TIME	SESSION 1A Materials Tribology I Legends A	SESSION 1B Lubrication Fundamentals I Legends B	SESSION 1C Engine and Drivetrain I Legends C
8 – 8:30 am	Tribology of Polybenzimidazole-Polyetheretherketone (PBI-PEEK) Blend, J.Wong, p. 30	Friction Modification Mechanism of Surface Pores, A. Khan, p. 30	Efficiency and Emission of EVs in Comparison to IC Engines: A Life Cycle Analysis, A. Erdemir, p. 31
8:30 – 9 am	Mechanical and Thermal Performance of Inter-penetrating versus Singular Networks of Dynamically Crosslinked Polymers, B. Ahammed, p. 30	Connecting Discontinuous and Continuous Tribological Models, G. Kastane,p. 31	An Insight into E-Mobilit, D. Tomazic, p. 31
9 – 9:30 am	Experimental Investigation into the Combined Effects of Roughness and Stiffness in Soft-Material Adhesion, A. Gujrati, p. 30	On the Surface Lift-Off Transition in Rough Surface EHL Contacts, J. Hansen, p. 31	Automotive Fluids for Electrified Vehicles, S. Halley, p. 31
9:30 –10 am	Experimental Measurements of Roughness-Dependent Adhesion in Hard-Materials Contacts, L. Thimons, p. 30	Novel Insight into Tribology of Carbon Black Soot Particles in Engine Oil, D. Halenahally Veeregowda, p. 31	Open Discussion
10 – 10:30 am	**Break**	**Break**	**Break**

TIME	SESSION 2A Materials Tribology II Legends A	SESSION 2B Lubrication Fundamentals II Legends B	SESSION 2C Engine and Drivetrain II Legends C
1:30 – 2 pm	Self-Organization in Materials Subjected to Severe Plastic Deformation: Relevance and Application to Wear Resistance of Metallic Alloys, P. Bellon, p. 40	Fluid Properties and Testing Parameters that Impact Lubricant Shear Stability, S. Sivakova, p. 41	Challenges and Opportunities with Lubricants for HEV/EV Vehicles, A. Gangopadhyay, p. 42
2 – 2:30 pm		Hyperbranched Polymers for Shear Stable Viscosity Index Improvers, L. Cosimbescu, p. 41	New Challenges for Tribologists and Lubrication Engineers From Vehicle Electrification, C. Shamie, p. 42
2:30 – 3 pm	Adhesion, Self-Welding and Static Friction Coefficient of Ni Alloys at Elevated Temperature, Md S. Rahman, p. 40	EHD Friction at Very High Pressure, H. Spikes, p. 41	Chevrolet Bolt Fluid Test Development, P. Lee, p. 42
3 – 4 pm	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**
4 – 4:30 pm	Understanding the Role of Protective Metal Oxides in Nanoscale Tribocorrosion, A. Lin, p. 40	Development of a Refined Full Cavitation Model Considering Vapor and Air, Y. Wang, p. 41	Newly Developed Lubricants for the Challenges of Electric Drivetrains, T. Bender, p. 42
4:30 – 5 pm	Evaluation of Friction Performance and Wear Reduction of Boronized Steels, B. Wong, p. 40	Multi-Scale Modeling of the Lubrication Between Rough Surfaces, N. Brunetiere, p. 41	Challenges and Outlooks for Transmission Fluids in Electric Vehicles, T. Murr, Shell p. 42
5 – 5:30 pm	Elevated Temperature Nanomechanical and Nanotribological Behaviors of Ni Alloys Surface Oxides: Part I-Experimental Study, Md S. Rahman, p. 40	Tribo-CAS Film with Unprecedented Lubrication and Wear Performance Characteristics, K. Chao, p. 42	Understanding Base Oils and Lubricants for Electric Drivetrain Applications, Y. Kwak, p. 42
5:30 – 6 pm	Elevated Temperature Nanomechanical and Nanotribo-logical Behaviors of Ni Alloys Surface Oxides: Part II – Finite Element Study, S. Salari, p. 40		Open Discussion
6 – 6:30 pm	The Wear Mechanism of Flexspline Materials Regulated by Novel Amorphous/Crystal Oxide Form Evolution on a Frictional Interface, C. Zhang, p. 41		

