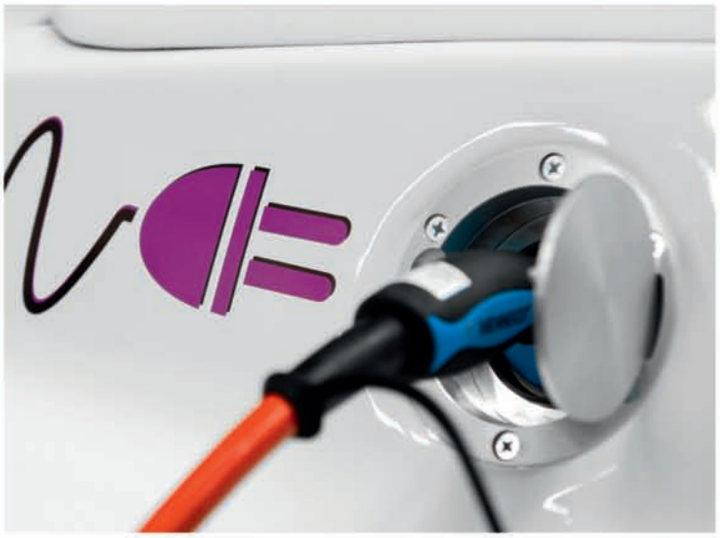

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BOOTH #111

May 21-25, 2023

Long Beach Convention Center, Long Beach, CA.

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Overview

Download the STLE Mobile App for the most up-to-date schedule. (pg. 15)

Sunday, May 21

Registration
6:30 am – 5:00 pm – **Convention Center Foyer**

Education Course Speakers Breakfast
7:00 am – 7:45 am – **Grand Ballroom**

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

- Advanced Lubrication 301: Advanced Additives – **104B**
- Basic Lubrication 101 – **102C**
- Gears 101 – **102B**
- Hydraulics 201: Hydraulic Fluids and Systems Overview – **101A**
- Metalworking Fluids 130: Metal Treatment Chemical – **101B**
- Sustainability: Biolubricants and Biofuels **(New!)** – **104A**
- Synthetics: Basics & Applications **(New!)** – **102A**

Refreshment Break
10:00 am – 10:30 am – **Foyer**

STLE New Member & Student Networking Reception
6:30 pm – 8:00 pm – **Bogarts & Co.**

Monday, May 22

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

Speakers Breakfast
7:00 am – 8:00 am – **Grand Ballroom**

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

- 1A • Lubrication Fundamentals I: Forecasting Trends – **101A**
- 1B • Rolling Element Bearings I – **101B**
- 1C • Sustainable Power Generation I – **102A**
- 1D • Materials Tribology I – **102B**
- 1E • Condition Monitoring I – **102C**
- 1G • Nonferrous Metals I – **103B**
- 1H • Commercial Marketing Forum I – **103C**
- 1I • Electric Vehicles I – **104A**
- 1K • Metalworking Fluids I – **201A**
- 1M • Herbert S. Cheng Memorial Symposium: Challenges in Lubrication and Tribology Modeling I – **202A**
- 1N • Nanotribology I – **202B**
- 1O • AI and Machine Learning I – **202C**

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

Opening General Session (10:30 am – 12:00 pm)
Keynote Address – **Grand Ballroom 1/2**

- **"Hydrogen is Here: Are You Ready?"**
  Speaker: Angel Wileman, Manager, Thermofluids, Southwest Research Institute (SwRI)

Lunch (on your own) – 12:00 pm – 1:30 pm

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

Technical Sessions (1:30 pm – 6:00 pm)

- 2A • Lubrication Fundamentals II: Marine Engines – **101A**
- 2B • Rolling Element Bearings II – **101B**
- 2C • Wind Turbine Tribology I – **102A**
- 2D • Materials Tribology II – **102B**
- 2E • Condition Monitoring II – **102C**
- 2F • Environmentally Friendly Fluids I – **103A**
- 2G • Nonferrous Metals II – **103B**
- 2H • Commercial Marketing Forum II – **103C**
- 2I • Electric Vehicles II – **104A**
- 2K • Metalworking Fluids II – **201A**
- 2M • Herbert S. Cheng Memorial Symposium: Challenges in Lubrication and Tribology Modeling II – **202A**
- 2N • Nanotribology II – **202B**
- 2O • AI and Machine Learning II – **202C**

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

Networking Reception
6:30 pm – 8:00 pm – **Hyatt Hotel**

Exhibition hours

- **Monday, May 22** (12:00 pm – 5:00 pm)
- **Exhibitor Appreciation Hour** (3:00 pm – 4:00 pm)
  Evonik Raffle (3:30 pm) – Must be present to win.
  (Booth #205)

TIME	SESSION 1A Lubrication Fundamentals I: Trends Room 101A	SESSION 1B Rolling Element Bearings I Room 101B	SESSION 1C Sustainable Power Generation I Room 102A
8:00 am – 8:30 am	What Makes a Sulfur Compound Inactive versus Active? An Examination of Sulfur Compounds and its Effect on Lubrication, J. Williams, p. 32	Experimental Validation and Comparison of Friction Torque Models for Rolling Element Bearings, J. Kelley, p. 32	
8:30 am – 9:00 am	Sustainable Cooperation in the Lubricant Industry – A Transformation Towards a Circular and Sustainable Lubricant Value Chain!, I. Herrmann, p. 32	Cryogenic Test and Evaluation of Pin-on-Disk with the Various Cage Materials for Solid Lubricated Bearings, W. Kwak, p. 32	Towards an Accelerated Protocol for the Evaluation of Solar Cells, E. Georgiou, p. 33
9:00 am – 9:30 am	Challenges for Lubrication R&D in Future Powertrains Applications and Potential Solutions in Precompetitive Research, C. Kunze, p. 32	Augmented Lubricant Replenishment for Rolling Bearings at Limited Lubricant Supply Conditions, P. Wong, p. 33	Advances in Varnish Condition Monitoring, E. Hepley, p. 33
9:30 am –10:00 am		An Improved Dynamic Bearing Model Considering Cage Lubrication, T. Russell, p. 33	Sustainable Aeroderivative Gas Turbine Operation Through Lubricant Chemistry Management, M. Hobbs, p.33
10:00 am – 10:30 am	**Break**	**Break**	**Break**
	SESSION 2A **Lubrication Fundamentals II: Marine Engines** **Room 101A**	**SESSION 2B** **Rolling Element Bearings II** **Room 101B**	**SESSION 2C** **Wind Turbine Tribology I** **Room 102A**
1:30 pm – 2:00 pm	Performance of Additives Improving Asphaltene Dispersancy in GII Base Stocks, A. Jha, p. 43	Contribution of Rolling Bearings to Improve Driving Range of Electric Vehicles, J. Modi, p. 44	
2:00 pm – 2:30 pm	Experimental Evaluation on a Special Cylinder Oil Additive Package Applied in Blender on Shipboard, J. Zhang, p. 43	Influence of Bearing and System Design on CO_2 Emission Savings, V. Bakolas, p. 44	Foaming in Wind Turbine Gearboxes: Causes, Impacts and Treatment Continued, M. Blumenfeld, p. 46
2:30 pm – 3:00 pm	Varnish Resistance Prediction Indicator (VRPI) for Group I-IV Lubricants, J. Fotue, p. 43	Influence of Form Deviated Bearing Seats on the Operating Behavior of Cylindrical Roller Bearings O. Koch, p. 44	Autonomously Triggered Application of Corrosion Preventing Lubricants, S. Flank, p. 47
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Study of Tribological Contact Condition Using the Non-linear Behavior of Longitudinal Ultrasonic Waves, S. Taghizadeh, p. 43	Experimental and Analytical Investigation of Oil Flow in a Ball Bearing, U. Arya, p. 46	Non-Invasive Detection of Cracks in Bearing Steel Using Ultrasound, G. Nicholas, p. 47
4:30 pm – 5:00 pm	Reduction of Carbon Footprint and Maintenance of Oil Life through Performance Selection of Lube Oils, G. Natrajan, p. 44	Experimental and Analytical Investigation of Angular Contact Ball Bearing Cage Pocket Lubrication, S. Aamer, p. 46	Sustainable Solutions for Wind Turbines, M. Combarros, p. 47
5:00 pm – 5:30 pm	Accelerating the Development of Piston-Liner Tribology in Marine Diesel Engines Using Ultrasonic Transducers, O. Spenceley, p. 44	In Situ Measurement of Grease Churn within a Full-Scale Cylindrical Roller Bearing, W. Gray, p. 46	Using a Rheometer to Test the Performance of Greases in an Oscillating Ball Bearing, M. Bartram, p. 47
5:30 pm – 6:00 pm		Long-Term Investigations of Different Bearing Configurations at Solid-Lubricated Rolling Bearings, M. Werner, p. 46	Sustainable Power Generation & Wind Turbine Tribology Business Meeting
6:00 pm – 6:30 pm			

SESSION 1D Materials Tribology I Room 102B	SESSION 1E Condition Monitoring I Room 102C		
Orientation Controls Tribological Performance of 3D-Printed Model Thermoplastics, S. Arfin Mahmood, p. 34	A Hybrid Modeling Approach for Transferring Machine Learning Assisted Condition Monitoring of Rolling Bearings to Differing Machine Types, C. Bienefeld, p. 34		8:00 am – 8:30 am
A Ready-to-Use Temperature Model for Polymer/ Steel Contacts, M. Kalin, p. 34	Application of Envelope Spectrum Analysis and Spectral Kurtosis to Diagnose Debris Fault in Bearing using Acoustic Signals, H. Omoregbee, p. 35		8:30 am – 9:00 am
Characterizing Billiard Chalk in the Cue Tip-Cue Ball Interface, A. Martin, p. 34	Anomaly Detection Methodology for Centrifugal Compressors and Steam Turbines, M. Khandelwal, p. 35		9:00 am – 9:30 am
Nanoscale Rate-and-State Friction, Atomic Insights Via Complex Sliding Protocols, J. McClimon, p. 34	The Opportunities of Rolling Bearing Impedance Signal Analysis for Condition Monitoring, F. Michael Becker-Dombrowsky, p. 35		9:30 am –10:00 am
Break	**Break**	**Break**	10:00 am – 10:30 am

SESSION 2D Materials Tribology II Room 102B	SESSION 2E Condition Monitoring II Room 102C	SESSION 2F Environmentally Friendly Fluids I Room 103A	
Effect of Diamond-Like Carbon Composition on Oxidation Reactivity and Friction, S. Jang, p. 47	Lifetime Extension Strategies in Wind Turbine Using an OCM – Oil Condition Monitoring Program, Y. Gomez, p. 50	Global Fluid Trends, E. Jones, p. 52	1:30 pm – 2:00 pm
Process-Structure-Property Driven Development of High-Quality MoS_2 Coatings, T. Babuska, p. 48	Suggested Sampling Methods for In-Service Oil and Grease Lubricated Equipment, V. Bunchek, p. 50	Using the Life Cycle Assessment (LCA) Tool to Determine the Carbon Footprints of Castor Oil Derivatives, T. Thompson, p. 52	2:00 pm – 2:30 pm
Quality Assurance Methods for MoS_2-Based Solid Lubricants, M. Dugger, p. 48	Optimizing Operational Savings with Fluid Analysis, H. Neicamp, p. 50	Potential of Lubricant Base Oils from Microalgae, B. Sharma, p. 52	2:30 pm – 3:00 pm
Exhibitor Appreciation Break	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	3:00 pm – 4:00 pm
Wear and Corrosion Resistant Ni-SiC Coatings Fabricated by Adaptive Additive Manufacturing, M. Tajedini, p. 48	A Sea Change in Fluid Analysis (a.k.a. Oil Analysis) Has Arrived, J. Poley, p. 50	Maximize Performance and Improve Sustainability Through Use of Group V Ester Technology, G. Stephenson, p. 52	4:00 pm – 4:30 pm
High-Frequency Reciprocating Tribological Assessment of MoVN-Cu Coating in Low-Viscosity Fuel Environments under Various Load, Temperature, and Sliding Velocity Conditions, K. Jacques, p. 48	Using Oil Analysis to Identify Incorrect Bearing Lubrication, E. Zabawski, p. 50	Overcoming the High Viscosity Limitation of Readily Biodegradable EAL Base Fluid, R. Navaratnam, p. 52	4:30 pm – 5:00 pm
Ultralow Wear PEALD Ternary Nitrides: Understanding Process-Structure-Property Relationships, K. Van Meter, p. 48	Using Oil Analysis to Determine Root Cause of an Overheated Gearbox, E. Zabawski, p. 50		5:00 pm – 5:30 pm
	Condition Monitoring Business Meeting		5:30 pm – 6:00 pm
			6:00 pm – 6:30 pm

MONDAY >>

TIME	SESSION 1G Nonferrous Metals I Room 103B	SESSION 1H Commercial Marketing Forum I Room 103C	SESSION 1I Electric Vehicles I Room 104A
8:00 am – 8:30 am	Emulsions for Aluminum Hot Rolling: Which Droplet Size Distribution is Beneficial to Lubricity?, A. Viat, p. 35	Chevron Phillips – PAOs in Thermal Management Applications, K. Hope, p. 36	
8:30 am – 9:00 am	Additives for High Lubricity Fully Synthetic Aluminum Machining Formulations, T. Meyers, p. 35	Huntsman – Amines for Fuel and Lube Applications, H. Zhao, p. 36	Electrical Behaviors of Tribocontacts in Association with Friction and Wear Properties as Key Concepts for Lubes in Electrified Powertrains, M. Woydt, p. 36
9:00 am – 9:30 am	Correlations Between Two Methods for Cloud Point and Pour Point Determination of Biobased Materials, G. Bantchev, p. 35	ANGUS Chemical Company – Addressing the Emerging Environmental and Performance Challenges of Tomorrow with ANGUS' Multifunctional Additives, M. Chen, p. 36	Can Conventional ATFs be Used Safely in Electrified Transmissions?, A. García Tuero, p. 38
9:30 am –10:00 am	Hot Mill Coolant Filtration Improvements, A. Knopp, p. 36	Colonial Chemical: ColaCor 186: A Unique Core Carboxylic Acid for Corrosion Inhibitors, S. Tang, p. 36	Development of Test Methods and Fluid Durability Study in Electrified Drivetrains, C. Hudson, p. 38
10:00 am – 10:30 am	**Break**	**Break**	**Break**
	SESSION 2G **Nonferrous Metals II** **Room 103B**	**SESSION 2H** **Commercial Marketing Forum II** **Room 103C**	**SESSION 2I** **Electric Vehicles II** **Room 104A**
1:30 pm – 2:00 pm	Improving Aluminum Cold Mill Lubricant Performance with a Surface Active Agent, T. Oleksiak, p. 54	Evonik Oil Additives: Novel Base Oil Technologies for Automotive Driveline Fluids, J. Langston, p. 54	Various Copper Corrosion Test Methods for Electric Drivetrain Fluid Evaluations, Y. Kwak, p. 56
2:00 pm – 2:30 pm	Carbon Negative Liquid Hydrocarbons: Next Generation GTL Technology Commercializing in the US, W. Anderson, p. 54	LANXESS – Advances in H1 Food Grade Calcium Sulfonate Greases: A Continued Vision 20 Years On, R. Dworet, p. 54	Next-Generation Tribology Component Technologies for E-Fluids, C. Chretien, p. 57
2:30 pm – 3:00 pm	Considerations for Changing Cold Rolling Base Oil, J. Anglin, p. 54	The Lubrizol Corporation – Redefining Long Drain Hydraulic Fluids, S. Basu, p. 56	Technologies for Improving the Performance of E-axle Fluids, M. Iino, p. 57
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Influence of Raw Material Quality Variations on the In-service Performance of Aluminum Hot Rolling Oils, J. Leimhofer, p. 54	ExxonMobil – EHC 340 MAX™: Elevating Extra Heavy Base Stocks, B. Duggal, p. 56	Performance Characteristics of Some EV Drivetrain Lubricants Under Electrified Condition, A. Erdemir, p. 57
4:30 pm – 5:00 pm	Nonferrous Metals Business Meeting	IMCD – A Sustainablexxx Solution for an Evolving World – Esters as Base Oils and Components to Design a More Innovative Future, V. Aruta, p. 56	Comparison of Electric Drive Unit Lubricant Aeration Under High Speed Operation, C. Frazier, p. 57
5:00 pm – 5:30 pm		OQ Chemicals – Synergistic Effects of a Blend of Polyalphaolefin and Polyol Ester for Potential High-Performance Lubricants in Electric Vehicles, K. Gross, p. 56	Electrically Conductive Nanoparticle Additives for Greases Used in Electric Vehicles and Other Applications, R. Jackson, p. 57
5:30 pm – 6:00 pm		Richful Lube Additive Company Development Progress by 2022, Y. Tao, p. 56	Sustainable E-Fluid Concepts for Electric Motor Cooling and Gearbox Lubrication, C. Dobrowolski p. 57
6:00 pm – 6:30 pm			

SESSION 1K
Metalworking Fluids I

Room 201A

	Improving Metalworking Fluid Efficiency by Creating Hydrophilic Protective Barriers, V. Demel, p. 38		8:00 am – 8:30 am
	Overcoming Metalworking Fluid Instability: Beyond HLB, H. Kim, p. 38		8:30 am – 9:00 am
	A Novel Way to Measure Stability and Shelf-Life of a Metalworking Fluid Formulation, R. Elupula, p. 38		9:00 am – 9:30 am
	Surfactant Roles in Emulsifiable Oils, R. Golden, p. 40		9:30 am –10:00 am
Break	Break	Break	10:00 am – 10:30 am

