

As the demand for biobased lubricating oils continues to rise in the research arena, there is a growing focus on exploring diverse oil types. Particularly high oleic oils offer enhanced stability and a richer oleic acid content compared to their regular soybean oil counterparts. This study 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, it was observed that additive compatibility for regular soybean oil was better against high oleic soybean oil. Additional physiochemical property analyses of experimented lubricants and surface characterization of sample surfaces were performed to reveal the dominant wear mechanisms.

4:00 pm – 4:20 pm

4002887: Environmentally Friendly Base Oils From Upcycled Plastic Waste

Robert Kennedy, Ryan Hackler, Aeternal Upcycling, Chicago, IL

Environmentally friendly base oils can be made directly from plastic waste. Catalytic hydrogenolysis converts polyethylene and polypropylene, which together make up more than 60% of plastic waste, into base oils with comparable properties to Group III and IV base oils. Plastics-as-feedstocks offer Scope 3 emissions savings to formulators and end users, through diversion of plastic from landfills and incineration and through the energy-efficient hydrogenolysis process, potentially more than halving the cradle-to-gate environmental impact of the base oil.

4:20 pm – 4:40 pm

4003733: Candidate Marine Turbine Lubricant Additives – Ionic Liquids with High Lubricity and Eco-Friendliness

Wenbo Wang, Huimin Luo, Louise Stevenson, Peijia Ku, Tom Geeza, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Tidal energy is able to generate clean, sustainable electricity via turbomachinery as a promising source in the portfolio of renewable energy sources. The development of environmentally acceptable lubricants (EALs) for marine turbomachinery is crucial to reducing the risk of conventional lubricants threatening marine ecosystems due to leakage or spillage incidents. Recently, eco-friendly and high-lubricity ionic liquids (ILs) were successfully invented at Oak Ridge National Laboratory and are being further developed as additives for tidal turbine gearbox lubrication. Compared with the commercial baselines, the 'not toxic' and 'readily biodegradable' IL-additized lubricants performed more effectively in reducing friction, wear loss, and mitigating rolling contact fatigue. In addition, the mechanisms of wear and the protection resulting from the ILs are being investigated through surface and tribofilm analyses.

4:40 pm – 5:00 pm

4005438: An Investigation of Film Formation and Pressure Viscosity Relation of Water-Based Lubricants in Elastohydrodynamic Contacts

Mushfiq Hasan, Marcus Björling, Roland Larsson, Luleå University of Technology, Luleå, Sweden

Recently water-based lubricants (WBL) became a subject of interest because of their sustainability and efficiency aspects. OEMs are considering these lubricants even in sophisticated applications such as automotive transmissions, where fossil-based lubricants have been used for decades. The film thickness variation across different contact conditions is a crucial design parameter. WBLs have a different composition compared to mineral oil, so the film formation needs to be investigated. Moreover, the pressure viscosity relation at moderately high pressure should be studied to better understand its behavior in gears and bearings contact. In this research, the elastohydrodynamic film formation of several formulated water-based lubricants is experimentally investigated. Moreover, the effect of shearing and temperature on film thickness is also studied. Later, the pressure viscosity relation of WBLs was studied up to 0.5Gpa pressure using optical method and high-pressure viscometer.

5:00 pm – 5:30 pm

Environmentally Friendly Fluids Business Meeting

Session 6F • 101 G

Sustainable Power Generation II

Session Chair: Elaine Hepley, Solana Consulting Services LLC, Indianapolis, IN

Session Vice Chair: Matthew Hobbs, EPT, Calgary, Alberta, Canada

1:40 pm – 2:20 pm

4002573: Effects of Tribology on CO_2 – Emissions in the Use Phase of Products – Contributions of Tribology to Defossilization (3rd Study of the German Society for Tribology)

Vasileios Bakolas, Tim Hosenfeldt, Schaeffler Technologies AG und Co KG, Herzogenaurach, Germany; Mathias Woydt, Matrilub, Berlin, Germany; Eberhard Bock, Freudenberg Sealing Technologies, Weinheim, Germany; Rolf Luther, FUCHS Lubricants, Mannheim, Germany; Christoph Wincierz, Evonik Operations GmbH, Darmstadt, Germany

Friction and wear occur all along the value chain. Therefore, tribology is an easy-to-implement technical option for the removal of CO_2 from the atmosphere – the CO_2 saved in the use phase (downstream) need not be generated in the extraction phase (upstream). Reducing friction and extending longevity provide industrial strategies for defossilization because CO_2eq.-savings generated by tribology occur anywhere and anytime. Friction reduction and longevity are thus "negative emission technologies" (NET) producing less or saving CO_2 during operation or are easy-to-implement as drop-in solutions. Tribology is based on a very diverse industrial platform and a key interdisciplinary technology for mitigating the CO_2 overhang expected by 2050. This third GfT (German Society for Tribology) study presents specific solution approaches, estimates the CO_2 value of selected tribological solutions and specifies the ways forward based on the technologies available.