SESSION 1D Gears I	SESSION 1E Commercial Marketing Forum I	SESSION 1G Wind Turbine Tribology I	
Music Row 1	**Music Row 5**	**Music Row 3**	
Complex Esters – A New Oxidatively Stable Lubricity Additive, K. Duncan, p. 32		Comparison of Ultrasonic Load Measurements on an Operational Wind Turbine Bearing with Those Predicted by Ricardo SABR, B. Clarke, p. 34	**8 – 8:30 am**
Efficiency Testing for Industrial Gearboxes, P. Norris, p. 3	Chevron Phillips Chemical Company's Synfluid® Metallocene Polyalphaolefins (mPAOs) Grease Applications, K. Hope, p. 32	Onsite Condition Monitoring for Offshore Wind Turbine Gearbox Lubricant Based on Colorimetry, K. Kojima, p. 34	**8:30 – 9 am**
A Short-Term Hot Hardness Evaluation of Advanced Aerospace Gear Steels, C. Wassel, p. 32	Dow: Seek Together with Dow!, A. Larson, The Dow Chemical Co., p. 32	Monitoring Load and Lubrication in a Wind Turbine Gearbox Rolling Bearing in the Field, G. Nicholas, p. 34	**9 – 9:30 am**
A New Thermally-Coupled Model for Prediction of Gearbox Power Losses, K. Chakravarthy, p. 32	Functional Products: Cost-Effective Formulating with Functional Products, D. Vargo, p. 32	Characterization of White Etching Areas in Annealed AISI 52100 Processed by High Pressure Torsion Tests, L. Wilches Peña, p. 34	**9:30 –10 am**
Break	**Break**	**Break**	**10 – 10:30 am**

SESSION 2D Gears II	SESSION 2E Commercial Marketing Forum II	SESSION 2G Wind Turbine Tribology II	
Music Row 1	**Music Row 5**	**Music Row 3**	
Softening Mechanisms in Carburized Aerospace Gear Steels during Short Term Exposure to High Temperature, A. Isaacson, p. 44	Songwon Fuel and Lubricant Antioxidants, W. Sawyer, p. 45	Determining Mechanical Properties of White Etching Areas in Carburized 8620 Steel Using Spherical Nanoindentation, J. Leung, p. 46	**1:30 – 2 pm**
Fatigue Calculations for Rough Surface Contacts with Measured and Synthesized Run-In Surface Roughness, H. Asadi, p. 44	ExxonMobil Chemical: Enabling Engine-oil Fuel Economy Through Base Stock Innovation, M. Sheehan, p. 45	Evaluating the Effect of Heat and Surface Treatments on the Formation of White Etching Cracks, B. Gould, p. 46	**2 – 2:30 pm**
Influence of Specific Film Thickness and Surface Roughness Properties on Micropitting Damage, A. Kadiric, p. 44	KAO Chemicals: Emulsifiers to Solubilizers – Spanning from Foam Control, Corrosion Inhibition to Fluid Longevity, S. Wohlfahrt, p. 45	Effect of Lubricant Stability on White Etching Area Evolution Under Severe Dynamic Load Sliding Contact, S. Kodoor, p. 46	**2:30 – 3 pm**
Exhibitor Appreciation Break	**Exhibitor Appreciation Break**	**Exhibitor Appreciation Break**	**3 – 4 pm**
Development of a CEC-Pitting Test Method for Gear Lubricants – Measures to Reduce Scattering and Micropitting Generation in Gear Pitting Tests, C. Illenberger, p. 44	Introducing LANXESS Additin® RC 3502 – A Novel Organic Friction Modifier Designed to Not Only Reduce Friction, But to Deliver Sustained Performance and Antiwear Protection During the Operation of the Lubricant, C. Davison, p. 45	The Role of Sulfur in Limiting Oil Drain Interval in Wind Turbine Main Gearbox Lubricants, M. Blumenfeld, p.48	**4 – 4:30 pm**
A Model for the Formation and Wear of Oxide Tribofilms on Aerospace Steels Under High-Speed Boundary Lubrication Conditions, S. McIntyre, p. 44	ANGUS Chemical Co.: A Natural Resource, M. Lewis, p. 46	Initiation Mechanism of White Etching Cracks Under the Influence of Electric Current, L. Wang, p. 48	**4:30 – 5 pm**
A Model for Gear Life with Surface and Subsurface Survival: Tribological Effects, G. Morales-Espejel, p. 45	Evonik: Novel Cost Saving Synthetic Solutions for the High-Tier Industrial Gear Oil Market, D. Gray, p. 46	Real Scale Test of an Innovative Sensor-Set for Early Risk Detection of White Etching Cracks at a 2.7-MW Wind Turbine Gearbox, F. Harzendorf, p. 48	**5 – 5:30 pm**
Industrial Gear Oil Models Based on High-Viscosity Naphthenic Base Oils and Viscosity Index Improvers, T. Norrby, p. 45	BASF: New Innovations and Developments in BASF Base Stock Technology, J. Lansing, p. 46	Wind Turbine Business Meeting	**5:30 – 6 pm**
Gears Business Meeting			**6 – 6:30 pm**