SESSION 2K
Metalworking Fluids II

Room 201A

	ASTM Standards Addressing Metalworking Fluid Health and Safety Issues, F. Passman, p. 58		1:30 pm – 2:00 pm
	The Study of Novel Calcium Overbased Sulfonates Used for Rust Preventives, J. Jianjun Wei, p. 58		2:00 pm – 2:30 pm
	Case Study of Monitor and Correction of Field Coolant Emulsions by Light Scattering Instrument and Good Correction Method, Y. Philip Zhao, p. 58		2:30 pm – 3:00 pm
Exhibitor Appreciation Break	Exhibitor Appreciation Break	Exhibitor Appreciation Break	3:00 pm – 4:00 pm
	Extreme Pressure Sulfurized Additives for Metalworking Fluid Ester-Based Formulation, G. Notheaux, p. 58		4:00 pm – 4:30 pm
	Sustainability Beyond Carbon Footprint, M. Stapels, p. 58		4:30 pm – 5:00 pm
	Chlorine Use in Stainless Steel Tube Manufacturing, J. Brooks, p. 58		5:00 pm – 5:30 pm
	Analysis of the Tool Margin-Wall Contact During MQL Deep-Hole Drilling of AISI 4140 Steel Through a Surface Integrity Study, P. Neal, p. 58		5:30 pm – 6:00 pm
			6:00 pm – 6:30 pm

MONDAY >>

TIME	SESSION 1M Lubrication and Tribology Modeling I Room 202A	SESSION 1N Nanotribology I Room 202B	SESSION 1O AI and Machine Learning I Room 202C
8:00 am – 8:30 am		Nano-scale Friction of Graphitic Surfaces in n-hexadecane, B. Baboukani, p. 42	Deep Learning Data-Driven Model for Coefficient of Friction Prediction of Lubricated Tribo-pairs, M. Oramas, p. 42
8:30 am – 9:00 am	Homogenization, HMM and Patir & Cheng: The Method that Changed the Game, A. Almqvist, p. 40	AFM Cantilever Tip Radius Estimation Through Contact Resonance Force Spectroscopy, T. Mathias, p. 42	
9:00 am – 9:30 am	A Mixed Lubrication Model of Piston-on-Ring Contacts Considering Temperature Dependent Shear Thinning and Elastic-Plastic Contact, R. Jackson, p. 40	The Effects of -H and -OH Termination on Adhesion, Friction, and Wear of Silicon-Silicon Interfaces: A Molecular Dynamics Investigation, J. Harrison, p. 42	Towards the Prediction of EHL Film Thickness Parameters by Machine Learning Approaches, M. Marian, p. 43
9:30 am –10:00 am	From Photosynthetic Carbon Capture to Self-Healing Tribofilms, Y. Jeng, pg. 40	Unique Frictional Characteristics of Germanium-based Nanofilm, C. Xu, p. 42	Digitalization: Bringing a "Frictionless" Future Closer to Reality, S. Gullapalli, p. 43
10:00 am – 10:30 am	**Break**	**Break**	**Break**
	SESSION 2M **Lubrication and Tribology Modeling II** **Room 202A**	**SESSION 2N** **Nanotribology II** **Room 202B**	**SESSION 2O** **AI and Machine Learning II** **Room 202C**
1:30 pm – 2:00 pm	Frontiers of Surface Engineering and ribology for a Green and Sustainable Future, A. Erdemir, p. 60	Invited Talk – The Nucleation, Growth, and Adhesion of Water Bridges in Sliding Nano-Contacts, B. Weber, p. 62	A New Perspective on Tribological Data via Advanced Statistics and Artificial Intelligence, N. Dörr, p. 64
2:00 pm – 2:30 pm	Fluid/Solid Interactions in Lubrication – Recent Developments and Future Perspectives, D. Dini, p. 60		Chemometric and FTIR Spectroscopy for Determination of Physicochemical Properties of Engine Oil, G. Natrajan, p. 64
2:30 pm – 3:00 pm	Unsteady Multiscale Simulation of Lubricated Rough Surfaces, N. Brunetiere, p. 60	Molecular Dynamics Investigation of the Friction Mechanism in a Humid Nanocontact, I. Stankovic, p. 62	Digital Advancements in Tribofilm Analysis, O. Ogunsola, p. 64
3:00 pm – 4:00 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4:00 pm – 4:30 pm	Explicit Flow-Continuity-Enforced Elastohydrodynamic Lubrication Analyses with a Mass Conservation Algorithm, S. Liu, p. 60	Using Friction Hysteresis of 2D Materials to Uncover Properties of the Substrate, P. Egberts, p. 62	Using Machine Learning Algorithms to Relate the Surface Topography of As-Built Surfaces to Additive Manufacturing Process Parameters, B. Raeymaekers, p. 64
4:30 pm – 5:00 pm	Strength from Weakness: Dynamicity in Biotribological Interfaces, W. Gregory Sawyer, p. 60	MXene Nanosheets Exhibiting Layer-Dependent Friction Properties, Eui-Sung Yoon, p. 62	How to Get to Big Data in Tribology? A Hands-on Example, N. Garabedian, p. 64
5:00 pm – 5:30 pm	Lubricant-Chemistry Kinetic Model of Boundary Lubrication by Oil Additives Using SOL, QM+MD, and Machine Learning, Z. Ye, p. 62	Nanoscale Friction of High Entropy Alloy Sulfide Thin Films in Comparison with Molybdenum Disulfide, G. Adabasi, p. 62	Panel Discussion
5:30 pm – 6:00 pm			
6:00 pm – 6:30 pm			

Session 1A | 101A

Lubrication Fundamentals I: Forecasting Trends

Session Chair: Mihir Patel, Chevron Oronite LLC, Richmond, CA

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

8:00 am – 8:30 am

3833921: What Makes a Sulfur Compound Inactive versus Active? An Examination of Sulfur Compounds and its Effect on Lubrication

John Williams, Mark Harr, Dover Chemical, Dover, OH

It is well known in the lubricants field that sulfur, commonly used as an EP has two different compound types, active sulfur and inactive sulfur, where active sulfur stains and is corrosive to yellow metals and inactive sulfur which does not stain nor corrode yellow metals. In this paper we seek to find out what makes the difference. At what sulfur chain length does sulfur become active? Does the cross linking make a difference on inactive vs active? In this paper and presentation, olefins and fatty acid esters will be sulfurized using a standard black sulfurizing process at varying molar amounts of sulfur vs 1 mole of the unsaturation. After sulfurizing the material, the various sulfur compounds will be separated using a LC-MS by Sulfur chain length amounts and by cross linkage and then checked using ASTM D0130-19 at 5% in 100 naphthenic oil by weight. From this study we will show at what sulfur chain number a sulfur compound becomes active and if cross linking is a factor.

8:30 am – 9:00 am

3835945: Sustainable Cooperation in the Lubricant Industry – A Transformation Towards a Circular and Sustainable Lubricant Value Chain!

Inga Herrmann, VSI Verband Schmierstoff-Industrie e.V., Hamburg, Hamburg, Germany

Sustainability is a key agenda item for the lubricants industry today and will remain so for decades to come. Without sustainable business models and corporate strategies, companies will find it difficult to remain competitive and thrive. Becoming climate neutral requires the responsible use of resources and environmental protection. The lubricants industry has a key role to play; lubricants are part of the solution, as they make a significant contribution by reducing friction, corrosion and wear, which in turn results in lower energy consumption, reduced greenhouse gas emissions and longer equipment life. Developing a common and meaningful methodology for calculating product carbon footprint is vital for the global lubricant industry to create a level playing field. Industry associations from all parts of the world are working together to develop a transparent and consistent methodology to allow the calculation and sharing of reliable and comparable data for finished lubricants.

9:00 am – 9:30 am

3823908: Challenges for Lubrication R&D in Future Powertrains Applications and Potential Solutions in Precompetitive Research

Christian Kunze, Dirk Arnold, Forschungsvereinigung Antriebstechnik e.V., Frankfurt, Germany

Ecological and economic challenges are changing the way lubricants and tribological systems will be developed, produced and applied. It is essential to know future requirements and address R&D demand. For this purpose, FVA uses the Technology Trend Radar and subsequent technology studies. These tools align the FVA research portfolio with relevant future topics and make this know-how available to its member companies to design future products and processes at an early stage. In Technology Trend Radar, mega trends are identified and checked for relevance to drivetrain industry. Trend studies ensure detailing of research demand. Out of this process, pre-competitive research projects are derived. Studies have been commissioned on e.g., Green Tech and bio-based lubricants. In parallel, concrete projects have been launched for future topics of lubricants and tribology. Results on bio-based lubricants, lubricants and coolants for e-mobility and new test and analysis methods will be covered.

9:30 am – 10:00 am

Open Slot

10:00 am – 10:30 am – Break

Session 1B | 101B

Rolling Element Bearings I

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

Session Vice Chair: Alexander Fletcher, AFRL/RQTM, Wright Patterson Air Force Base, OH

8:00 am – 8:30 am

3931726: Experimental Validation and Comparison of Friction Torque Models for Rolling Element Bearings

Josephine Kelley, Gerhard Poll, Leibniz University Hannover, Garbsen, Germany

A bearing friction torque model that decomposes the total friction torque of a rolling element bearing into several components is investigated; friction due to churning losses, sliding friction, hydrodynamic rolling friction, and hysteresis friction are modelled individually. For some of these submodels, several modelling approaches have been proposed in literature, sometimes with very different results. In particular, modelling choices for the churning losses and hydrodynamic rolling friction have a big impact on the final estimated bearing torque value. A comprehensive comparison is presented, using nearly 1600 measured bearing torque values from literature. The bearing type, size, loading, speed, and lubricant are varied, enabling an extensive evaluation of the submodels.

8:30 am – 9:00 am

3813088: Cryogenic Test and Evaluation of Pin-on-Disk with the Various Cage Materials for Solid Lubricated Bearings

Wonil Kwak, Yeongdo Lee, Jeonkook Lee, Yongbok Lee, Korea Institute of Science and Technology, Seoul, Republic of Korea

In the interaction of solid lubrication, the friction mechanism can determine the effect on the bearing performance of cryogenic fluids (liquid nitrogen) through tribometer experiments. In this study, friction mechanism analysis was performed considering the coupling of bearing friction characteristics and fluid dynamics by the dynamic interactions between the bearing components. In addition, in order to improve friction performance in a cryogenic environment, a pin-on-disk test was conducted according to various composite materials. The purpose of this study is to understand the correlation between parameters affecting the improvement of solid lubrication performance in cryogenic fluid environments and diagnostic parameters for predicting the lifetime. In particular, this paper proposes a dimensionless friction coefficient classification factor that can satisfy an appropriate wear rate and predict its lifetime for the operating stability of ball bearings.

9:00 am – 9:30 am

3813004: Augmented Lubricant Replenishment for Rolling Bearings at Limited Lubricant Supply Conditions

Patrick Pat-lam Wong, City University of Hong Kong, Kowloon, Hong Kong

Regulating the lubricant supply to a bearing can reduce viscous friction, that may be lessened or withdrawn by lowering the lubrication effect. Thus, to better use the available lubricant in a bearing is important. This work presents a wettability surface pattern: an untreated oleophilic lubrication track sandwiched by oleophobic surfaces. Droplet transportation on the pattern surface was simulated. A liquid droplet fell to the centerline of the track. It expanded along the track till equilibrium. On the oleophobic regions, it retreated after a maximum spreading distance was attained. The liquid flow towards the central track is due to the wettability difference. It is good to the replenishment for bearing lubrication. The derived surface pattern was implemented on ball bearing raceways. These replenishment-augmented rolling bearings were tested. They attained low bearing friction at limited lubricant supply, due to the improved replenishment by the wettability-patterned raceway.

9:30 am – 10:00 am

3833954: An Improved Dynamic Bearing Model Considering Cage Lubrication

Thomas Russell, Farshid Sadeghi, Purdue University, West Lafayette, IN

A dynamic bearing model for deep groove ball bearings was developed to investigate the influence of oil lubrication & cage design on the motion of bearing components (i.e., bearing raceways, balls, and cage) and overall bearing friction. The effects of cage lubrication were included in the dynamic simulation with both a local cage pocket friction model and a global cage drag loss model. The local pocket friction model solves for the state of starved, hydrodynamic lubrication inside of each cage pocket to capture drag torque and dynamic behavior. Additionally, relations derived from a regression analysis on a series of CFD simulations are used to describe the global drag force on the cage due to lubricant churning inside of the bearing cavity. Results from the dynamic bearing model are used to investigate the frictional contribution of cage geometries as a function of bearing operating conditions.

10:00 am – 10:30 am – Break

Session 1C | 102A

Sustainable Power Generation I

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

Session Vice Chair: Elaine Hepley, POLARIS Laboratories, Indianapolis, IN

Session Starts at 8:30 am

8:30 am – 9:00 am

3812250: Towards an Accelerated Protocol for the Evaluation of Solar Cells

Emmanouil Georgiou, Angelos Koutsomichalis, Hellenic Air-Force Academy, Athens, Greece; Dirk Drees, Lais Lopes, Falex Tribology, Rotselaar, Vlaams Brabant, Belgium; Tom Van Der Donck, Jean-Pierre Celis, KU Leuven, Leuven, Belgium

Solar cells are expected to operate for 20-30 years. However, due to the synergism of thermal cycles and vibrations, wear phenomena can occur, especially at the tube connections. In this work we attempt to establish a test protocol for the characterization of the wear degradation of solar selective coatings. As a first step the dominant wear mechanisms were identified and then different test methods were applied to validate these mechanisms on the lab-scale. In particular, three main test-approaches were used: (a.) reciprocating sliding tests at the meso load to simulate localized scratching of the antireflection nano-layer, (b.) reciprocating sliding tests at higher temperatures to simulate the effect of thermal cycling which leads to the expansion of the tube and (c.) fretting mode II tests caused by vibrations. Based on the results, a better understanding of the failure mechanisms can be obtained, which we hope that can be utilized to further improve the quality and lifetime of solar cells.

9:00 am – 9:30 am

3833897: Advances in Varnish Condition Monitoring

Elaine Hepley, POLARIS Laboratories, Indianapolis, IN

When varnish formations in the oil reach a saturation point, the resulting deposits can be detrimental to the operating equipment and drastically reduce the overall service life of the lubricant. Condition monitoring is a well-known tool for evaluating the system's health and preventing varnish from causing a critical loss in fundamental lubricant design properties such as water separability and inhibiting corrosion, foam, and air release, and, most importantly, maintaining component longevity and uptime. This informative session will explore traditional varnish load monitoring techniques and how, paired with alternative analysis methodologies can provide insightful correlations into soluble and insoluble degradation by-products, L*a*b values, and more – identifying the varnish stage and type can be an invaluable aid to prevent critical agglomeration levels and influence what mitigation methods may be best to effectively eliminate varnish and keep systems operating optimally.

9:30 am – 10:00 am

3830424: Sustainable Aeroderivative Gas Turbine Operation Through Lubricant Chemistry Management

Matthew Hobbs, EPT, Calgary, Alberta, Canada

Aeroderivative gas turbines (GTs) are the most efficient heat engines ever developed. On their own, they have efficiencies on the order of 45%, however, this can be increased to 80% in a cogen arrangement. With efficiencies well above those of industrial GTs, aeroderivative use is becoming more important to meet rising demands sustainably. Moreover, their fast-start ability makes these GTs appealing as peakers that are relied on when renewable output is inadequate. While aeroderivative GTs are efficient, jet lube monitoring and maintenance practices lag behind those of industrial GT lubricants. Indeed, most jet oil programs neglect the application's primary cause of failure: inadequate management of the GT's lifeblood: it's oil. Since maintenance and sustainability go hand-in-hand, methods for better jet oil management can further reduce the impact of aeroderivative GTs. Specifically, lubricant chemistry management allows aeroderivative users to produce power even more sustainably.

10:00 am – 10:30 am – Break

Session 1D | 102B

Materials Tribology I

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

Session Vice Chair: Faysal Haque, Miami University, Oxford, OH

8:00 am – 8:30 am

3849839: Orientation Controls Tribological Performance of 3D-Printed Model Thermoplastics

Samsul Arfin Mahmood, Emily Guo, Amanda Sterling, Kyle Schulze, Auburn University, Auburn, AL

Recent studies on additive manufacturing show that mechanical properties can be altered in a controlled manner by adjusting the relationship between build orientation and the applied loading from the service. In this work, the effect of build orientation on the tribological properties of 3D-printed PLA – Polylactic acid and ABS- Acrylonitrile butadiene styrene is investigated. PLA and ABS samples are printed using material extrusion with three different build orientations. Tribological results show that variation in build direction relative to the sliding direction leads to anisotropic wear properties. The best wear properties are achieved when the layers are oriented orthogonally to the sliding direction. The coefficient of friction remains mostly unaffected. PLA samples demonstrate significantly better tribological properties compared to ABS. Varying the sliding speed between the interacting surfaces also affects the wear properties of both PLA and ABS.

8:30 am – 9:00 am

3814091: A Ready-to-Use Temperature Model for Polymer/Steel Contacts

Mitjan Kalin, University of Ljubljana, Ljubljana, Slovenia

This work focusses on development of a contact temperature model for polyoxymethylene (POM)/steel in contacts typical for many tribological model test, like pin-disc, with ambition for its use for contacts in real components of similar heat-sink volume. Two-step methodology consisted of (1.) combining the tribotests with measurement of heat flux along the polymer pin with the theoretical thermodynamic analyses to calculate the contact temperatures as a function of selected tribological parameters. In a second step, (2.) a model that predicts the contact temperatures based on contact-load parameters and the heat-sink volume used to remove the heat from the contact, and which is independent of contact geometry, was developed. Typical contact pressures (1.6 – 4.8 MPa) and sliding velocities (0.4 – 1.0 m/s) for pin-disc tests or small polymer gears were used to obtain a broad range of contact severity in terms of (pv), namely 0.6 – 4.8 MPa.m/s (8-fold increase).