2:20 pm – 2:40 pm

3986386: Evaluation of Experimentally Developed High-Performance Polymer Composites for Hydropower Bearings

Nazanin Emami, Julian Somberg, Kim Berglund, Luleå University of Technology, Luleå, Norrbotten, Sweden

Moving away from fossil-based lubricants in hydropower bearings and the changing operating conditions puts high demands on the currently used bearing materials. With service life being the limiting factor of current materials, there is a need for high performance alternatives. In this work, two experimentally developed multiscale composites are evaluated with respect to commercially available materials. A novel tribometer was used enabling contact pressures of up to 40 MPa. Experiments were performed under dry, water and EAL lubricated conditions, simulating guide vane and Kaplan runner bearings. The results indicated especially low dry sliding friction and wear for the developed composites. The introduction of water did not lead to a consistent friction and wear reduction, which is linked to the absence of a transfer film. The EAL reduced friction and wear by up to 85%. However, the absence of an effective transfer film makes both pin and counter surface more prone to abrasive wear.

6F

2:40 pm – 3:00 pm

3998419: Tribological Characterization of Carbon Composites for High Temperature Gas-Cooled Pebble Bed Reactor

Tomas Grejtak, Wenbo Wang, James Keiser, Nidia Gallego, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

High temperature gas-cooled pebble bed reactors use carbon composite spherical pebbles to encapsulate fuel particles. During operation, pebbles continuously pass through the reactor multiple times before they are discharged. Sliding, rolling, and impact among the pebbles and against the reactor wall cause surface damage and generation of hazardous dust. Tribological behavior of the carbon composite pebbles in these extreme temperatures that can reach 650°C is not well understood. In this work, the sliding wear and friction properties of carbon composite pebbles were characterized using a pin-on-disk configuration. The tests were performed in an argon environment at a range of temperatures up to 650°C. Key parameters such as pebble-on-pebble normal force and sliding speed were estimated from actual operation of the reactor. Morphological characterization and compositional analysis of the worn surfaces were used to determine the underlying wear mechanisms.

3:00 pm – 3:40 pm – Break

3:40 pm – 4:00 pm

4001699: Understanding the Biomass Fouling Process on the Screw Feeder for Pyrolysis Reactors

Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Biomass fouling-caused feed line plugging is a major challenge in pyrolysis preconversion. The fouling products are believed to accumulate under combined thermal and mechanical stresses. This work investigated the biomass fouling phenomena via materials characterization, thermal analysis, and experimental validation. A seized screw feeder from an actual reactor was examined to reveal the deposit's morphology, composition, and mechanical properties. Thermal analyses were carried out for both the screw feeder and the conveying biomass using a combined analytical and numerical approach. A bench-scale tribometer was modified to simulate the fouling process with relevant gas environment, temperature, contact pressure, and sliding speed. Results suggested that tailoring the operating conditions, such as a lower contact pressure or a faster sliding, and modifying the screw feeder surface, such as a smoother finish or an anti-sticking coating, could effectively reduce the fouling deposition.

4:00 pm – 4:20 pm

4002597: Lubricant Chemistry Management – The Proactive Solution to Turbine Oil Problems

Matthew Hobbs, EPT, Calgary, Alberta, Canada

Turbines are responsible for 97% of US power generation. The vast majority of this production is from gas and steam turbines, which employ rotating steel shafts that can weigh > 100 tons. Since these are supported by a lubricant, energy availability depends largely on turbine oil performance. Fortunately, many quality turbine oils are available. In general, these are 97 – 99% base oil and 1 – 3% additive (which serves mainly to protect the base oil). Indeed, base oil plays, by far, the most significant role in fulfilling turbine lubrication requirements. Maintaining base oil health should, therefore, be a priority. There has, however, been a recent trend towards allowing oils to degrade, and then altering their chemistries in an attempt to "undo" this harmful breakdown. Evidence suggests that this strategy is problematic, and that turbine performance can best be assured by proactive lubricant chemistry management, which instead maintains base oils so they can perform as intended.