MONDAY >>

TIME		SESSION 1J Nanotribology I Cumberland 3	SESSION 1K Metalworking Fluids I Cumberland 4
8 – 8:30 am			Computational Study Aimed at Determining the Kinetics of Branched Esters Against Aminolysis, M. Fennimore, p. 36
8:30 – 9 am		Development of Next Generation Coolants Using Nanofluids for Meeting Future Cooling Challenges in EV and Hybrid Vehicle Applications, S. Tung, p. 36	An Innovative Edger Rolling Oil for Steel Plants, P. Bhatnagar, p. 36
9 – 9:30 am		Influence of Copper Oxide and Tungsten Carbide Nanoparticles on Micropitting Under Boundary Lubrication, S. Roy, p. 3	Metalworking Fluids and Chloride Corrosion on Iron Alloys, J. Burke, p. 37
9:30 –10 am		Synergistic Effects Between Silver and Palladium Nanoparticles in Boundary Lubrication, C. Kumara, p. 36	Polyalkylene Glycol as Performance Wear Lubricant Additive on Straight Oil, E. Lima, p. 37
10 – 10:30 am	Break	Break	Break

	SESSION 2H Testing in Soft Tribology Music Row 2	SESSION 2J Nanotribology II Cumberland 3	SESSION 2K Metalworking Fluids II Cumberland 4
1:30 – 2 pm	Relating Sensory Perception to the Tribology of Milk, G. Hully, p. 48	Invited Talk: Molecular Behaviors in Thin Film Lubrication, J. Luo, p. 49	Comprehensive Investigations of Tribology Properties of Metalworking Fluid Chemistries on Multi-Metals, Y.Philip Zhao, p. 50
2 – 2:30 pm	Test Methods with Natural and Artificial Specimen for Biotribological Applications, F. Rummel, p. 48		Go Figure: Using Analytics and Statistics in Metalworking, E. Jon Schnellbacher, p. 50
2:30 – 3 pm	Finger-Pad Gripping: Understanding the Influential Factors, R. Maiti, p. 48	Why Many Liquids Appear to Solidify During Squeeze-Out – Even When They Don't, H. Gao, p. 49	Coolant Emulsion Properties and Field Performance of Metal Removal Fluids, Y. Philip Zhao, p. 50
3 – 4 pm	Exhibitor Appreciation Break	Exhibitor Appreciation Break	Exhibitor Appreciation Break
4 – 4:30 pm		Dynamic Behavior of a Droplet Under Vibration Condition, J. Xu, p. 49	New Innovations in Rust Preventive Sustainability, A. Hadler, p. 50
4:30 – 5 pm		Effect of the Dispersion of Nanoparticle Additives on Their Lubricity for Use in Metalworking Fluids (STLE Early Career Award Winner), S. Beesabathuni, p. 49	Parts Cleaning Fundamentals – Importance of Cleaning and Rinsing, S. Patel, p. 50
5 – 5:30 pm		Interfacial Nano-Mechanics of Friction Modifiers, K. Tamura, p. 49	Metalworking Fluids Business Meeting
5:30 – 6 pm		Study of the Nanoscale Wear Behaviors of Gallium Nitride Using Molecular Dynamics, P. Zhu, p. 49	
6 – 6:30 pm			