9:00 am – 9:30 am

3831914: Characterizing Billiard Chalk in the Cue Tip-Cue Ball Interface

Alan Martin, The University of Sheffield, Leeds, West Yorkshire, United Kingdom

Billiards sports such as snooker and pool are a multimillion-dollar industry. Viewing figures from across the globe lead to revenues from ticket sales and broadcasting rights, meaning substantial tournament prizes for professionals. Sponsorship opportunities (of these events and of players) are driven by amateur interest in the sports, played at home and in more serious settings such as snooker clubs and sports bars. In billiards, chalk is added to the cue tip to increase friction between the tip and cue ball. The greater coefficient of friction allows a player to hit the cue ball off-center. This imparts spin on the cue ball, influencing where the cue ball will ultimately come to rest, following impact with a target ball or cushion. This is the true skill of the games; to be able to control where the cue-ball finishes in order to set up subsequent shots. However, the mechanics of the game, particularly the frictional mechanisms of chalk, are little understood, so will be discussed.

9:30 am – 10:00 am

3819733: Nanoscale Rate-and-State Friction, Atomic Insights Via Complex Sliding Protocols

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

Rate-and-state friction (RSF) describes the history-dependent friction seen in many materials. No single RSF equation adequately describes all RSF behavior. Our prior work shows that the predictions of one RSF law are obeyed in slide-hold-slide testing protocols for nanoscale silica-silica contacts. To interrogate the nanoscale RSF response in more detail, we have made modifications to the standard slide-hold-slide testing protocol which isolate discrete aspects of the response, such as removing the lateral stress during the hold to impose truly static ageing, variation of the speed before the hold to show that system memory can be retained across 100s of hold time, and quantifying the slip during the hold time to demonstrate "slip strengthening." The diversity of responses is inconsistent with any existing form of the RSF laws. Insight into the physics of the sometimes non-intuitive behavior is provided by kinetic Monte Carlo simulation of the interfacial bonding dynamics.

10:00 am – 10:30 am – Break

Session 1E | 102C

Condition Monitoring I

Session Chair: Alfredo Garcia, Luval SA, San Bernardo, Chile

Session Vice Chair: TBD

8:00 am – 8:30 am

3809926: A Hybrid Modeling Approach for Transferring Machine Learning Assisted Condition Monitoring of Rolling Bearings to Differing Machine Types

Christoph Bienefeld, Bosch, Renningen, Germany

Aiming towards reliability- and cost-optimized predictive maintenance strategies for rolling bearings, condition monitoring is an essential aspect. In this context, Machine Learning (ML) algorithms have a key role for interpreting real-time measurements. In the presented case, vibration data is used for condition monitoring of a fixed bearing type within a test bench environment. Given the current state of the art, transferring trained ML algorithms for condition monitoring to other types of machines is a major challenge. Re-training the algorithms for each individual machine type generates high effort in terms of additional measurements. Addressing that issue, this contribution will first explain the hurdles underlying transferability. Subsequently, some of these hurdles will be addressed using knowledge of structure-borne sound propagation within the machine. The resulting hybrid model incorporates a combination of physics-based and data-driven methods.

8:30 am – 9:00 am

3812707: Application of Envelope Spectrum Analysis and Spectral Kurtosis to Diagnose Debris Fault in Bearing using Acoustic Signals

Henry Omoregbee, University of Lagos, Nigeria, Lagos, Nigeria; Mabel Olanipekun, Tshwane University of Technology, Pretoria, Gauteng, South Africa; Bright Edward, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

Debris fault diagnosis based on acoustic signals in rolling element bearing running at low speed and high radial loads are more of low amplitudes, particularly in the case of debris faults whose signals necessitate high sensitivity analyses. As the rollers in the bearing rolls over debris trapped in grease used to lubricate the bearings, the envelope signal created by amplitude demodulation carries additional diagnostic information that is not available through ordinary spectrum analysis of the raw signal. The kurtosis value obtained for three different scenarios (debris induced, outer crack induced and a normal good bearing) couldn't be used to easily identify whether the used bearings were defective or not. It was established in this work that the envelope spectrum analysis detected the fault signature and its harmonics induced in the debris bearings when bandpass filtering of the raw signal with the frequency band specified by kurtogram and spectral kurtosis was made.

9:00 am – 9:30 am

3841570: Anomaly Detection Methodology for Centrifugal Compressors and Steam Turbines

Manish Khandelwal, Sandeep Kogge, L&T Technology Services, Bengaluru, India

Steam turbine and Compressors are critical equipment in a chemical process plant whose failure may result in even catastrophic losses. A reliability plan should be implemented which helps to maximize production value by implementing successful asset maintenance. In this paper, a data-driven integrated framework for health prognostics for steam turbines and compressors with the objective of detecting anomalies at an early stage. Anomaly detection refers to detecting data points, events, or behavior that do not comply with expected or normal behavior. This paper proposes a method for increasing the transparency and explain ability of anomaly detection to indicate which parts of a system contribute to the deviation from expected behavior. The results show that the proposed method detect abnormal behavior in Steam turbines and compressors accurately and reliably and indicate why it deviates. Historical examples of similar faults are not required for the proposed approach to detect faults.

9:30 am – 10:00 am

3806620: The Opportunities of Rolling Bearing Impedance Signal Analysis for Condition Monitoring

Florian Michael Becker-Dombrowsky, Technical University of Darmstadt, Darmstadt, Hesse, Germany

Condition monitoring of technical systems has an increasing importance for the reduction of downtimes based on unplanned breakdowns. Bearing damages lead to a high number of machine failures. State of the art is the indirect bearing observation by vibration or component temperature measurement. Measuring the electrical bearing impedance in situ has the ability to get information about bearing revolution speed and bearing loads. The damage detection and localization in the bearing is also possible, like early research could show. Here, the impedance signal of five fatigue tests is investigated using individual feature selection. The feature behavior is analyzed and explained, it can be shown that the three different bearing operational time phases can be differentiated by analyzing the signal features. Explainable features show a significant change in their behavior before the occurrence of initial damages even minutes before the vibration signals of the test rig vary from normal state.

10:00 am – 10:30 am – Break

Session 1G | 103B

Nonferrous Metals I

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

Session Vice Chair: Grigor Bantchev, USDA/ARS/NCAUR, Peoria, IL

8:00 am – 8:30 am

3833550: Emulsions for Aluminum Hot Rolling: Which Droplet Size Distribution is Beneficial to Lubricity?

Ariane Viat, Constellium Technology Center, Voreppe Cedex, France

Aluminium is usually hot rolled thanks to an oil-in-water emulsion with typical oil concentration being 1-10%. The emulsion stability relies on chemical (surfactant) and mechanical (stirring) actions. The surfactants create specific oil droplets dispersed in the water phase, depending on their affinity with oil and water (HLB) and the surfactant mix selected. Consequently, the particle size distribution can be mono- or multimodal, with variable droplet sizes. To what extent does the lubricity of the emulsion depend on such oil droplet size distribution? This paper investigates the relation between tribological performance and oil droplets population in the emulsion, hence emulsion stability. Various stability tests are carried out (light scattering, diffractometry) to perform deep analysis of how the oil droplets behave in emulsion. The destabilization phenomena help to explain how the oil film is created in the roll bite to ensure best lubricity.

8:30 am – 9:00 am

3811844: Additives for High Lubricity Fully Synthetic Aluminum Machining Formulations

Tiffany Meyers, Steffen Glaenzer, Clariant Corporation, Mount Holly, NC

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

9:00 am – 9:30 am

3831286: Correlations Between Two Methods for Cloud Point and Pour Point Determination of Biobased Materials

Grigor Bantchev, USDA/ARS/NCAUR, Peoria, IL

The ASTM methods D97 and D2500 are well accepted and widely used for measuring the pour points (PP) and cloud points (CP) of lubricants. However, these require relatively large volumes (50mL) of sample which can be problematic when screening a large number of lubricants during the early stages of lubricant candidate selection. The newer methods D5949 (PP) and D5773 (CP) require much smaller volumes (microliters) and are easier to perform. However, they are not currently as widely

accepted. In the current report, the CP and PP of ~40 biobased materials (estolides, isoestolides, their esters and vegetable oils) were measured by the two sets of ASTM methods and the results correlated. The correlations between the two methods were poor: r2=0.68 for PP and r2=0.60 for the CP; however, they could be improved by correction equation using the viscosity of the samples.

9:30 am – 10:00 am

3832150: Hot Mill Coolant Filtration Improvements

Andrea Knopp, Constellium, Ravenswood, WV

The purpose of this presentation is to discuss the path necessary to investigate filtration improvements on Hot Mill lubricants. This would begin in what data is important for a baseline, testing methods, filter paper types, and outcomes gained. This process is applied to both tandem and reversing mills. The ultimate goal is to provide the simplest path to make a process improvement savings, regardless of coolant type or metal production.

10:00 am – 10:30 am – Break

Session 1H | 103C

Commercial Marketing Forum I

Session Chair: TBD

Session Vice Chair: TBD

8:00 am – 8:30 am

3907383: Chevron Phillips – PAOs in Thermal Management Applications

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

PAOs are well known as synthetic base oils for lubrication having excellent properties at high and low temperature extremes. Heat transfer is becoming more important than ever and especially so for emerging applications in electric vehicles and computer architecture design. Thermal management in applications such as immersion cooling for data centers and electric vehicles requires considerable attention to the physical properties of the base oil and materials compatibility of components submerged in the base oil. This presentation will highlight the performance properties for good heat transfer, dielectric properties, and material compatibility of Synfluid® PAOs and the tests that are being used to evaluate potential fluids. Selecting the best fluid will aid energy reduction, sustainability, and equipment longevity.

8:30 am – 9:00 am

3901784: Huntsman – Amines for Fuel and Lube Applications

Haibo Zhao, Huntsman Corporation, The Woodlands, TX

Huntsman corporation is the world leader of the amine productions. Our ethylene amines and polyether amines are widely used as either key formulation components or additive building blocks for fuel and lube additives production. We will introduce our ethylene amines and polyether amines product portfolio and production capability in this presentation. We will also discuss how Huntsman amine products are used in the application of fuel deposit control agents, lube dispersants, friction modifiers and corrosion inhibitors.

9:00 am – 9:30 am

3905158: ANGUS Chemical Company – Addressing the Emerging Environmental and Performance Challenges of Tomorrow with ANGUS' Multifunctional Additives

Min Chen, ANGUS Chemical Company, Buffalo Grove, IL

Emerging trends in metalworking fluids are driving formulators toward additives that provide high performance while meeting complex sustainability goals. From developing multi-metal formulations that reduce waste to increasing use of bio-based raw materials in formulations compatible with next-gen machinery, ANGUS has the tools to help formulators address evolving metalworking fluids requirements. ANGUS' multifunctional CORRGUARD™ neutralizers, ALKATERGE™ emulsifiers and DMAMP™ corrosion inhibitors are proven to deliver performance and environmental benefits essential to the sustainable success of the global metalworking fluids industry. This commercial presentation will provide new perspectives on how the functionality, versatility and profile of ANGUS additives can improve the productivity and sustainability of tomorrow's metalworking fluids, even in the most demanding environments.

9:30 am – 10:00 am

3905948: Colonial Chemical: ColaCor 186: A Unique Core Carboxylic Acid for Corrosion Inhibitors

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

ColaCor 186 is a carboxylic acid closely mimicking the dibasic acid. Its unique structure enables its superior performance in corrosion protection and hard water tolerance to the conventional dibasic acids. In addition to ferrous protection, ColaCor 186 based amine carboxylates can provide protection for other metals. This presentation will be discussing on the key performance attributes and applications of ColaCor 186 and products derived from it.

10:00 am – 10:30 am – Break

Session 1I | 104A

Electric Vehicles I

Session Chair: Farrukh Qureshi, The Lubrizol Corporation, Wickcliffe, OH

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

Session Starts at 8:30 am

8:30 am – 9:00 am

3816216: Electrical Behaviors of Tribocontacts in Association with Friction and Wear Properties as Key Concepts for Lubes in Electrified Powertrains

Mathias Woydt, MATRILUB, Berlin, Germany; Gregor Patzer, Optimol Instruments GmbH, Munich, Germany

Electrically powered vehicles with lithium-ion batteries or fuel cells are todays favored mainstream in politics about the mobility turnaround. With the use of rolling bearings, the high energy density in electrified powertrains and electrostatic fields induced by magnetic fields, arcing forms a type of damage that has received little attention to date. Beside the bulk electrical properties of fluids and greases, the resulting electrical properties of tribofilms represent a key issue. Hairpins in the stator are a hitherto underestimated source of tribological challenges, because its insulating lacker must be compatible with transmission and/or cooling fluids. Micro-vibrations of hairpins bring the risk of fretting wear and

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short circuits. This presentation provides an overview of the resulting tribological and electrical properties of tribofilms, materials and fluids used in electrified drive trains, and how these can already be tribometrically tested in practice on a laboratory scale.

9:00 am – 9:30 am

3815343: Can Conventional ATFs be Used Safely in Electrified Transmissions?

Alejandro García Tuero, Noelia Rivera Rellán, Eduardo Rodríguez Ordóñez, Rubén González Rodríguez, José Luis Viesca Rodríguez, University of Oviedo, Gijón, Asturias, Spain

The position of the electric motor inside the transmission in hybrid electric vehicles (HEV) put it in contact with the automatic transmission fluid (ATF). For that reason, the ATF has additional electric requirements. In this work, the electrical compatibility of three different commercial ATFs is tested by measuring electrical conductivity, resistivity, permittivity, dielectric dissipation factor and breakdown voltage, and their tribological performance was studied through Stribeck curves, traction, and reciprocating tests. The original additive concentration was modified to higher and lower concentrations to check the impact on electrical compatibility and tribological properties. The results showed that, although the electrical conductivity increases with higher additives concentration, the ATFs remained compatible and the dielectric properties were also good for HEVs. Simultaneously, the tribological performance of these ATFs was improved at higher additive concentration.

9:30 am – 10:00 am

3840017: Development of Test Methods and Fluid Durability Study in Electrified Drivetrains

Cole Hudson, Southwest Research Institute, San Antonio, TX

Three complementary programs have been undertaken to determine the real-world conditions that stress a fluid in an electric or hybrid-electric vehicle (EV/HEV) drive unit and determine what a "failed" fluid looks like at the end of its life. By utilizing in-vehicle testing on chassis dynamometers, road conditions have been closely replicated to simulate the stressors that a fluid undergoes during its life cycle. This report serves as an update to this ongoing project in which a Chevy Bolt, Toyota RAV4 Prime Hybrid, and Hyundai Ioniq5 were disassembled, documented, extensively instrumented, tested for efficiency and range, and set on a 100,000-mile fluid durability test cycle. Incidental findings, used fluid analyses, and operational data will be presented from all three programs.

10:00 am – 10:30 am – Break

Authors and Presenters Invited to Attend Speakers Breakfast

Lead authors and education course instructors are invited to the Speakers Breakfast: **Sunday through Thursday, May 21-25 (7:00 am – 8:00 am)** in the Grand Ballroom to meet with session and paper solicitation chairs (PSCs) for a continental breakfast on the days of their presentations. This is a great time to review the session schedule and note any last-minute changes. Speakers should plan on attending.

Session 1K | 201A

Metalworking Fluids I

Session Chair: Kevin Saunderson, BP Lubricants USA Inc., Dousman, WI

Session Vice Chair: Karen Harrington, Fuchs Lubricants Company, Harvey, IL

8:00 am – 8:30 am

3809282: Improving Metalworking Fluid Efficiency by Creating Hydrophilic Protective Barriers

Volker Demel, Matthias Reihmann, Gelita AG, Eberbach, Baden-Württemberg, Germany

With increasing costs for energy, raw materials and waste disposal, efficiency of processes and metalworking fluids becomes an ever more relevant factor. Following this trend, it's important to reduce downtime due to pipe clogging, deposits in the machines, as well as reduced drag out and support tool life. In this talk we will present results of adding natural hydroxyproline rich proteins (HRPs) to water miscible metalworking fluids, which show positive effects in this regard. It is observed that HRPs build nano-meter thin layers on metals, glass, and plastics – forming a hydrophilic, protective barrier against hydrophobic deposits such as lime soaps, resins or sulphonates. The machine centers stay longer clean and are easier to flush, leading to less energy consumption and downtime. The same mechanism prevents the oleophilic phase of a metalworking fluid to stick to the work pieces, reducing drag out.

8:30 am – 9:00 am

3811097: Overcoming Metalworking Fluid Instability: Beyond HLB

Hoon Kim, Michael Creamer, Zschimmer & Schwarz US, Gordon, GA

Instability of MWF typically prompted by change in water hardness, temperature, shear force, chemical or microbial decomposition of emulsifiers & contamination. Since instable emulsion can deteriorate MWF performances and detrimentally affect the product quality, durability & reliability, the emulsion stability has been one of the key elements to ensure MWF efficiency. Having said that, optimal emulsifier selection plays a crucial role in maintaining robust emulsion stability and adds many beneficial impacts on MWF quality such as better resistance to hard water, lower risk of foaming, and desirable functions of other additives. Along this line, two key parameters for choosing correct emulsifiers have been investigated in terms of chemical structures, HLB (Hydrophilic Lipophilic Balance) value and CPP (Critical Packing Parameter). In this presentation, we will introduce useful structure-property-performance relationships of various surfactants to optimize product performances & quality.