4:20 pm – 4:40 pm

4077163: Impact of the Lubricant Chemistry on Knock Sensitivity of a Gas Engine Running on Hydrogen

Zoe Fard, Thijs Schasfoort, HF Sinclair, Mississauga, Ontario, Canada

Wind and solar power output fluctuates throughout the year. Long term storage of renewable electricity is a big challenge. One possible storage method is conversion of electricity to hydrogen. With a stationary gas engine, the stored hydrogen can be converted back to electricity and useful heat. The combustion of hydrogen, however, comes with its own challenges. Hydrogen ignites easily and burns fast. The risk of pre-ignition and knocking is therefore high. Lubricating oil in the combustion chamber may influence pre-ignition and knocking. In collaboration with a major European OEM, Petro-Canada Lubricants have investigated how the lubricant composition influences the knock sensitivity of an engine running on 100% Hydrogen. A matrix of formulations has been defined and tested at the R&D test bed of the manufacturer. The effects of the lubricant formulation on engine knock as well as lube oil induced pre-ignition have been investigated. This paper describes the test methods and findings.

4:40 pm – 5:00 pm

Sustainable Power Generation Business Meeting

Member Ambassadors – your connection to the STLE community!

STLE's Annual Meeting welcomes a diverse group of individuals, including long-standing members/attendees, newcomers, and first-time attendees. As an attendee, we encourage you to reach out and connect with our Member Ambassadors, who are fellow industry peers that can help answer general questions about STLE and facilitate introductions to other members of our community, which will provide you an opportunity to network and build relationships. You can connect with these volunteers who will be wearing black **"Member Ambassador"** buttons throughout the week and will also be available at the STLE Membership Booth in the Minneapolis Convention Center foyer across from the Registration Desk.

Session 6G • 101 H

Tribochemistry III

Session Chair: Pial Das, Mechanical Engineering, Iowa State University, Ames, IA

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

1:40 pm – 2:00 pm

3982296: Tribological Performance and Durability of an In-Situ-Deposited Carbon Tribofilm Derived from Cycloalkane Molecules

Zaid Al Hassan, Harry Wise, Tobias Martin, Shuangbiao Liu, Q. Jane Wang, Yip-Wah Chung, Northwestern University, Evanston, IL; Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD

Wear-protective coatings on tribo-component surfaces are usually applied via vapor deposition methods. Once worn, they can only be restored through component disassembly. In our study, we explored in situ carbon tribofilm deposition using cycloalkane-derived molecules. These molecules, when dissolved in lubricants, can induce tribopolymer formation under stress and temperature at asperities. We tested cyclopropane-carboxylic acid (CPCa) as an additive in polyalphaolefin and dodecane, successfully depositing micron-thick carbon tribofilms in 15 minutes during pin-on-disk testing. These films provided a ten-fold reduction in wear. Even after CPCa removal, these tribofilms continued to provide wear protection for up to 40 hours. Detailed surface examination using Raman spectroscopy helped us unravel the underlying mechanism for such extended durability of these carbon tribofilms. This research suggests a unique approach to provide unlimited replenishment of wear-protective coatings.

2:00 pm – 2:20 pm

4006441: Ultrafast Phonon Energy Dissipation at Multi-layer Graphene Interfaces

Haolei Dai, Tsinghua University, Beijing, China

Phonon is the main source of frictional energy dissipation during the Interfacial van der Waals interactions in graphene interface which holds great potential in achieving superlubricity application. Develop advanced phonon disspation detection technique is necessary for understanding the origin of friction and designing new materials. Here, we observed a greatly enhanced double resonance Raman mode with a distinctive dip-to-peak evolution feature in multi-layer graphene with a home-built broadband coherent anti-stokes Raman spectroscopy. our results may help deepening the understanding of the origins of friction and understand the reason for superlubricity failure due to defect.

6I • 101J

Commercial Marketing Forum VI

Session Chair: TBD

Session Vice Chair: TBD

1:40 pm – 2:00 pm

4111748: ADEKA Corporation – Advancing Carbon Neutrality in Lubricant Additives, ADEKA's Innovations with MoDTC and Other Functional Materials

James Shim, ADEKA USA CORPORATION, Hasbrouck Heights, NJ; Kenji Yamamoto, ADEKA Corporation, Tokyo, Japan

ADEKA Corporation, a key player in the lubricant industry for over 50 years, has been manufacturing organic molybdenum compounds since the 1970s, notably MoDTC for enhancing friction performance in engine oils to boost fuel economy. With the imperative to reduce carbon emissions, there is a growing shift towards low-friction lubricants. While typical MoDTC concentrations in fuel economy engine oil range from 700 to 1,000 ppm as molybdenum, formulations with lower MoDTC levels of 200 to 400 ppm are also gaining popularity for enhancing lubricant performance. This presentation will explore strategies for achieving low-friction formulations using MoDTC, alongside ADEKA's latest developments in polymer colloids friction modifiers, non-PFAS defoamers, and bio-based esters, all aimed at promoting carbon neutrality in the lubricant industry. These efforts exemplify ADEKA's commitment to sustainable innovation in lubricant technology.