SESSION 1L Nonferrous Metals I Cumberland 5	SESSION 1M Fluid Film Bearings I Cumberland 6	
Static Multiple Light Scattering as a Tool to Characterize Stability and Size of Nonferrous Fluids, M. Gould, p. 37	On The Effect of Journal Kinematics on the Force Coefficients of a Test Squeeze Film Damper Supplied With an Air in Oil Mixture, L. San Andrés, p. 38	8 – 8:30 am
Friction Reduction on Anodized Alumina by Impregnating Ashless Fillers, S. Asadauskas, p. 37	On the Static Load Performance of a Large Size, Heavily Loaded Spring Supported Thrust Bearing, R. Koosha, p. 38	8:30 – 9 am
Update on Challenges in Machining Aluminum Alloys, N. Canter, p. 37		9 – 9:30 am
Aluminum Staining: Achieving Performance without Sacrificing Fluid Longevity, C. Cooper, p. 37	The Performance of Small Centre Pivoted PTFE Thrust Bearings in Low to Medium Speed Applications, S. Dixon, p. 38	9:30 –10 am
Break	**Break**	10 – 10:30 am

SESSION 2L Nonferrous Metals II Cumberland 5	SESSION 2M Fluid Film Bearing II Cumberland 6	
Thermal Behavior of Polyformates of Milkweed and Soybean Oils, R. Harry-O'kuru, p. 50	Adapting Fluid Film Bearing Technology for the New Context of Industry 4.0, I. Santos, p. 52	1:30 – 2 pm
Development of Novel and Safer Dt-MPM Antioxidants and MoIn Multifunctional Corrosion Inhibitors for Industrial Applications, A. Cholli, p. 51		2 – 2:30 pm
Effect of Isomerization on the Physical and Tribological Properties of Oleic Acid, G. Biresaw, p. 51	Dynamic Experimental Research of Controllable Squeeze Film Damper, C. Chen, p. 52	2:30 – 3 pm
Exhibitor Appreciation Break	**Exhibitor Appreciation Break**	3 – 4 pm
Scuffing Performance of Brass-Cast Iron Contact Pair in Hydraulic Fluid, M. Cinta Lorenzo Martin, p. 51	A New Test Rig to Meet Industrial Applications: Startup and Performance of a Two Lobe Journal Bearing, J. Bouyer, p. 52	4 – 4:30 pm
Water Soluble/Dispersible Corrosion Inhibitors for Nonferrous Metalworking Fluids, T. Meyers, p. 51	Ultrasonic Oil Film Measurements in Journal Bearings, S. Beamish, p. 52	4:30 – 5 pm
Synthesis and Detailed Characterization of Dimer and Trimer Acid Products Using Acid Zeolite Catalysts, H. Ngo, p. 51	Development of A Gaseous Cavitation Model for Oil-Film Bearing Considering Thermal Effect, A. Ding, p. 52	5 – 5:30 pm
Nonferrous Business Meeting	Experimental Investigations of Oil Pockets Effect on the Lubrication Regime Transition of Journal Bearings, J. Sep, p. 52	5:30 – 6 pm
	Fluid Film Bearings Business Meeting	6 – 6:30 pm

stle Nashville MAY 19-23, 2019

Attendees can download available 2019 STLE Annual Meeting extended abstracts and presentation slides online at www.stle.org/annualmeeting during and after the meeting.

Presentations also are available in the Annual Meeting section of the STLE 365 app (under the Events app section). Be sure to check the STLE website and 365 app for the latest updates on presentations that have been added as they become available.

Session 1A • Legends A

Materials Tribology I

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

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

8 – 8:30 am | Tribology of Polybenzimidazole-Polyetheretherketone (PBI-PEEK) Blend

Janet Wong, Imperial College London, London, United Kingdom

High performance polymers such as polybenzimidazole (PBI) and Polyetheretherketone (PEEK) are used in high temperature tribological applications. In this work, we compare the high temperature tribological performance of PBI, PEEK, PBI-PEEK and carbon-fiber reinforced PBI-PEEK when they are rubbed against steel in unlubricated conditions. In some cases, materials transfer are observed. The process of materials transfer are investigated and possible mechanisms and determining factors are discussed. The properties of transfered materials are characterised and are correlated to tribological performances of these polymers. Our results suggest that heat management at the rubbing contact may play a significant role in the friction and wear experienced by the rubbing pair.