9:00 am – 9:30 am

3831459: A Novel Way to Measure Stability and Shelf-Life of a Metalworking Fluid Formulation

Ravinder Elupula, Formulaction, Piscataway, NJ

Metalworking fluids (MWFs) are engineered fluids made to optimize metalworking operations as rolling, drawing, grinding, cutting. They are complex formulations with multiple purposes: reducing friction, mitigate heating degradation, flush away residues, protect from corrosion, achieve desired surface finish. MWF formulations can contain tens of ingredients, the major one being oil, water and emulsifiers supplemented by a large range of additive like corrosion inhibitors, lubricity additives, defoamers, biocides, anti-mist agents, dyes, extreme pressure agent, metal deactivators, wettings agents, antioxidants. As a result, optimization of MWF is elevated at the level of science and stability is a critical parameter to be probed at every stage of the product line.

SEQENS Announces New Partnership For Lubricant Additives In The U.S.

To reinforce its global presence, SEQENS is pleased to announce its new partnership with Univar Solutions. Through the new partnership, Univar Solutions will reliably distribute SEQENS lubricants additives in the U.S. and Canada.

For more than 50 years, SEQENS has supported its customers in the development and formulation of metalworking and protection fluids, and greases with a wide offering of technologies:

- Extreme pressure sulfurized additives
- Antiwear additives
- Emulsifiers
- Corrosion inhibitors
- Protection additives
- High tech greases

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1K

9:30 am – 10:00 am

3833753: Surfactant Roles in Emulsifiable Oils

Robert Golden, Pilot Chemical Company, Cincinnati, OH

Surfactants are the essential components of emulsifiable oils. They have a preference for residing at interfaces: liquid/liquid, air/liquid, or solid/liquid. They are responsible for stabilizing drops of oil in water, water in oil, corrosion inhibition and foam. Their behavior has to be governed by a physical and consistent set of rules, but elucidating these rules is the real tricky part. There are numerous models for surfactant behavior, each based on some physical aspect, but none are complete, and their predictive capability is extremely limited. The largest deficiency for the metalworking fluid industry is the lack of calculable predictability of a mixed surfactant system. Proposed here is a model outline meant to explain some of the interesting and useful properties for emulsifiable oils, and characterize some of the physical attributes that, if they could be quantified, result in a means to calculate, predict, and find the optimal performance.

10:00 am – 10:30 am – Break

Session 1M | 202A

Herbert S. Cheng Memorial Symposium

Challenges in Lubrication and Tribology Modeling I

Session Chair: Q. Jane Wang, Northwestern University, Evanston, IL

Session Vice Chair: TBD

This symposium invites presentations to honor Professor Herbert S. Cheng, discussing achievements in more than four decades of the Patir-Cheng average flow model and challenges in modeling lubrication and tribology facing the future technology developments. Symposium Starts at 8:30 am.

8:30 am – 9:00 am

3884945: Homogenization, HMM and Patir & Cheng: The Method that Changed the Game

Andreas Almqvist, Roland Larsson, Peter Wall, Luleå University of Technology, Luleå, Sweden; Greg de Boer, University of Leeds, Leeds, United Kingdom

It is not an exaggeration to say that the method addressing the mixed-lubrication problem introduced by Patir and Cheng (P&C) in the late 1970s was revolutionary. With this novel method, it became possible to study the effect of surfaces of (more or less) arbitrary rough nature, while previous studies had been focusing on surfaces with more simplistic roughness features, such as longitudinal or transverse striated irregularities. The P&C method can be considered to belong to the group known as Heterogeneous Multiscale Methods (HMM), where the problem is divided into a few coupled but distinctly separable scales that can be considered sequentially. In this group of problems, the branch of mathematics known as Homogenization can also be included. This paper is devoted to the significant similarities, as well as differences, that exist between these methods.

9:00 am – 9:30 am

3891451: A Mixed Lubrication Model of Piston-on-Ring Contacts Considering Temperature Dependent Shear Thinning and Elastic-Plastic Contact

Robert Jackson, Nolan Chu, Auburn University, Auburn, AL

This work develops a numerical methodology for predicting the performance of an automotive piston ring system by considering multiple scales of contact and lubrication mechanics. The finite element method will be used to model the mechanical deformations of the piston ring surfaces at large scales. A statistical rough surface method that renders asperities as elastic-plastic wavy surfaces predicts the solid contact area. The flow factor form of the Reynolds equation formulated for actual piston and ring surfaces will be solved to consider the effects of mixed-hydrodynamic lubrication. The lubricant viscosity depends both on temperature and shear rate. This will allow for the regimes of boundary, mixed and full-film lubrication to be considered. The model predicts friction for various loads and speeds that are then compared to experimental measurements. The results predict operation mostly in the mixed lubrication regime, but variation in friction with load, speed and temperature.

9:30 am – 10:00 am

3899130: From Photosynthetic Carbon Capture to Self-Healing Tribofilms

Yeau-Ren Jeng, National Chang Kung University, Tainan, Taiwan

The current mineral lubricants to mitigate friction are potentially creating as many problems as they are solving because mineral oils are as environmentally damaging as the additives used to enhance their performance. Therefore, new carbon-neutral solutions are required. Our solution is inspired by the fact that vegetable oil can create a functioning non-stick, low-friction surface on a Chinese wok by seasoning it at elevated temperatures. We optimize our vegetable oil formulations with soothing ingredients to spontaneously generate self-healing amorphous carbon (a-C) films while functioning as a high-performance lubricating system. As a result, our green formulations can outperform similar mineral-oil formulations under extreme lubricating conditions.

10:00 am – 10:30 am – Break

Exhibitor Appreciation Hour and Evonik Raffle

Two hours of dedicated exhibit time will occur at this year's trade show:

Monday, May 22 and Tuesday, May 23 (3:00 pm – 4:00 pm) in Hall B. All other annual meeting activities will be closed during this time, and refreshments will be served! Come view the industry's newest products and technologies from more than 100 companies.

As part of the **Exhibitor Appreciation Hour,** Evonik is hosting raffles on Monday and Tuesday, May 22 and 23, at 3:30 pm in the exhibit hall. You must be present at Evonik **(Booth 205)** at the time of drawing to win. Evonik is raffling two Yeti soft coolers.


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Session 1N | 202B

Nanotribology I

Session Chair: Wai Oo, University of California, Merced, Merced, CA

Session Vice Chair: TBD

8:00 am – 8:30 am

3834331: Nano-scale Friction of Graphitic Surfaces in n-hexadecane

Behnoosh Sattari Baboukani, University of California, Berkeley, Berkeley, CA; Zhijiang Ye, Miami University, Oxford, OH; Prathima Nalam, University at Buffalo, Buffalo, NY

Sliding-induced friction behavior of a single-asperity silica probe against few-layer graphene and bulk graphite is measured in n-hexadecane using an atomic force microscope (AFM). The load-dependent nanoscale friction measurements display friction hysteresis, i.e., higher friction forces during unloading of the contact than loading at a given normal load. Quasi-static force-separation curves identify four layers of n-hexadecane on graphitic surfaces. Molecular dynamic simulations illustrate that the solvated n-hexadecane molecules within the contact carry the probe load and determine the generated contact area, affecting friction hysteresis. Further, during AFM probe sliding, a molecular pile-up of n-hexadecane in front of the tip is observed. It has also been shown that the friction behavior of graphene changes by immersion time. n-hexadecane molecules diffuse between graphene and the supporting substrate and undergo a structural transition over time which impacts friction.

8:30 am – 9:00 am

3812927: AFM Cantilever Tip Radius Estimation Through Contact Resonance Force Spectroscopy

Thomas Mathias, Philip Egberts, University of Calgary, Calgary, Alberta, Canada

In Atomic Force Microscopy (AFM), the cantilever probe tip radius is a key parameter when characterizing the system's response. Currently, several measurement techniques are utilized to directly determine the cantilever tip radius. However, these techniques all have shortcomings including higher equipment costs, complexity, and increased testing time. In this paper a new procedure to estimate the tip radius is explored incorporating the technique of contact resonance. This is accomplished first by measuring the frequency response spectrum of the cantilever when free and in contact with a sample. Then by applying cantilever contact resonance and contact mechanics models together the cantilever tip radius is estimated. Various models were included in this study considering changes in cantilever geometry, damping, and surface adhesion. This procedure was applied to several cantilever probe types and surface materials including contact, tapping, and colloid particle probes of many sizes.

9:00 am – 9:30 am

3833291: The Effects of -H and -OH Termination on Adhesion, Friction, and Wear of Silicon-Silicon Interfaces: A Molecular Dynamics Investigation

Judith Harrison, US Naval Academy, Annapolis, MD; Robert Carpick, University of Pennsylvania, Philadelphia, PA; J. David Schall, North Carolina AT&T University, Greensboro, NC

The chemistry at contacting interfaces strongly affects adhesion and friction, but we lack understanding of the controlling atomistic mechanisms. For silicon, this creates challenges and opportunities for technologies including nano/micro-electromechanical systems, semiconductor manufacturing, and flexible electronics. To develop insights for such systems, the work of adhesion for Si-Si interface was examined using reactive molecular dynamics. Simulated systems were composed of two Si(111) surfaces with varying levels of surface termination with equal mixtures of randomly placed -H and -OH groups. These were compared with fully terminated surfaces with varying ratios of -OH and -H. Adhesion was affected by non-bonded, bonded, and polar interactions. The bonding mechanisms and their effect on friction as a function of termination and load were also examined. Simulation results are compared to experimental results from in-situ transmission electron microscopy-based nanoindentation.

9:30 am – 10:00 am

3810859: Unique Frictional Characteristics of Germanium-based Nanofilm

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

A new class of two-dimensional (2D) materials based on germanium, are potential candidates for applications as polarization photodetectors, semiconductors and field effect transistors due to their narrow band gap, high carrier mobility and the typical in-plane anisotropic layered structure. While their electronic properties have been examined, limited experimental study of their mechanical properties has been conducted to assess them for this application in comparison to conventional 2D materials. In this study, the friction behavior of supported GeAs was studied by AFM and MD simulation. A novel inverse-layer-dependent friction behavior was found, where larger friction was observed with thicker GeAs coverage. This trend is unlike the layer-dependent friction observed on conventional 2D materials, where friction decreases with increasing coverage. The underlying mechanism is likely linked to its unique electronical performance.

10:00 am – 10:30 am – Break

Session 1O | 202C

AI and Machine Learning I

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

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

8:00 am – 9:00 am

3834306: Deep Learning Data-Driven Model for Coefficient of Friction Prediction of Lubricated Tribo-pairs

Maria Victoria Granja Oramas, C. Fred Higgs III, Rice University, Houston, TX

The prediction of tribological behavior based on output data streams is often considered an empirical science since it is difficult to fully describe underlying processes with mathematical terms, e.g., by differential equations. Machine Learning provide opportunities to elucidate the relationship between operating and performance parameters in complex tribological processes while uncovering emergent patterns. This project aims to develop a deep learning data-driven model capable of predicting the coefficient of friction(COF) of lubricated tribosystems. Modeling capabilities that can accurately predict the coefficient of friction across three major lubrication regimes – boundary, mixed and hydrodynamic – are allusive. Extensive data collection will be conducted by running tribological tests covering the entire range of the Stribeck curve, and efforts are made to train the model. Once the model is optimized, it could be deployed to predict the COF of any lubricated ball-on-flat tribosystem.

9:00 am – 9:30 am

3823140: Towards the Prediction of EHL Film Thickness Parameters by Machine Learning Approaches

Max Marian, Pontificia Universidad Católica de Chile, Macul, Región Metropolitana, Chile

Non-dimensional similarity groups and analytically solvable proximity equations can be used to estimate integral fluid film parameters of elastohydrodynamically lubricated (EHL) contacts. In this contribution, it is demonstrated that machine learning (ML) approaches (support vector machines, Gaussian process regressions, and artificial neural networks) can predict film parameters more efficiently and with higher accuracy and flexibility compared to sophisticated EHL simulations and analytically solvable proximity equations, respectively. It is verified that the trained ML approaches can achieve coefficients of determination above 0.99, whereby the size of the data base, the hyperparameters and the architecture influence the prediction accuracy. It can be assumed that ML approaches will boost the prediction of EHL parameters and traction losses in multibody system dynamics simulations.

9:30 am – 10:00 am

3834040: Digitalization: Bringing a "Frictionless" Future Closer to Reality

Sravani Gullapalli, Edward Malisa, Oluwaseyi Ogunsola, Shell Global Solutions (US) Inc., Houston, TX; Dillawar Syed, Shell Global Solutions (UK), London, United Kingdom

Reducing friction losses in machines is coveted as it translates to reduced wear, improved fuel and engine efficiency, energy savings and improved sustainability performance. Mini Traction Machine (MTM) measures frictional properties of lubricants under a wide range of rolling and sliding conditions. This test generates extensive data points in unstructured data format. Scientists spend enormous time on extraction, data analysis and data transformation of the raw MTM output. In addition, there is no visibility of historical tests. The SPARK team automated the conversion of unstructured data to structured content leveraging technologies such as cloud storage and natural language processing. This conversion in turn "made accessible" historic tribology data and enabled the creation of a centralized, searchable database, which reduces data duplicates, enables the comparison and ranking historically tested lubricants and drives easy data-driven insights.

10:00 am – 10:30 am – Break

Session 2A | 101A

Lubrication Fundamentals II: Marine Engines

Session Chair: Ashish Jha, Chevron, Richmond, CA

Session Vice Chair: Brendan Miller, Chevron Oronite Company, Richmond, CA

1:30 pm – 2:00 pm

3833984: Performance of Additives Improving Asphaltene Dispersancy in GII Base Stocks

Ashish Jha, Chevron, Richmond, CA

Growing use of GII base oils creates challenges in handling asphaltene deposits in Marine TPEO applications. Intrinsic properties of GII base oils dictate a more challenging environment for additives to work effectively toward asphaltenes compared to that in GI base oils. This presentation describes improvements made in asphaltene dispersancy in GII base oils. Parallel benefits in terms of reduced component interaction will also be presented.

2:00 pm – 2:30 pm

3819130: Experimental Evaluation on a Special Cylinder Oil Additive Package Applied in Blender on Shipboard

Jie Zhang, Li Kai, Chen Ligong, Tao Yida, Richful Lube Additive Co. Ltd., Xinxiang, Henan, China

According to IMO 2020 regulation, two options of cylinder oil need to be chosen by shipowners. One is 40BN to fit low sulfur fuels. The other is 70BN or 100BN to fit high sulfur fuels with scrubber system. Electronic control instead of mechanical mode enhances the clean ability and lifetime for system oil due to its function of cooling in piston crown and lubricating for servo system. Blender on shipboard can constantly consume used system oil to blend cylinder oil and fresh oil is replenished into crankcase. So, system oil gets refresh and components in crankcase become clean. In this study, we aim to evaluate the properties of this additive package by in-house simulating tests, such as Pressure scanning calorimetry, Caterpillar micro-Oxidation test, Hot tube tester, Panel coker tester, SRV, SEM and EDS. From the test results, we can conclude that the candidates additive show better capacities of deposit control and friction resistance comparing with the commercial references.

2:30 pm – 3:00 pm

3811850: Varnish Resistance Prediction Indicator (VRPI) for Group I-IV Lubricants

Joseph Fotue, TotalEnergies Marketing Cameroon, Douala, Cameroon

In recent years, industries have witnessed an increase in varnish-related problems. Varnish is one of the most harmful contaminants impacting lubrication systems severely and leading to component failures, unplanned shutdowns, and costly downtime. Varnish precipitation in a system is affected by operating conditions, the oil, and the environment. Responding to varnish with a suitable solution is critical. Many solutions exist to mitigate varnish in a system. However, since prevention is better than cure, the first line of defense is choosing an excellent varnish resistance lubricant. Is there an indicator that can show the lubricant's varnish resistance? If yes, this indicator will depend on oxidation resistance and product solvency. In this article, we propose a lubricant calculated parameter: VRPI (Varnish Resistance Prediction Indicator) useful to easily evaluate different formulations and to make better purchasing decisions.

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

4:00 pm – 4:30 pm

3802552: Study of Tribological Contact Condition Using the Non-linear Behavior of Longitudinal Ultrasonic Waves

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

When the amplitude of incident ultrasonic waves is small (linear ultrasound), waves reflected from a contact contain information about the contact state. However, it is not possible with a single measurement to distinguish between reflection from an oil film and a solid contact (i.e., whether it is mixed or hydrodynamic lubrication). This limitation can be improved using a high-power ultrasonic wave (non-linear ultrasound). The reflected wave from the contact is distorted, and higher order frequencies are generated in the wave. It this study, a new reflection coefficient (second order reflection coefficient) using non-linear ultrasound, is presented. This has a different response to a dry contact and a lubricated film. By combining both linear reflection coefficient and second order reflection coefficient they can be to independently give the lubricant thickness and tribological contact conditions.

2A

4:30 pm – 5:00 pm

3833947: Reduction of Carbon Footprint and Maintenance of Oil Life through Performance Selection of Lube Oils

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

The International Maritime Organization has set a target to cut emissions by 50% in 2050 against the 2008 emission levels. Initiatives to cut carbon footprint with alternative fuels, and exhaust gas scrubbers have gained interest. This focal point of emission reduction from fuels eclipses some of the other potential approaches such as the contribution of selecting the right lube oil. The right lube oil not only helps in reducing emissions by lowering fuel consumption but also contributes to substantial monetary savings. Preliminary investigations showed that there could be as much as 10.7% in energy efficiency characteristics between oils of the same type and grade but differ in brands. This paper discusses the long-term benefits of selecting the right lube oil based on performance factors such as an oil's energy efficiency, ability to resist oxidation, amount of saturates & lower molecular weight fractions present in the oil, and its potential to deter deleterious contaminants.