Session 6J • 200 DE

Electric Vehicles VI

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

Session Vice Chair: TBD

1:40 pm – 2:20 pm

4000841: Electric Vehicle Testing – Correlation of Benchtop and Rig Tests Using Ester Containing Fluids

Alexei Kurchan, Cargill Inc, Plainsboro, NJ; Gareth Moody, Chris Clayson, David Gillespie, Cargill, Snaith, East Yorkshire, United Kingdom

The testing of electric vehicles using electric drive units offers the best and most realistic data for testing efficiency of gear fluids giving a good insight into performance in the real world and whilst this can be costly, the efficiency boosts obtained by lubricant modifications and variations to components can be evaluated in a range of different driving speeds and loads. This work will discuss the results of EDU testing of formulations and the benefits of esters whilst also evaluating the importance of simple benchtop tests and how well they can correlate to full size EDU testing.

6J

2:20 pm – 2:40 pm

4005830: 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.

2:40 pm – 3:00 pm

3982753: Plastic Thrust Washers Enable Space Savings, Efficiency in Electric Drive Units

Greg Poterala, Solvay Specialty Polymers, Commerce Township, MI

Developers of electric vehicle drivelines are challenged to create systems that deliver maximum driving performance while simultaneously addressing consumer concerns about range anxiety. Efficiencies are gained through design of units integrating the motor, electronics, and geartrain into a single unit. Planetary helical gear sets are growing in adoption due to compact size (lightweighting advantage), power transfer, and noise reduction. Historically metal needle bearings are needed to counter the resultant axial loads. Polyamideimide (PAI) is a moldable, curable plastic with excellent friction and wear properties, making it suitable for plastic thrust washers that can replace metal needle bearings in EDUs. This presentation will illustrate the suitability of PAI in thrust washers for driveline use, including relevant mechanical property data & friction and wear testing. We will also present case history of PAI thrust washer use in serial automotive automatic transmissions

3:00 pm – 3:40 pm – Break

3:40 pm – 4:00 pm

4002984: Influence of Ionic Liquids as Lubricant Additives on Electrically-Induced Bearing Damage

Sudip Saha, University of North Dakota, Grand Forks, ND; Jack Janik, German Mills, Robert Jackson, Auburn University, Auburn, AL; Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

In electric vehicles and other applications leakage currents can cross lubricated bearing and gear interfaces to cause significant damage. Electrical arc or plasma initiation causes damage by inducing localized rapid temperature rise and discharge. The discharges may result in micropitting on the surface. Ionic liquids contain charged ions and are known to possess higher conductivity than conventional paraffinic and synthetic oils. Ionic fluids also are shown to improve the friction and wear reducing capabilities of lubricants. Therefore, this study investigates the influence of ionic liquids as additives in PAO-based lubricants on the electrically induced bearing damage. The experiments were conducted using a single spherical rolling element test under a controlled DC current. Initial results showed insignificant benefits of the selected ionic liquids, which may be due to the ionic liquid providing ionic conductive pathways rather than electron or metallic pathways.

4:00 pm – 4:20 pm

3990426: Electrification Effects on Oxidation Performance and Corresponding Changes Dielectric Properties of Drivetrain Lubricants

Joshua Conner, Southwest Research Institute, San Antonio, TX

As electric drive unit design continues to incorporate a common fluid for lubrication of the rotating components and cooling of the electric motor, the electrification of lubricant testing equipment enables test methods that are more representative of electric vehicle applications. This study evaluates: 1.) how oxidation affects the dielectric properties (relative permittivity, dissipation factor, electrical conductivity, and dielectric breakdown voltage) of various drivetrain lubricants and 2.) how oxidation performance may be impacted by different types of electric and magnetic fields. A common drivetrain lubricant oxidation test was used to study these effects, under both electrified and non-electrified conditions.

4:20 pm – 4:40 pm

4001995: Shear Stability and Thermal Performance Analysis of Engine Oils for Electric Vehicles

Deepak Veeregowda, Fabio Alemanno, Ducom Instruments, Groningen, Netherlands

As electric vehicle (EV) adoption rises, optimizing lubrication solutions is crucial. Engine oils formulated for EVs are vital for powertrain efficiency and component durability, yet their shear stability is often overlooked. This study assesses and compares shear stability in various EV oils using standard tests like ASTM D4172-B and CEC L-45-99. Applying a custom thermal cycling procedure to the tests reveals differences in friction behavior and thermal properties, both in a Four Ball Tester and KRL Shear Stability Tester. The tribological results were then linked to and justified by the chemical and physical properties of the oils. The results emphasize the importance of choosing EV oils with suitable shear stability for optimal lubrication and system durability. This research aids lubricant manufacturers, engineers, and researchers in selecting appropriate EV engine oils for boundary/mixed lubrication and elastohydrodynamic lubrication applications.

4:40 pm – 5:00 pm

Electric Vehicle: Engine & Drivetrain Business Meeting

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