5:00 pm – 5:30 pm

3812345: Accelerating the Development of Piston-Liner Tribology in Marine Diesel Engines Using Ultrasonic Transducers

Oliver Spenceley, University of Sheffield, Leeds, United Kingdom

Compliance to new and pending maritime emission legislation requires marine engines to operate at greater efficiency and reduce emissions. An increase in fuel efficiency and a reduction in emissions can be achieved simultaneously by minimizing excessive cylinder lubricant oil in the combustion chamber. A measurement system to define the oil film thickness (OFT) in real-time has been developed in order to optimize the cylinder lubricant oil feed rate, reducing parasitic energy loss, and minimizing emissions produced from the burning of excess oil. Ultrasound transducers were installed on the outside of the liner on a full-size marine engine test bed. The transducers emit ultrasonic pulses which reflect from the inner wall of the liner. As the piston passes by the reflection is recorded and used to deduce the OFT between ring and liner, as well as residual oil on the liner surface, it was shown that the minimum oil film thickness ranged from 2.5-10 µm as the rings passed the transducers.

5:30 pm – 6:00 pm

STLE New Members and Students Invited to Networking Reception

New STLE members and students are invited to a networking reception on **Sunday, May 21 (6:30 pm – 8:00 pm)** at Bogarts & Co. Please join us in welcoming new members of the STLE community and the next generation of tribologists for an evening of networking and great food.

This is a ticketed event for new members and students only!

Session 2B | 101B

Rolling Element Bearings II

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

Session Vice Chair: Alexander Fletcher, AFRL/RQTM, Wright Patterson Air Force Base, OH

1:30 pm – 2:00 pm

3812856: Contribution of Rolling Bearings to Improve Driving Range of Electric Vehicles

Jitesh Modi, Schaeffler Group USA, Troy, MI

Range anxiety has been a key challenge for the electric vehicles. Rolling bearings can provide a significant contribution to increase driving range through system understanding, effective analytical tools and application of innovative bearing solutions. Using advanced bearing steels, special heat treatments and surface coatings can help to enhance overall performance and driving efficiency of electric vehicles. On basis of discrete examples of innovative bearings, their optimized arrangements and holistic system design approach, the overall benefits of rolling bearings in electric vehicles are described.

2:00 pm – 2:30 pm

3831269: Influence of Bearing and System Design on CO_2 Emission Savings

Vasilios Bakolas, Philipp Rödel, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

In this paper, a series of parameters related to bearing designs will be compared to one another in the context of their energy efficiency and CO_2 emissions. Apart from parameters such as roughness and osculation, the effect that bord geometry, cage design and tolerances have on friction will be investigated. Furthermore, the effect that bearing installations have on the overall energy efficiency of a system will also be discussed to show that bearing optimization paired with system understanding for specific applications can lead to the optimum reduction of CO_2 emissions. A series of application designs will be evaluated, and the degree of optimization will be quantified.

2:30 pm – 3:00 pm

3812197: Influence of Form Deviated Bearing Seats on the Operating Behavior of Cylindrical Roller Bearings

Oliver Koch, Onur Atalay, RPTU, Kaiserslautern, Germany

There is a comprehensive set of standards and recommendations to design roller bearings in terms of tolerances. To avoid negative effects of the operating behavior of bearings the bearing manufacturers specify very precise tolerances for the bearing seats (IT4 … IT6). This leads of course to high manufacturing costs. But it is an open question if these precise tolerances are really necessary for a smooth operation of rolling bearings. Experimental studies of cylindrical roller bearings mounted on bearing seats with different waviness show a potential impact of the deviation on creeping of bearing rings. In addition, Multibody-Simulations (MBS) show that a certain waviness on the inner or outer raceway can generate a series of high energy pulses at a rate equal to the ball pass frequency relative to the inner or outer raceway. Because the inner ring is rotating the waves enter and leave the load zone causing a variation in the rolling element-raceway contact force.

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

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2B

4:00 pm – 4:30 pm

3799607: Experimental and Analytical Investigation of Oil Flow in a Ball Bearing

Ujjawal Arya, Farshid Sadeghi, Purdue University, West Lafayette, IN, Andreas Meinel, Hannes Grillenberger, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

This investigation aims to examine and visualize the oil flow inside a ball bearing. A counter-rotating ball bearing test rig was designed and developed such that both bearing races can be rotated simultaneously in opposite directions, allowing for observation of a single cage pocket in a stationary reference frame. The oil flow inside the bearing was analyzed using a high-speed camera and transparent cages. Bubble Image Velocimetry was used to track bubbles generated due to oil aeration and to study the flow inside the bearing. UV dye was used to observe oil starvation inside the cage pocket, which was influenced by raceway motion, oil fill level, cage pocket shape, and oil properties. Results from CFD models developed in Ansys Fluent corroborated well with the experimental results for oil flow. The current work provides the most detailed validation of a ball bearing CFD model to date, and the current modelling can be extended to investigate new cage designs.

4:30 pm – 5:00 pm

3810080: Experimental and Analytical Investigation of Angular Contact Ball Bearing Cage Pocket Lubrication

Saeed Aamer, Farshid Sadeghi, Purdue University, West Lafayette, IN, Andreas Meinel, Hannes Grillenberger, Schaeffler Technologies AG & Co KG, Herzogenaurach, Germany

This study aims to investigate lubricant flow experimentally and analytically in a ball bearing cage. A custom bearing test apparatus, incorporating a transparent bearing cage (TBC), was developed to study lubricant flow within the cage for various ball speeds and cage positions relative to the ball. The TBC was manufactured based on the original bearing cage geometry and was positioned in the test apparatus, relative to the ball, using a precision XYZ table. A multiphase CFD model was developed to simulate the operating conditions of the test apparatus. The model results agreed well with the experimental trends. The results demonstrated that as the cage was moved closer to the ball, lubrication conditions changed and fluid striated over the ball surface, resulting in greater air entrapment within the cage. Furthermore, increasing ball speed promoted starvation of lubricant supply to the cage. The CFD model also highlighted the role of surface tension in lubricant striation patterns.

5:00 pm – 5:30 pm

3831812: In Situ Measurement of Grease Churn within a Full-Scale Cylindrical Roller Bearing

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

Within this work a full-scale cylindrical roller bearing test rig was instrumented with ultrasonic piezoelectric elements, the waves of which are sensitive to lubricant film thickness, and can propagate through solid and liquid media, meaning direct access to the rolling contacts is not necessary. This means machinery modifications are kept to a minimum, and measurements are in-situ. Ultrasonic sensors were instrumented across the roller axis and results show that as fresh grease churns, the amount of free surface lubricant shortens towards the contact center, indicating starvation that is known to occur in greased bearings. However, this shortening is not consistent across the roller axis, and instead is more severe towards the roller-flange contacts. Additionally, films are not of a consistent thickness across the axis. The work findings give key insights into grease churn and reflow, as well as the potential for an ultrasonic approach to measure these parameters in field bearings.

5:30 pm – 6:00 pm

3830272: Long-Term Investigations of Different Bearing Configurations at Solid-Lubricated Rolling Bearings

SMichel Werner, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany; Stefan Emrich, Institut fur Oberflachen- und Schichtanalytik GmbH (IFOS), Kaiserslautern, Germany; Oliver Koch, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany; Michael Kopnarski, Institut fur Oberflachen- und Schichtanalytik GmbH (IFOS), Kaiserslautern, Germany

This contribution presents an investigation of solid-lubricated rolling bearings, which use a special, modified cage, where the cage pockets of the cage serve as a lubricant depot, besides the function of guiding the rolling elements. Investigations of the bearing system within the bearing service life are presented, and the torque curve, the wear mass and surface analyses are discussed. With respect to the elemental surface condition, the surfaces of the bearing rings and balls are examined with respect to the mass of the elements on them. Furthermore, service life investigations with different material pairings are presented, which show the service life achieved, the torque curve, the wear development and the surface analysis. The influence of the variation of cage material and ball coating on the wear of the bearing components is described, as well as how the distribution of the elements on the surface of selected tests differs.

Session 2C | 102A

Wind Turbine Tribology I

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

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

Session Starts at 2 pm

2:00 pm – 2:30 pm

3833961: Foaming in Wind Turbine Gearboxes: Causes, Impacts and Treatment Continued

Michael Blumenfeld, ExxonMobil Research & Engineering, Annandale, NJ; Kurtis Hartlen, Imperial Oil, Brights Grove, Ontario, Canada; Marianne Rodgers, Wind Energy Institute of Canada, 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 the 2022 STLE Annual Meeting, 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. Data showing the lubricant performance over time after different conversion strategies will also be presented. Finally, a discussion on the basis of foaming in lubricants will provide context for operators in solving and preventing future foam issues.

2:30 pm – 3:00 pm

3831417: Autonomously Triggered Application of Corrosion Preventing Lubricants

Sharon Flank, Jonathan Schupp, InfraTrac Inc., Smithsburg, MD

3D printing enables a novel approach to delivering lubricants autonomously in remote/hazardous locations. 3D printed microcontainers containing lubricant are affixed to the component potentially requiring maintenance. These storage shells are constructed of a durable polymer material. After lubricant is injected into the shells each is sealed with a second, less durable polymer. The capping polymer is selected for its sensitivity to one or more expected fault conditions (excess heat, friction, vibration, or acidity). Polymer #2 is printed atop the shells with a graduated depth leaving some shells thinly capped while others are covered more thickly. If a fault condition arises its presence acts to erode the fault-sensitive caps until the payload is released, starting with the shells that are most thinly capped. The self-lubrication/repair process is triggered autonomously by environmental conditions without action required by maintenance personnel.

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

4:00 pm – 4:30 pm

3811827: Non-Invasive Detection of Cracks in Bearing Steel Using Ultrasound

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

A significant proportion of wind turbine gearbox bearings fail through axial cracking associated with white-etching cracks (WEC). Post-mortem examinations of these failed bearings usually involve destructive sectioning of the bearing to be analyzed under a microscope for the presence of WECs. For a large bearing component, this can be time consuming, especially when having to section blindly for WEC concentrated regions. In this work, ultrasound was trialed as a potential method to locate regions of high WEC concentrations which subsequently facilitates targeted sectioning at these regions of interest. WECs were generated within two bearing steel roller specimens using a MPR test rig with critical lubricants. A focused probe was used to transmit ultrasonic waves to the WEC concentrated specimen within a water bath. Amplitude as well as non-linear behavior of ultrasonic reflections were used to deduce the presence of cracks within the roller specimens.

4:30 pm – 5:00 pm

3811250: Sustainable Solutions for Wind Turbines

Mar Combarros, Marc Alumà, IQL, Castellgalí, Barcelona, Spain; Ariadna Emeric, Gerard Cañellas, Àngel Navarro, Taro Ehara, Industrial Química Lasem, Castellgalí, Spain

The gearbox of a wind power turbine must convert a low-speed high torque of the turbine blades to a low torque high-speed rotation of the generator shaft. Due to the low accessibility of the wind turbines specially while offshore, the oil change is a critical point. Therefore, an extended life-service of the lubricant is required and a high oxidative stability and hydrolytical stability are essential. Furthermore, micropitting is of extreme relevance because of its long-life expectation, unsteady wind, low velocities, high loads, and contamination. A sustainable alternative is presented offering an increased life-service and a reduced micropitting in comparison with a standard formulation. Sustainability is understood as a reduction of the environmental impact measured as an assessment of the life cycle of the product which includes: the origin of the raw materials, manufacturing, its performance and its biodegradability.

5:00 pm – 5:30 pm

3867432: Using a Rheometer to Test the Performance of Greases in an Oscillating Ball Bearing

Michael Bartram, The University of Sheffield, Sheffield, South Yorkshire, United Kingdom

Oscillation in ball bearings can lead to failure in the form of either fretting or false brinelling. Grease lubrication can worsen the problem, as under certain oscillation conditions grease leads to starvation in the contact a lot more quickly than oil. This can cause problems for offshore wind turbines – pitch bearings typically operate under oscillating conditions. Due to their size (>5m diameter) and location (offshore), replacement is incredibly expensive. Therefore, extending the bearing life is desirable, which can be done by extending the life of the grease. Testing of grease on oscillating ball bearings is currently done either using a specialized rig, or using a simplified setup (e.g., ball-on-disc). However, many rheometers can precisely measure oscillating motion, and are already found in many labs. A custom attachment has been developed to mount a thrust bearing in a rheometer for use as a novel testing method to analyze the performance of greases under oscillating motion.

5:30 pm – 6:00 pm

Sustainable Power Generation & Wind Turbine Tribology Business Meeting

Session 2D | 102B

Materials Tribology II

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

Session Vice Chair: Adam DeLong, Florida State University, Tallahassee, FL

1:30 pm – 2:00 pm

3813080: Effect of Diamond-Like Carbon Composition on Oxidation Reactivity and Friction

Seokhoon Jang, Seong Kim, Pennsylvania State University, State College, PA; Muztoba Rabbani, Ashlie Martini, University of California, Merced, Merced, CA

Although hydrogenated diamond-like carbon (HDLC) exhibits superlubricity and wear protection in inert conditions, its superlubricity depends on the sp^2/sp^3 carbon ratio and H content and is often lost due to surface oxidation. Therefore, understanding the dependence of HDLC composition on its oxidation reactivity and frictional behavior in O_2 and H_2O is important for the design of HDLC that provides superlubricity in oxidizing environments like humid air. However, investigating these relationships using ex-situ analyses of tribo-tested HDLC is challenging since HDLC surfaces are usually subject to air-oxidation after friction testing. Here, this issue is overcome by characterizing oxidation reactivity and friction of HDLC in O_2 and H_2O as a function of the composition of HDLC based on Raman spectroscopy, Langmuir-type kinetic analysis, and reactive molecular dynamics simulations.

2:00 pm – 2:30 pm

3848254: Process-Structure-Property Driven Development of High-Quality MoS_2 Coatings

Tomas Babuska, Michael Dugger, Steven Larson, John Curry, Sandia National Laboratories, Albuquerque, NM; Brandon Krick, Florida State University, Tallahassee, FL

Sputtered molybdenum disulfide (MoS_2) coatings have been used extensively in aerospace applications due to their ultra-low steady-state coefficients of friction (μss < 0.05) and low wear rates in inert environments. Developing MoS_2 coatings for demanding applications with predictable and reliable performance over time requires tuning the coating microstructure through process variations to promote high wear resistance, low μi, high density, and resistance to oxidation. Here we investigate the role of processing parameters such as argon pressure, bias voltage, and power density on resulting coating microstructural characteristics, tribological properties and oxidation resistance. Additionally, we investigate the batch variability and impact of processing variables on coating microstructure and properties for multiple deposition runs using parameters such as wear rate and hardness to quantify batch quality. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

2:30 pm – 3:00 pm

3832185: Quality Assurance Methods for MoS_2-Based Solid Lubricants

Michael Dugger, Mark Rodriguez, Sandia National Laboratories, Albuquerque, NM; Olivia Smithhisler, Michael Walsh, Theresa Pond, Kansas City National Security Campus, Kansas City, MO

Much research has been devoted to formulating MoS_2-based solid lubricants for use in extreme environment aerospace applications. The run-in and steady-state performance in different operating environments, as well as microstructure and aging behavior of films, are all important attributes to be considered when selecting a film for a particular application. However, rigorous characterization does not end once the specific coating has been identified. Large investments of time and money frequently involved with these applications warrant a rigorous quality assurance program to ensure that the solid lubricants will behave predictably for the service life of the mechanism. This presentation will describe one approach for insuring quality and reliable performance of MoS_2-based solid lubricant coatings over several years of production.

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

4:00 pm – 4:30 pm

3832904: Wear and Corrosion Resistant Ni-SiC Coatings Fabricated by Adaptive Additive Manufacturing

Mohsen Tajedini, Peter Renner, Hong Liang, Texas A&M University, College Station, TX

To date, various coatings, have been employed to protect metallic alloys for many industrial applications, still, there is a need for a cost-effective and easy-fabricable coating method. In this presentation, we discuss about a new approach to applying Ni-SiC coating on steel substrates. The coatings were found to be highly corrosion and wear-resistive compared to bare steel. The wear rates were reduced by 80%, and the hardness was improved by more than twice. In electrochemical measurement, the corrosion current density of coatings was reduced by ~5 orders of magnitude compared with the reference sample, while the mass loss was only about 1% of steel substrate. Detailed discussion will be provided in this presentation.

4:30 pm – 5:00 pm

3833836: High-Frequency Reciprocating Tribological Assessment of MoVN-Cu Coating in Low-Viscosity Fuel Environments under Various Load, Temperature, and Sliding Velocity Conditions

Kelly Jacques, Asghar Shirani, Jesse Smith, Thomas Scharf, Andrey Voevodin, Samir Aouadi, Diana Berman,University of North Texas, Denton, TX; Scott Walck, Stephen Berkebile, US Army DEVCOM Army Research Laboratory, Aberdeen Proving Ground, MD; Osman Eryilmaz, Argonne National Laboratory, Lemont, IL

Inhibiting the tribological failure of mechanical assemblies which rely on fuels for lubrication is an obstacle to maintaining the lifetime of these systems with low-viscosity fuels. In the present study, a MoVN-Cu nanocomposite coating was tribologically evaluated in low viscosity fuels as a function of temperature, load, and sliding velocity conditions. Transmission electron microscopy was used to confirm the presence of nanoscale copper clusters within the coating which provide catalytic surfaces for the formation of tribofilms. Characterization of the MoVN-Cu worn surfaces confirmed the presence of an amorphous carbon-rich tribofilm. The tribological assessment of the MoVN-Cu coating reveals that the coefficient of friction decreased with increasing contact pressure. These findings suggest that MoVN-Cu is a promising protective coating for fuel-lubricated assemblies due to its adaptive ability to replenish lubricious tribofilms from hydrocarbon environments.

5:00 pm – 5:30 pm

3834225: Ultralow Wear PEALD Ternary Nitrides: Understanding Process-Structure-Property Relationships

Kylie Van Meter, Santiago Lazarte, Brandon Krick, Florida State University, Tallahassee, FL; Md. Chowdhury, Nicholas Strandwitz, Lehigh University, Bethlehem, PA; Mark Sowa, Veeco ALD, Waltham, MA; Alexander Kozen, University of Maryland, College Park, MD

Metal nitride coatings are frequently used in tribological applications due to their high wear resistance and friction reducing properties. Compared to traditional TiN films, multi-metal nitrides such as TiVN are found to be lower wear and friction and have higher oxidation resistance. Plasma-enhanced atomic layer deposition (PEALD) techniques enable atomic level thickness and composition control, allowing for the growth of thin (~100nm), conformal, conductive films at low deposition temperatures, where conventional CVD techniques are limited. These capabilities make PEALD nitride films candidates for microelectronics and MEMS/NEMS. Recently, PEALD ternary nitrides have achieved ultralow wear rates (K < 10-7 mm3/Nm). However, there lacks a fundamental understanding of the process-structure-property relationships in PEALD films. This work investigates the effects of deposition parameters, linking film structure, physical, mechanical, and chemical properties to tribological behavior.

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Monday, May 22 | Technical Sessions

Session 2E | 102C

Condition Monitoring II

Session Chair: Kemberlee Snelling, Trico Corporation, Davison, MI
Session Vice Chair: TBD

1:30 pm – 2:00 pm

3801921: Lifetime Extension Strategies in Wind Turbine Using an OCM – Oil Condition Monitoring Program

Yesid Gomez, Adolfo Malaga, Jose Ignacio Ciria, Bureau Veritas Spain – OCM, Eibar, Gipuzkoa, Spain

Despite continuous innovation in wind turbine designs, lubrication systems, improvements in the properties of the different materials and in the formulations of the lubricants used, maintenance problems in all technologies persist, as a consequence of the fatigue of the components, or by external contamination that can cause accelerated wear of the components. Through the results of this study, we have been able to understand these modes of degradation, and above all, it has led us to propose new alternatives within the OCM – Oil Condition Monitoring programs that have allowed us to improve the early detection of possible failures and to be able to thus extend the useful life of the gearbox.

2:00 pm – 2:30 pm

3812603: Suggested Sampling Methods for In-Service Oil and Grease Lubricated Equipment

Victoria Bunchek, Raymond Dalley, Trico Corporation, Pewaukee, WI; Bernie Hall, Checkfluid, London, Ontario, Canada; Richard Wurzbach, MRG Laboratories, York, PA; George Staniewski, Tribology Consultant, Mississauga, Ontario, Canada

The purpose of this guide is to provide best practices for sampling in-service lubricant to decrease the variability between used oil analysis samples and improve the effectiveness of the data to make the resulting maintenance actions more meaningful and impactful as it relates to equipment safety, reliability, and lifespan. For the purposes of this guideline, equipment is divided into groups based on the techniques needed to satisfy sampling in general reservoirs; low, medium, and high pressure circulating lubricant systems; small reservoirs; hostile environments; and in grease-lubricated applications. In each category methods of basic, better, and best are provided. Equipment-specific direction is provided here to better serve anyone involved in taking used oil and grease samples or utilizing the data provided by such samples. The goal is to produce an evolving sampling guideline document for practicing end-users throughout the world.

2:30 pm – 3:00 pm

3836660: Optimizing Operational Savings with Fluid Analysis

Henry Neicamp, POLARIS Laboratories, Indianapolis, IN

The success of a fluid analysis program is usually measured by the amount of money, or the number of assets saved. Managing equipment in an organized manner is a vital step towards saving assets and money, so you can accurately track your return on investment. Embracing predictive maintenance technology is essential to maintaining healthy equipment, lowering maintenance time, and reducing costs. There are several actions maintenance professionals can take to maximize the value sampling provides. Learn hands-on tips for retrieving the optimum data to get the most actionable information from your management reports and sample report recommendations. Learn how to optimize finding the issues plaguing your fluid analysis program and use that information to increase your payoff several times.

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

4:00 pm – 4:30 pm

3833723: A Sea Change in Fluid Analysis (a.k.a. Oil Analysis) Has Arrived

Jack Poley, CMI, Miami, FL

Fluid analysis dates to early 20th Century, when testing was primarily to determine lubricant viability; simple tests for contamination, e.g., water, precipitated solids, and degradation, e.g., viscosity; initiated by oil companies. Circa 1948, a railroad began testing for wear metals, like iron and copper. Wear metals testing signaled emphasis on the asset itself rather than the lubricant. This initial paradigm shift became the first CM discipline. There are now 8 paradigm shifts in fluid analysis, each adding scope and value, including onsite testing equivalency with remote brick and mortar labs, automated, artificial intelligence software to evaluate data and render advisories, full spectrum, large particle wear metals analysis and mixed-mode condition monitoring. These paradigms redefine and reinforce fluid analysis as the most valuable CM discipline for lubricated assets. Holistic Condition Monitoring – the 8th paradigm, leads the way.

4:30 pm – 5:00 pm

3833861: Using Oil Analysis to Identify Incorrect Bearing Lubrication

Evan Zabawski, Eurofins TestOil, Strongsville, OH

Far too often an oil change is performed on an asset when poor oil analysis results reveal high levels of wear, yet this does not truly address the root cause of the wear. Using an example of a bearing with high wear debris alarms but no alarms on the lubricant properties, see how to detect a common issue frequently found in bearing applications. Through guidance on proper interpretation techniques, discover how to interpret an oil analysis report to determine the causes of the alarmed data, identify commonly misdiagnosed root causes and decide on the best course of action.

5:00 pm – 5:30 pm

3833854: Using Oil Analysis to Determine Root Cause of an Overheated Gearbox

Evan Zabawski, Eurofins TestOil, Strongsville, OH

Determining what is wrong with a gearbox that runs hot but shows no signs of wear and the oil level is correct can be difficult. What if the oil properties are degrading, and the oil life is short? This session will show how to find commonly misdiagnosed or overlooked issues. A case study example of a medium-sized gearbox with a seemingly obvious lubricant failure will be presented to illustrate how oil analysis data can identify a lubricant selection problem. Learn how to apply this knowledge to future oil analysis reports to correctly diagnose the true root cause of an alarmed condition.

5:30 pm – 6:00 pm

Condition Monitoring Business Meeting

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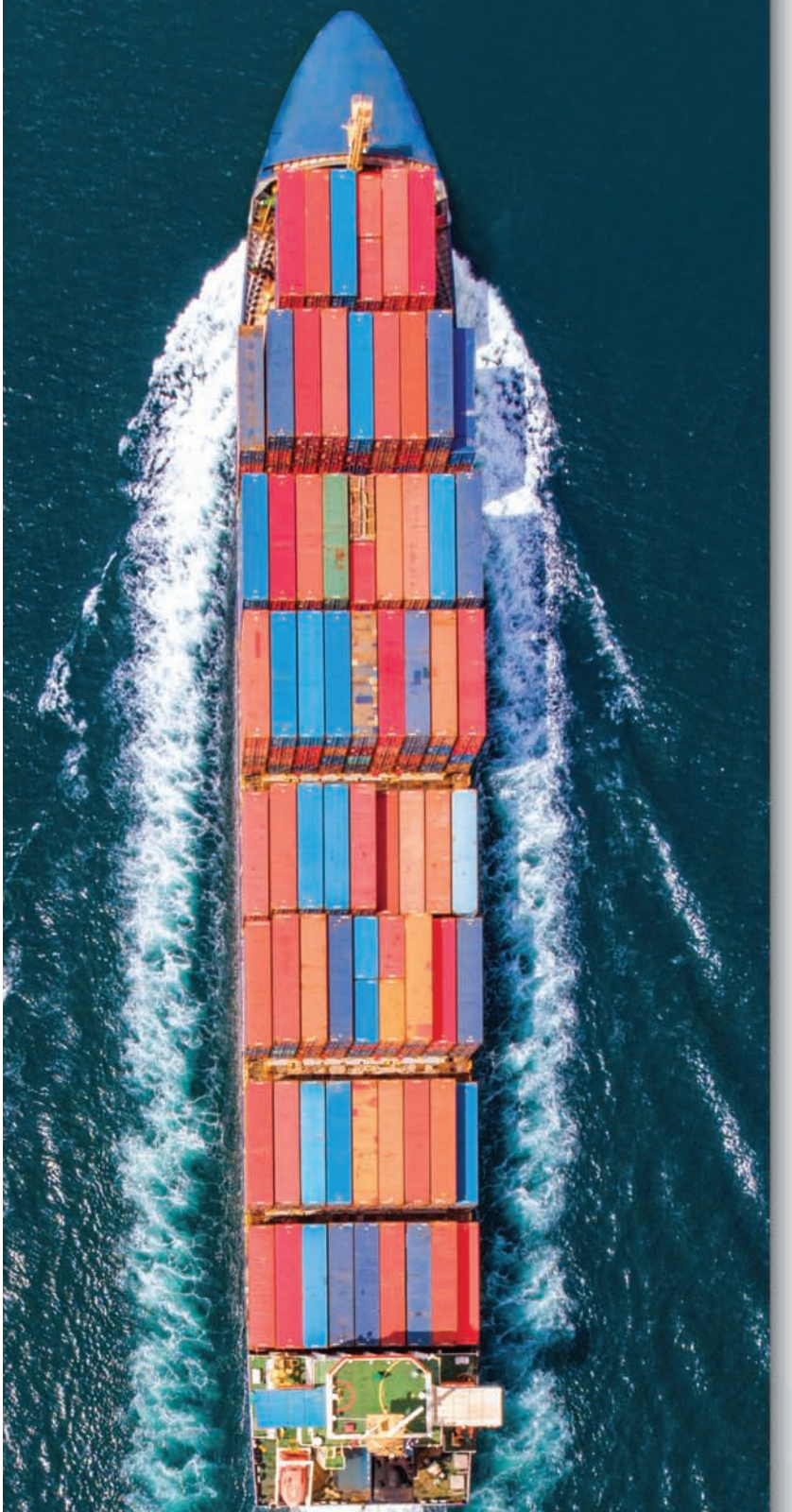

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Presenter: **Dr. Clifford Pratt**

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Session 2F | 103A

Environmentally Friendly Fluids I

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

Session Vice Chair: Daniel Garbark, Battelle Memorial Institute, Columbus, OH

1:30 pm – 2:00 pm

3811431: Global Fluid Trends

Edward Jones, Hangsterfer's Labs Inc., Mantua, NJ

Environmentally friendly fluids are sometimes simple and sometimes very complex formulas and technology. There exist several internationally and industry wide recognized governmental and independent agencies that greatly influence trends in acceptable technology. These agencies and their guidelines will be reviewed along with reasons why certain ingredients have or will become obsolete. The utilization of sustainable lubricant ingredients will also be reviewed and steps that need to be taken now. The presentation will contain information based on US, Canada, EU, UK, Japan and China governments, and industrial sectors that include aerospace, automotive, electronic, and medical. The impact on manufacturing processes will also be discussed. The choice to use environmentally friendly fluids should not be solely pushed on us by governments creating a reactive response, it goes beyond that and is a moral decision for the greater good and industry needs to be proactive with these decisions.

2:00 pm – 2:30 pm

3812469: Using the Life Cycle Assessment (LCA) Tool to Determine the Carbon Footprints of Castor Oil Derivatives

Travis Thompson, Biosynthetic Technologies, Indianapolis, IN

With concepts like sustainability and environmental performance gaining momentum in the lubricant industry, many companies are finally seeking ways to incorporate such characteristics into their product lines. While such terms seem simple at first glance, their subjective nature can make them difficult to understand and implement. One tool for navigating such concepts in a more objective way is the Life Cycle Assessment (LCA). A cradle-to-gate LCA has been conducted on a set of lubricant base oils and additives (castor oil derivatives), with an emphasis on understanding the true carbon footprint of these products. Direct and indirect emissions were considered, covering areas such as agriculture, feedstock transport, manufacturing, and waste management. This report provides a more comprehensive and objective measurement of the products' carbon footprints, allowing for a more quantitative understanding and a better basis for comparison to different types of products.

2:30 pm – 3:00 pm

3830719: Potential of Lubricant Base Oils from Microalgae

Brajendra Sharma, USDA/ARS/NEA/ERRC, Wyndmoor, PA; Derek Vardon, Robert McCormick, National Renewable Energy Laboratory, Golden, CO; John Scott, University of Illinois at Urbana-Champaign, Champaign, IL; Kenneth Doll, USDA-ARS-National Center for Agricultural Utilization Research, Peoria, IL; Timothy Strathmann, Colorado School of Mines, Golden, CO

Potential of hydrocarbons extracted from microalgal species Botryococcus braunii (B. braunii) race B were evaluated as a biobased lubricant. B. braunii biomass contains 55.6% (dry weight basis) extractable lipids comprised primarily of C31 and C33 botryococcenes. The extracted botryococcene oil displayed a remarkably high viscosity index (>300), favorable cold flow properties, marginally better oxidation stability than soybean oil, and tribological performance comparable to soybean oil and PAO oil. These lubricant properties can be ascribed to the high degree of branching present in C31 and C33 botryococcene molecules. The presentation will discuss the potential of botryococcene oil as biobased lubricant and feedstock for jet fuel.

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

4:00 pm – 4:30 pm

3810970: Maximize Performance and Improve Sustainability Through Use of Group V Ester Technology

Gemma Stephenson, Kevin Duncan, Cargill, Snaith, United Kingdom

This paper will show that through using Group V ester base fluids, it is possible to achieve both high performance and excellent sustainability credentials in unison. Innovation and lifecycle thinking when designing products are crucial when engineering fluids with excellent intrinsic and extrinsic sustainability properties. Herein, we compare conventionally used base oils (Groups I–IV) with innovative ester technologies, looking not only at their inherent sustainability benefits, but also at their handprint – their tribological performance and benefits in-use, using testing that is applicable to both industrial and automotive applications. This paper will show that esters exhibit excellent friction reduction benefits when compared to Group I–IV counterparts. Studies have shown that this can relate to improved energy efficiency in tribological systems.

4:30 pm – 5:00 pm

3832044: Overcoming the High Viscosity Limitation of Readily Biodegradable EAL Base Fluid

Ramesh Navaratnam, Jerry Wu, Patech Fine Chemicals, Dublin, OH

As the demand of Environmentally Acceptable Lubricants (EALs) significantly grows, more and more industries that required heavy loading operation no longer satisfy with current EAL viscosity range. They need higher viscosity EAL for better wear protection. However, to achieve higher viscosity, the based fluids need to have higher molecular weight (MW) but as is well known that higher MW leads poor biodegradability. Therefore, how to make the high viscosity base fluid readily biodegradable will be a big challenge. In this presentation, we will show how we broke the viscosity limitation and successfully develop several high viscosity readily biodegradable base fluids. We will demonstrate the hydrolytic stability, lubricity, oxidation stability of these fluids. Since these types of fluids are sometimes used as viscosity modifiers or additive solubilizer, we will also show their compatibility with PAO, specifically in HEPR application.

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Session 2G | 103B

Nonferrous Metals II

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

Session Vice Chair: Annie King, Total Energies, Linden, NJ

1:30 pm – 2:00 pm

3818372: Improving Aluminum Cold Mill Lubricant Performance with a Surface Active Agent

Thomas Oleksiak, Quaker Houghton, Oswego, IL

Cold rolling oils for rolling aluminum typically use a low viscosity base oil in combination with additives. Additives used in the process include fatty alcohols, fatty esters, and low levels of fatty acid. A surface-active agent was investigated as a means to improve efficiency of boundary lubricant additives. Aluminum wetting and surface energy experiments were used to analyze the effectiveness of this additive. Tribology testing will also be reported. Performance in the field will be analyzed relative to the observed surface chemistry and tribology analysis.

2:00 pm – 2:30 pm

3833171: Carbon Negative Liquid Hydrocarbons: Next Generation GTL Technology Commercializing in the US

William Anderson, ClearShift, Avon, IN

This presentation will discuss the technology and products being produced at demonstration plants of next generation GTL technology, making normal paraffins solvents and oils that are carbon negative. A combination of updated GTL technology called "Cool GTL" and SMR syngas production utilizing cutting-edge reverse water gas shift technology makes liquid hydrocarbons for the masses from man-made CO2. A fresh take on decarbonization. Looking to have a flagship plant operational in 2025/2026.

2:30 pm – 3:00 pm

3833991: Considerations for Changing Cold Rolling Base Oil

James Anglin, Allegheny Petroleum, Monroeville, PA

Most base oils for cold rolling of aluminum are relatively highly refined narrow cut hydrocarbon products. While making a change from one product to another might seem straightforward, many considerations are involved and the cost for a misstep can be high. Commercial, technical, and regulatory factors need to be considered and balanced against those for the incumbent. This presentation will delve into these considerations.

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

4:00 pm – 4:30 pm

3848321: Influence of Raw Material Quality Variations on the In-service Performance of Aluminum Hot Rolling Oils

Josef Leimhofer, AMAG Rolling GmbH, Ranshofen, Austria

Oils for hot rolling of aluminum are complex mixtures of several raw materials, which are technical products and mixtures themselves. Their properties (e.g., emulsion stability, cooling properties, lubricity) are crucial for their use. Even minor changes in the composition of the oils can have severe consequences for the rolling process and therefore, the composition of these fluids is critical and thus, constantly monitored. Fluctuations in the composition of rolling oils can originate (e.g., from variations in the quality of the raw materials or from the formulation process). In this work, these variations in the quality of some raw materials for aluminum hot rolling oils are investigated and judged with respect to the impact on their in-service performance. For this purpose, standard analytical techniques are applied as well as highly sophisticated techniques (Nuclear Magnetic Resonance spectroscopy: NMR), and results of these investigations are presented.

4:30 pm – 5:30 pm

Nonferrous Metals Business Meeting

Session 2H | 103C

Commercial Marketing Forum II

Session Chair: TBD

Session Vice Chair: TBD

1:30 pm – 2 pm

3909095: Evonik Oil Additives: Novel Base Oil Technologies for Automotive Driveline Fluids

Justin Langston, Helmut Melchior, Gabriela Fedor, Thomas Schimmel, Evonik Oil Additives, Horsham, PA

Automotive gear oils must protect against wear, corrosion, and oxidation in severe operating conditions. Unlike conventional axle oils, electrical driveline fluids must meet additional requirements, such as thermal conductivity and copper corrosion. These requirements and extended fluid life expectations require high-performance components when formulating fluids. To reach viscosity targets and ensure stay-in-grade viscosity, formulators use shear-stable, high-viscosity base stocks in combination with low-viscosity base stocks. This paper will share the performance of novel synthetic high-viscosity base stocks. When incorporated in automotive gear oils and e-driveline fluid formulations, these novel base stocks offer unique solvency and low-temperature performance advantages. Furthermore, they work well with a wide range of base oils, providing formulation flexibility, and have low product carbon footprints, allowing for more sustainable formulations.

2:00 pm – 2:30 pm

3801832: LANXESS – Advances in H1 Food Grade Calcium Sulfonate Greases: A Continued Vision 20 Years On

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

LANXESS was the first to introduce and produce H1, Food Grade, Calcium Sulfonate Complex (CSC) greases and has done so for the past 20 years. This presentation is an overview of our past as the leading technology developer to our latest developments. With the introduction of CSC greases to the food processing machinery lubrication market, industrial level performance had been introduced into this market. With exceptional performance in high humidity and varied conditions present in food manufacturing, CSC greases deliver, at the core of the technology, industrial formulated grease performance with the compliance of an H1 lubricant. A potential challenging regulatory situation has become a significant opportunity to push our grease performance to the next level of thermal and oxidative performance for longer life CSC greases for food manufacturing applications. This presentation will review the strengths of CSC grease in food grade applications with focus on current developments.

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2:30 pm – 3:00 pm

3909050: The Lubrizol Corporation – Redefining Long Drain Hydraulic Fluids

Shubhamita Basu, The Lubrizol Corporation, Wickliffe, OH

Hydraulic fluids used in modern equipment are expected to withstand severe operating environments while protecting the hydraulic system components and preventing unforeseen downtime. In addition, the oil drain intervals (ODIs) are expected to be longer than ever to increase productivity and uptime while reducing waste and improving sustainability. However, there is no standard way to define long drain hydraulic fluids. TOST lifetime (ASTM D943 test), often used as an indicator of long ODI, is not correlated to real-world service life. In this talk, we propose an alternate way to define long drain hydraulic fluids that can provide a more comprehensive prediction of longer fluid life.

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

4:00 pm – 4:30 pm

3909121: ExxonMobil – EHC 340 MAX™: Elevating Extra Heavy Base Stocks

Bob Duggal, ExxonMobil Technology & Engineering Company, Spring, TX

ExxonMobil has previously announced the introduction of a unique high-viscosity Group II clear and bright base stock – EHC 340 MAX™ – at a large scale, scheduled for startup in 2025. EHC 340 MAX™ will be available globally. EHC 340 MAX™ complements the viscosity range of the existing EHC™ slate with a base stock that is comparable in viscosity to Group I bright stock but allows customers to blend a wide range of high viscosity finished lubricants where traditional Group I base stocks use is limited. The new product is suitable for lubricants that require extra high viscosity, low temperature performance, high oxidation stability, high viscosity index, and a high flashpoint, which is critical for high temperature applications. Intended applications include gas engine oils, marine lubricants, greases, engine oils, industrial oils, and gear oils. In this discussion, we will review the application breadth and performance benefits of this innovative product in key lubricant applications.

4:30 pm – 5:00 pm

3908135: IMCD – A Sustainable Solution for an Evolving World – Esters as Base Oils and Components to Design a More Innovative Future

Vincenzo Aruta, John O'Keefe, IMCD GROUP, Milan, Italy

In the changing world of lubrication, the word "innovation" is closely linked to the environment. When it comes to defining sustainable lubricants, there is no simple, global definition or standard; the terms "bio," "sustainable" and "renewable" are used interchangeably, even though they have different and sometimes interconnected meanings. The ability to design extremely versatile but sustainable molecules is now synonymous with innovation. The ester family has a key role to play, both as base oils and components. Natural esters or triglycerides offer good lubricity, excellent viscosity index, and beneficial environmental and sustainable aspects. Synthetic esters, in contrast, offer higher oxidative and hydrolytic stability and other positive attributes. The choice of ester is important, with the levels of double-bond saturation offering different performance aspects to support the desired result. IMCD explains the options available when considering the use of esters in your lubricant formulation.

5:00 pm – 5:30 pm

3910814: OQ Chemicals – Synergistic Effects of a Blend of Polyalphaolefin and Polyol Ester for Potential High-Performance Lubricants in Electric Vehicles

Kyle Gross, OQ Chemicals Corporation, Bay City, TX

A blend of Synfluid® Polyalphaolefin 2 cSt (PAO-2) and Oxlube® L7-NPG shows beneficial effects for a future driveline lubricant application in electric vehicles (EVs). The addition of Polyol Esters (POEs) to PAOs shows an improvement in thermal and dielectric properties. These blends provide synergistic effects on properties like flash point, pour point, and kinematic viscosity resulting in greater low and high temperature performance. Additionally, the 80/20 PAO/POE blend displays better thermal properties versus PAO-2, with a potential for efficient cooling of electric motors. Furthermore, the dielectric properties of this blend are advantageous for electric vehicles, showing a higher breakdown voltage in comparison to PAO-2. Overall, the 80/20 PAO/POE blend offers a range of benefits for use in EVs, in addition to its well-known additive solubility, lubricity and seal compatibility, making it a promising solution for the next generation of high-performance e-driveline fluids.

5:30 pm – 6:00 pm

3905306: Richful Lube Additive Company Development Progress by 2022

Yida Tao, Richful Lube Additive, Xinxiang, Henan, China

Richful entered the lubricant additive industry in 2003 by commercializing a calcium alkyl phenol sulfonate detergent with remarkable performance. In the following years, Richful had enriched their product portfolio by making several key components. From the early 2010s, Richful put in the effort to develop DI packages demanded by the market. For the last decade, several mature DI products have been launched because of continuous investing in DI formulation researching and running qualification programs through worldwide anthropized test institutions. At the same time, Richful has been recognized by the global market with their service and reliable supply despite the global logistic constraints in recent years.

Session 2I | 104A

Electric Vehicles II

Session Chair: William Anderson, Afton Chemical Corporation, Richmond, VA

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

1:30 pm – 2:00 pm

3833969: Various Copper Corrosion Test Methods for Electric Drivetrain Fluid Evaluations

Yungwan Kwak, Christopher Cleveland, Afton Chemical Corporation, Richmond, VA

Many OEMs have accelerated vehicle electrification in recent years to meet global regulations on pollutants, greenhouse emissions, and to increase fuel economy. A key component of the electric drive unit is an electric motor constructed with a significant amount of magnet wire. Copper metals can also be found in various other parts, such as (but not limited to); solenoids, printed circuit boards (PCBs), solder materials, and connectors. Poor protection against copper corrosion could lead to a failure with the motor and/or power electronics. Therefore, it's critical for a fluid to provide corrosion protection. This presentation discusses various copper corrosion tests for EV fluid evaluation. This includes 1.)

brief introduction of ASTM D130 copper corrosion test and its variations, 2.) copper wire corrosion test with PCB, 3.) copper corrosion test with PCB under electrification, 4.) stacked PCB test for conductive deposit tests, 5.) varnish coated copper corrosion test, and more.

2:00 pm – 2:30 pm

3808209: Next-Generation Tribology Component Technologies for E-Fluids

Christelle Chretien, Solvay, Bristol, PA

E-driveline units are mechanically less complex than traditional transmissions. However, they run under harsher conditions: higher speed, torque, higher temperatures, presence of electricity and new materials. Based on these new requirements, the core formulation of an E-fluid should be constituted of a robust tribology system made of anti-wear/extreme pressure agents and friction modifiers. This presentation will show how developmental tribology additives can bring solutions to these new EV requirements.

2:30 pm – 3:00 pm

3823603: Technologies for Improving the Performance of E-axle Fluids

Mari Iino, Shigeki Matsui, Shingo Matsuki, Akira Tada, Toshitaka Nakamura, ENEOS Corporation, Yokohama, Kanagawa, Japan

The lubricating performance of reduction gears and the cooling performance of motors are required for E-axle fluids. Here, low viscosity is effective for improving gear efficiency and motor cooling performance. However, extreme low viscosity leads to deterioration of fatigue life of the bearings and anti-seizure performance of the gears. Reducing the traction coefficient is effective to improve fatigue life. We examined a high-performance base oil with a low traction coefficient. Extreme pressure agents (EPs) are essential for anti-seizure performance, but they deteriorate insulation performance. The development of EPs with high anti-seizure performance while maintaining insulation was carried out. By applying a high-performance base oil and developed EPs, highly effective gear durability and deterioration prevention were confirmed on EV units and an electric vehicle (EV) test. A significant improvement on an E-axle efficiency test and an EV electric consumption test were also observed.

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

4:00 pm – 4:30 pm

3835030: Performance Characteristics of Some EV Drivetrain Lubricants Under Electrified Condition

Ali Erdemir, Pushkar Deshpande, Leonardo Farfan-Cabrera, Seungjoo Lee, Texas A&M University, College Station, TX; William Anderson, Yungwan Kwak, Afton Chemical Corporation, Richmond, VA

Despite intensified efforts, there remain many challenges with respect to the lubrication performance of new electro-fluids (e-fluids) for use in future electric vehicles. Here, we compare the friction and wear performance of some e-fluids under electrified test conditions. Using surface and structure analytical techniques, we determine significant differences in the physical and chemical nature of the boundary films that formed under electrified test conditions. Specifically, boundary films formed under electrified conditions consisted primarily of harder forms of iron oxides which triggered severe abrasive wear. In some cases, the level of oxidation was not as severe and hence these e-fluids were able to provide better protection against wear. It looks that in EV drivetrains, electrical and tribological issues are intertwined in a very complex manner and hence the future fluid solutions must keep in mind not only the tribological but also the electrical realities of these vehicles.

4:30 pm – 5:00 pm

3839909: Comparison of Electric Drive Unit Lubricant Aeration Under High Speed Operation

Cole Frazier, Nolan Erickson, Cole Hudson, Southwest Research Institute, San Antonio, TX

Compared to internal combustion engines, motors used in electric vehicles typically spin at much higher speeds. Electric drive lubricants must perform in these high-speed environments – protecting gear interfaces and cooling components. The degree to which air is entrained in lubricant as it functions around rotating components at 15,000+ RPM is currently not well quantified. Air entrainment in the lubricant can cause poor heat transfer and reduce wear protection, which highlights the importance of measuring aeration in a representative way. At STLE's 2022 conference, SwRI presented aeration data collected on a drive unit with a 2-stage architecture. To further this effort to other drive units, SwRI repeated the experiment on a new drive unit with different speed characteristics, but similar two-stage gear architecture. In this presentation, SwRI will present how aeration results collected under the same test methodology compare for different drive units with similar architecture.

5:00 pm – 5:30 pm

3854042: Electrically Conductive Nanoparticle Additives for Greases Used in Electric Vehicles and Other Applications

Robert Jackson, Samuel Bond, German Mills, Auburn University, Auburn, AL

Electrified mechanical contacts and electrical connectors are an integral part of electric vehicles, and their reliable performance is essential. This has become increasingly important for electric vehicles where leakage current could potentially load the motor bearings and many other contacts in the drive system. It has been shown that this current can rapidly accelerate surface degradation via small scale arcing across lubricating films. Recent work suggests that metallic nanoparticle additives in lubricants could be used to improve the performance of these contacts. This work investigates silver nanoparticle enhanced greases under electro-tribological loads and in comparison to base and fully-formulated oils. The results suggest that the nanoparticles do enhance performance by reducing pitting from arcing, although oils with other additives also appear to have an enhanced performance.

5:30 pm – 6:00 pm

3810965: Sustainable E-Fluid Concepts for Electric Motor Cooling and Gearbox Lubrication

Christopher Dobrowolski, Shell Global Solutions, Hamburg, Germany

With the automotive world looking to quickly electrify, lubricant manufacturers are designing fluids that can best protect those highly integrated electric powertrains. E-motor friendly and efficient lubricant solutions are lower in sulfur and have lower viscosity. The next challenge is to provide lower CO_2 intensive products to decarbonize not only emissions but also the actual components used for producing and running cars, like the lubricant. In order to balance the technical properties and requirements with available and more sustainable components and base oils, Shell has generated a study to assess key aspects of those next generation formulations for transmission fluids. The study aims to generate and assess data for understanding performance aspects like efficiency and the potential to formulate low viscous fluid solutions, oxidation stability, material compatibility and CO_2 footprint.

Session 2K | 201A

Metalworking Fluids II

Session Chair: Jill Myers, The Timken Company, North Canton, OH

Session Vice Chair: Jeffrey Mackey, Advanced Chemical Concepts, Inc., Carmel, IN

1:30 pm – 2:00 pm

3802879: ASTM Standards Addressing Metalworking Fluid Health and Safety Issues

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

ASTM Subcommittee E34.50 on Standards addressing metalworking fluid health and safety issues was Chartered in 1992. The subcommittee's initial focus was to provide usable guidance that would help metalworking fluid end-users to reduce health risks associated with inhalation, skin-contact, or ingestion exposures. Over the course of the past 30 years, E34.0 has developed fourteen new standards and has two more in progress. The subcommittee's standards address metalworking fluid exposure control, test protocols for microbiological contaminants, and guides for testing metalworking fluid properties not related to performance. This presentation will provide an overview of E34.50's standards and their relevance to industry stakeholders.

2:00 pm – 2:30 pm

3809305: The Study of Novel Calcium Overbased Sulfonates Used for Rust Preventives

James Jianjun Wei, Wayne Mackwood, LANXESS, Toronto, Ontario, Canada

Historically barium sulfonate based rust preventives have been considered superior alkali metal sulfonates for corrosion inhibition. However, with the increasingly stringent government regulations for environmental and health protection, the use of barium sulfonates has been significantly decreased due to the toxic nature of barium and high cost of its waste disposal. In this work, we have examined the use of calcium sulfonates, and in particular their soap composition as well as the optimum TBN/Soap ratio needed to achieve excellent corrosion inhibition. The focus was on the potential replacement for the industry standard 70 TBN overbased barium sulfonate, but comparisons were also made with neutral Ba sulfonate. Several standard corrosion test methods were used to evaluate and compare their performances. The test results demonstrate that different calcium sulfonate containing products can offer much better rust inhibition characteristics than a 70 TBN barium sulfonate.

2:30 pm – 3:00 pm

3810790: Case Study of Monitor and Correction of Field Coolant Emulsions by Light Scattering Instrument and Good Correction Method

Yixing Philip Zhao, Quaker Houghton, Conshohocken, PA

An important aspect of the sustainability for soluble metalworking fluids is sump longevity. Our formulators put a lot of affords to develop robust MWF products with good lubricity, excellent emulsion stability, good biostability, environmentally friendly and good resistance to various contaminations such as tramp oils. However, if people do not maintain MWF in the field, any good product can go bad. Fouled fluids cause health/safety issues and productivity loss due to coolant separation by tramp oils or other contaminations. This paper presents a case study of monitoring field coolant stability by a light scattering instrument which detects small oil droplet changes and predicts emulsion stability much earlier than our eyesight and other traditional test methods. The talk will focus on the monitor of tramp oil effects on emulsion stability. This method helped greatly, along with a good correction process, a recovery process with a fouled coolant fluid due to tramp oil in a large sump.

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

4:00 pm – 4:30 pm

3810961: Extreme Pressure Sulfurized Additives for Metalworking Fluid Ester-Based Formulation

Guillaume Notheaux, SEQENS, Porcheville, France

Sustainability is becoming a key factor to consider when developing a lubricant. Thus, metalworking fluid formulators are looking for alternative base oils to meet environmental and performance requirements especially for extreme pressure additives. Using esters as base oils helps to face this new challenge, but the related consequence is often the copper corrosion performance. In this context, mastering the sulfurization process is the key parameter to fine tune the right extreme pressure sulfur additives. Distribution of the sulfur bridge length, concept of labile sulfur, impact on active sulfur and the thermogravimetric analysis curves, will be the tools exposed to propose an extreme pressure additive, sulfurized compounds and non-copper corrosive in an ester base oil.

4:30 pm – 5:00 pm

3811719: Sustainability Beyond Carbon Footprint

Michael Stapels, Kao Chemicals GmbH, Emmerich, Germany

Metalworking manufacturers and end-users face numerous new regulations and sustainability trends. While ideal performance and price competitiveness has been the golden standard of success for decades, additional factors such as the product carbon footprint and renewable carbon content are recent parameters to be considered. To get the holistic picture, it is important in pondering on one side the renewability, multifunctionality, efficiency and hazard level of additives and on the other side the performance, fluid longevity and hazard level of works of a fluid until its waste disposal and recycling. It is indispensable to study the complete metalworking fluid life cycle to ensure a responsible use of our resources. A reasonable, measurable, and comparable approach is desirable on our way towards improvement of sustainability in metalworking and in the prevention of misunderstood and misleading product positionings.

5:00 pm – 5:30 pm

3808450: Chlorine Use in Stainless Steel Tube Manufacturing

James Brooks, RichardsApex Inc., Philadelphia, PA

Stainless steel tubing is critical for nuclear, medical, aerospace, military, and countless other applications. These high strength alloy tubes are nearly universally formed using chlorinated lubricants. Therefore, when regulatory agencies increase pressure on the use of chlorinated paraffin, the stainless-steel tube industry bears a significant burden. This presentation attempts to provide an impartial explanation for the purpose of chlorine in the stainless-steel tube industry, a legitimate strategy for phasing it out, and the consequences of those actions.

5:30 pm – 6:00 pm

3833657: Analysis of the Tool Margin-Wall Contact During MQL Deep-Hole Drilling of AISI 4140 Steel Through a Surface Integrity Study

Peter Neal, University of Sheffield, Sheffield, South Yorkshire, United Kingdom

Many automotive manufacturers have adopted Minimum Quantity Lubrication (MQL) to reduce the environmental impact and cost of their machining operations. There is limited understanding of the influence of

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this lubrication type on the quality of the machined surface, particularly with regards to high strength materials. In this study, MQL and flood coolant methods are compared in high speed deep-hole drilling of AISI 4140 martensitic steel using optimized double-margin tooling. A regression model is generated for cutting forces and surface roughness and microstructural evolution is examined through application of XRD and EBSD techniques. High temperature compression testing is also conducted to characterize the change in flow behavior of the material with temperature and strain. It is proposed that the tool margin-wall contact is a key contributor to surface integrity and warrants further investigation.

Session 2M | 202A

Herbert S. Cheng Memorial Symposium

Challenges in Lubrication and Tribology Modeling II

Session Chair: Q. Jane Wang, Northwestern University, Evanston, IL

Session Vice Chair: TBD

1:30 pm – 2:00 pm

3887538: Frontiers of Surface Engineering and ribology for a Green and Sustainable Future

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

Friction and wear collectively consume nearly a quarter of the world's energy output and causes more than 8 gigatons of CO_2 emissions annually. With increasing mobility and industrial activities, there is no doubt that adverse impact of friction and wear on energy and environment will continue to intensify in coming years. Accordingly, there is an urgent need for more efficient, green, and long-lasting tribological solutions that can help reverse such an unsustainable trend. In recent years, great strides have been made in the design of new materials and surface engineering technologies that can literally vanish friction and wear. In this presentation, a comprehensive overview of recent advances in friction and wear control technologies is provided especially within the framework of advanced functional coatings. Special emphasis is placed on those discoveries that can save energy, improve durability, and thus protect the environment for a sustainable future.

2:00 pm – 2:30 pm

3857547: Fluid/Solid Interactions in Lubrication – Recent Developments and Future Perspectives

Daniele Dini, Imperial College London, London, United Kingdom

Fluid-solid interactions are ubiquitous in lubricated systems and control the majority of the processes in tribological contacts. Recent advances in computational methods and resources have fueled numerical studies to explore novel techniques for solving a plethora of problems involving lubrication across the scales with increased degree of sophistication. Applications vary from the solution of automotive systems to soft tissue lubrication, biomedical devices, triboelectric nanogenerators etc. The present contribution provides an overview of the recent methodological advances, some inspired by the work of Prof. Herbert Cheng, to tackle a multitude of complex lubrication problems. Various cases are presented and compared to results generated by other existing solvers and other experimental data to validate the proposed frameworks. The talk will conclude with a perspective that looks at the outstanding issues in this field and proposes a way forward to tackle at least some of them.

2:30 pm – 3:00 pm

3833491: Unsteady Multiscale Simulation of Lubricated Rough Surfaces

Noel Brunetiere, Arthur Francisco, Institut Pprime, Futuroscope Chasseneuil Cedex, France

When dealing with lubrication of rough surfaces, averaging methods such as homogenization or flow factors suffer from a lack of accuracy when the surfaces are nominally parallel while deterministic approaches are limited to the simulation of small areas. It is now known that multiscale methods can overcome both limitations. A fine mesh named bottom scale mesh is used to obtain an accurate pressure distribution. To reduce computation burden, this mesh is split in several sub-domains connected through a top scale mesh ensuring global mass conservation. In many lubrication problems, the situation is transient, and it is important to extent these multiscale methods to time-varying problem. In this work, the development of a transient multiscale approach is presented. Several examples of application such as squeeze problems and lubrication of two rough surfaces are presented.

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

4:00 pm – 4:30 pm

3833864: Explicit Flow-Continuity-Enforced Elastohydrodynamic Lubrication Analyses with a Mass Conservation Algorithm

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

Starvation may occur in a lubricated interface globally and locally around asperities, and cavitation may appear around divergent spaces at different scales. Various modified Reynolds equations with mass conservation algorithms have been developed to deal with starvation/cavitation. However, numerical flow-continuity examinations have been neglected in most lubrication analyses, and actual levels of flow-continuity of numerical solutions have not been demonstrated. This work explicitly evaluates flow values, along the velocity direction, passing a single mesh width as well as the total width of a computation domain. This work reveals the importance of low-pressure regions (dimensionless pressure < 1%) to flow continuity, and film-reformation boundaries of starvation/cavitation zones. Hybrid relaxation factors are utilized with the unity assigned to the low-pressure regions. This numerical solver is further applied to study the lubrication of dimpled surfaces.

4:30 pm – 5:00 pm

3854905: Strength from Weakness: Dynamicity in Biotribological Interfaces

W. Gregory Sawyer, Research Institute of Industrial Science and Technology, Gainesville, FL

Dynamic hydrogel networks are a central feature of biological systems – soft, living, active matter. For example, wet epithelial surfaces form the largest interface in biological systems and are protected by the continuous production and maintenance a functionally graded dynamic aqueous gel, mucous. These gels are formed from a wide array of heavily glycosylated proteins (mucins and glycoproteins) and use "flickering" supramolecular and dynamic-covalent intermolecular interactions as crosslinkers. Mucous is responsible for key cell-protective and barrier functions including hydration, lubrication, and solid contaminant removal.

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5:00 pm – 5:30 pm

3854202: Lubricant-Chemistry Kinetic Model of Boundary Lubrication by Oil Additives Using SOL, QM+MD, and Machine Learning

Zhijiang (Justin) Ye, Miami University, Oxford, OH; Chao Zhang, Shanghai University, Shanghai, China

Structure oriented lumping approach organizes a set of certain of structural features or groups for any tribochemical molecule. Based on the molecular lump of participating materials and reaction rules, the boundary lubrication model can describe the processes of complex tribochemical reaction on molecular level and predict antiwear film formation and removal. Both hybrid quantum chemical molecular dynamics simulations and experiments are conducted to generate high-throughput synthetic data for machine learning training, validation, testing and prediction. QM Materials Studio DMol3software, MD LAMMPS with ReaxFF force field, and deep learning are exploited to understand the causality between the microstructural features and the multiscale properties. Application of all rules to all components of the mixture by using each reaction rule as the outer loop and each structure vector group as the inner loop generates the entire reaction network representing the chemistry of the process.

Session 2N | 202B

Nanotribology II

Session Chair: Mehmet Baykara, University of California, Merced, Merced, CA

Session Vice Chair: TBD

1:30 pm – 2:30 pm

3847661: Invited Talk – The Nucleation, Growth, and Adhesion of Water Bridges in Sliding Nano-Contacts

Bart Weber, Felix Cassin, Rachid Hahury, Thibault Lancon, Steve Franklin, Advanced Research Center for Nanolithography, Amsterdam, Netherlands

We provide experimental observations of the nucleation and growth of water capillary bridges in nanometer gaps between a laterally moving Atomic Force Microscope (AFM) probe and a smooth silicon wafer. We find rising nucleation rates with increasing lateral velocity and a smaller separation gap. The interplay between nucleation rate and lateral velocity is attributed to the entrainment of water molecules into the gap by the combination of lateral motion and collisions of the water molecules with the surfaces of the interface. The capillary volume of the full-grown water bridge increases with distance between the two surfaces and can be limited by lateral shearing at high velocities. Our experimental results demonstrate a novel method to study in situ how water diffusion and transport impacts dynamic interfaces in the nanoscale, ultimately leading to friction and adhesion forces at the macroscale.

2:30 pm – 3:00 pm

3831137: Molecular Dynamics Investigation of the Friction Mechanism in a Humid Nanocontact

Igor Stankovic, Institute of Physics Belgrade, Zemun, Belgrade, Serbia; Olivier Noel, Le Mans Universite, Le Mans, France; Pierre-Emmanuel Mazeran, Sorbonne Universites, Universite de Technologie de Compiegne, Compiegne, France

Water molecules' role in the friction behavior mechanism of a hydrophobic and hydrophilic nanocontact is still poorly understood. It is commonly accepted that the water molecules are squeezed out of the contact of hydrophobic surfaces or pulled between hydrophilic surfaces. We demonstrate that an intuitive paradigm needs to be refined using circular mode atomic force microscopy [1,2] experiments coupled with molecular dynamics simulations. As a result, we present a new mechanism considering a capillary bridge produced within the sliding nanocontact by the accumulation of water adsorbed on the substrate [3]. Then we show how a full slip regime of the capillary bridge sliding on the substrate perfectly explains the observed tribological behaviors.

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

4:00 pm – 4:30 pm

3832988: Using Friction Hysteresis of 2D Materials to Uncover Properties of the Substrate

Philip Egberts, Chaochen Xu, University of Calgary, Calgary, Alberta, Canada; Zhijiang (Justin) Ye, Miami University, Oxford, OH

Two-dimensional (2D) materials exhibit physical properties that promise to significantly improve both dry and oil-based lubricants. While many studies have shown the impact of 2D materials on reducing friction, a model that describes the factors affecting their lubricating properties has not yet been developed. Here, we re-examine two factors, including substrate adhesion and water intercalation, and observe their impact with atomic force microscopy experiments on the stiffness of the 2D material and its lubrication properties to better link friction with physical parameters of the lubricant and substrate. Further, mechanistic insight into the sliding contact was developed using molecular dynamics simulations that replicated the experimental measurements. In these simulations, the substrate energy, surface roughness, and intercalated water showed to significantly impact the contact area of the sliding interface between an asperity and the 2D material.

4:30 pm – 5:00 pm

3833606: MXene Nanosheets Exhibiting Layer-Dependent Friction Properties

Eui-Sung Yoon, Prashant Pendyala, Seon Joon Kim, Korea Institute of Science and Technology, Seoul, Republic of Korea

MXenes are a new class of 2D solid-state-friction materials with atomically thin multi-layered structures. The layers of MXenes were shown to exhibit large inter-layer binding due to the presence of a large number of functional groups. How such large inter-layer binding affects the nanoscale friction was not understood. We experimentally investigated the nanoscale frictional properties of layers of MXene nanosheets using friction force microscopy. We showed that the friction of MXenes reduced as the number of layers increased. Using the puckering mechanism of friction, we showed that out-of-plane mechanical properties of MXene layers primarily influence the nanoscale friction behavior of MXenes. Furthermore, contrary to the prevalent understanding, we showed that higher inter-layer binding in MXenes helps the layer-dependent behavior enhancing the overall frictional performance. Our study critically enables further exploration of MXenes as nanoscale solid-state lubricants.

5:00 pm – 5:30 pm

3813225: Nanoscale Friction of High Entropy Alloy Sulfide Thin Films in Comparison with Molybdenum Disulfide

Gokay Adabasi, Joshua Ancheta, Emmanuel Maldonado, Mehmet Ozdogan, Mehmet Baykara, University of California, Merced, Merced, CA; Aditya Deshpande, Koichi Tanaka, University of California, Los Angeles, Los Angeles, CA; Suneel Kodambaka, Virginia Tech, Blacksburg, VA

The outstanding wear and corrosion resistance exhibited by high entropy alloys (HEA) make them ideal candidates for coatings in mechanical systems. On the other hand, the question of whether HEA thin films will also act as solid lubricants remains open. Here, we perform

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nanoscale friction measurements on HEA-sulfide ((VNbTaMoW)S_2) thin films via AFM. Results reveal 1.) the influence of deposition time on film morphology and 2.) the presence of isolated areas of low friction on film surfaces. We compare the friction results on (HEA)S2 thin films with those on sputter-deposited molybdenum disulfide (MoS_2) and find that they are on the same order. Finally, variable temperature X-ray diffraction (XRD), performed up to 800°C, reveals that (HEA)S2 films exhibit improved oxidation resistance when compared with MoS_2 films. Combined, the results show that (HEA)S_2 thin films exhibit remarkable potential as environmentally-resistant solid lubricant coatings.

Session 2O | 202C

AI and Machine Learning II

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

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

1:30 pm – 2:00 pm

3833889: A New Perspective on Tribological Data via Advanced Statistics and Artificial Intelligence

Nicole Doerr, Georg Vorlaufer, Josef Prost, AC2T research GmbH, Wiener Neustadt, Austria

Recent developments in data science, in particular methods from machine learning (ML) and artificial intelligence (AI), promise new opportunities in gaining detailed knowledge about processes, e.g., operation of machines. In combination with large data sets ("big data"), computers can be trained to classify the current health status of machine elements, e.g., bearings, gears, and predict the remaining useful life based on on-line sensor data. At AC2T research GmbH, methods of data science are used to, e.g., identify friction regimes in tribometer experiments, correlate chemical information from different lubricants, or detect changes in the wear behavior of test specimen. Therefore, data is usually generated by on-line sensors or by ex-post analytical devices such as FTIR spectrometer. Some recent examples from our institute including the classification of operating conditions of self-lubricating bearings and the correlation of oil degradation and wear behavior are discussed.

2:00 pm – 2:30 pm

3833776: Chemometric and FTIR Spectroscopy for Determination of Physicochemical Properties of Engine Oil

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

Lubrication oil is particularly important to maintain the optimum performance and reliability of a combustion engine. Currently, routine tests are carried out using ASTM procedures, which can be time-consuming and require a large amount of lubricant sample and solvent. Chemometrics offers a wide range of multivariate analysis methods that enable a more thorough use of test data. In this study, Fourier-transformed infrared spectroscopy together with prediction models such as partial least square (PLS) and PLS-DA (discriminant analysis) helped to create a model for the prediction of Total Base Number (TBN) and chemical composition (Paraffin, Naphthene, and Aromatic (PNA) content) of the engine oil samples for oils with a viscosity range between 70-150 cSt. A strong correlation between values of TBN by the FTIR-PLS model and ASTM D2896 was determined. Also, the correlation between PNA content predicted by FTIR – PLS method and ASTM D3238 was acceptable.

2:30 pm – 3:00 pm

3831643: Digital Advancements in Tribofilm Analysis

Oluwaseyi Ogunsola, Shell Global Solutions (US) Inc., Houston, TX; Sanket Deshmukh, Rishu Saxena, Shell India Markets Pvt Ltd., Bangalore, India; Grace Uche, Shell Information Technology International Inc., Houston, TX; Gary Pollock, Altin Veliu, Shell Global Solutions (UK), London, United Kingdom

One of the key functions of a lubricant is to form a protective film that reduces friction and wear between moving parts. This protective film is called the tribofilm. Mini traction machine is an experimental setup which enables acquisition of tribofilm images in-situ. By analyzing these tribofilm images, valuable information and statistics regarding the film thickness and uniformity can be extracted, thereby determining the protective capability of a lubricant. Currently, tribofilm image analysis is a manual workflow which can be a subjective and time-consuming process. Our presentation will feature in-depth explanation on how we digitally automated the tribofilm image analysis workflow to extract objective metrics of lubricant tribofilm/friction performance. We further highlight the use of AI/ML algorithms to assist lubricant innovation and product development.

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

4:00 pm – 4:30 pm

3840701: Using Machine Learning Algorithms to Relate the Surface Topography of As-Built Surfaces to Additive Manufacturing Process Parameters

Bart Raeymaekers, Virginia Tech, Blacksburg, VA

Metal additive manufacturing (AM) enables rapid fabrication of structural parts with complex geometry. Recent research demonstrates the importance of the relationship between the surface topography of metal AM parts and its mechanical properties because surface defects and porosity relate to the fatigue life of the part. Furthermore, costly post-processing of as-built AM surfaces drives the need to manufacture tailored as-built surface topography. In this presentation, we discuss deriving data-driven models from surface topography data and laser-powder bed fusion (L-PBF) process parameters using machine learning (ML) algorithms. We quantify the prediction accuracy of models derived from different ML algorithms and show that decision tree and artificial neural network algorithms result in the highest prediction accuracy. This research is relevant to transitioning metal AM from rapid prototyping to producing functional end-use parts, by reducing the need for costly post-processing.

4:30 pm – 5:00 pm

3834513: How to Get to Big Data in Tribology? A Hands-on Example

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

Applying machine learning and active research data management in tribology have been slower to adopt than in other scientific communities. Arguably, the main hurdle is also what makes tribology a distinctly exciting field – its extreme multidisciplinarity. Public funding agencies have been clear in their policy commitments: scientists need to treat data as a valuable societal resource and not just as a path to a publication. Industrial R&D departments have also realized the long-term value of "good data". In this presentation, we will exemplify the specific framework of solutions which our group has been developing for over 3 years. The two core principles fundamental to the framework are community engagement and FAIR data (Findable, Accessible, Interoperable, Reusable). With this framework we aim to link tribological results to other already digitalized domains so that we can apply scalable artificial intelligence techniques for better-controlled friction, wear, and lubrication systems.

5:00 pm – 6:00 pm | Panel Discussion