8:30 – 9 am | Mechanical and Thermal Performance of Interpenetrating versus Singular Networks of Dynamically Crosslinked Polymers

Ballal Ahammed, Zhijiang Ye, Nethmi De Alwis, Dominik Konkolewicz, Mehdi Zanjani, Miami University, Oxford, OH

Dynamically crosslinked polymers and composites have received great attention recently due to their unique properties such as self-healing, malleability, and shape memory which are desirable for many tribological applications. However, it is still lack of understanding how the configurational arrangement and the nano/microstructure affect the mechanical, tribological and thermal properties. Here, we report a combined computational (Molecular Dynamics simulations) and experimental study of the mechanical and thermal properties of two main categories of self-healing polymer composites: Interpenetrating Networks (IPNs) and Single Networks (SNs). We evaluate and discuss the configurational details and structural impact on the mechanical and thermal performance. Our results show that IPNs outperform SNs in terms of their mechanical and thermal properties provided that the overall crosslinker densities are the same within the two network types.

9 – 9:30 am | Experimental Investigation into the Combined Effects of Roughness and Stiffness in Soft-Material Adhesion

Abhijeet Gujrati, Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA, Siddhesh Dalvi, Ali Dhinojwala, The University of Akron, Akron, OH

Many theoretical models predict the adhesion of soft materials on hard surfaces, but experimental validations of these models are limited. One reason is that adhesion depends on surface topography and, as most surfaces have multi-scale roughness; experimental roughness parameters vary depending on measurement size and technique. Here we performed adhesion tests using hemispherical lenses of polydimethylsiloxane with varying elastic modulus and polycrystalline diamond surfaces with varying roughness. The surface topography was characterized across length scales to calculate scalar and spectral roughness parameters. Adhesion tests were performed with in-situ optical measurements and results were analyzed using a multi-scale mechanics model. The accuracy of the model depended on how the topography was measured and which assumptions were made. The adhesion data shows the combined effects on adhesion of the surface roughness of the hard material and the elastic modulus of the soft material.

9:30 – 10 am | Experimental Measurements of Roughness-Dependent Adhesion in Hard-Materials Contacts

Luke Thimons, Abhijeet Gujrati, Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA

Adhesion in hard contacts is highly sensitive to roughness. Recent models suggest large-scale adhesion depends on topography across many length scales. In this experimental investigation, micro- to millimeter-scale spheres of alumina and steel were brought into contact with silicon and nanodiamond substrates of varying roughness. The tips and substrates were characterized across multiple length scales using stylus profilometry, AFM, and in some cases, TEM. Adhesion tests were performed and results were analyzed in light of three types of models: single-scale elasticity (e.g. extensions to the model of Greenwood and Williamson); single-scale rigid-body (e.g. the "modified Rumpf" model described by Rabinovich); and multi-scale elasticity (e.g. models by Persson). In all cases, simple scalar roughness parameters failed to capture the observed behavior. Better agreement between model predictions and experiments was achieved using spectral analysis and accounting for multi-scale roughness.

10 – 10:30 am | Break

Session 1B • Legends B

Lubrication Fundamentals I

Session Chair:
Lelia Cosimbescu, Pacific Northwest National Laboratory, Richland, WA

Session Vice Chair:
Jodie Nelson, American Refining Group, Inc, Bradford, PA

8 – 8:30 am | Friction Modification Mechanism of Surface Pores

Arman Khan, Qian Wang, Northwestern University, Evanston, IL, Zhe Li, Yuchuan Liu, Fanghui Shi, General Motors, Detroit, MI

Surface features in the form of dimples, textures, and grooves have been shown to result in friction reduction and the associated mechanisms are well established. Here, we report another mechanism referred to as "artificial slip mechanism" which could be another reason that could explain the low friction capability of these porous surfaces. Comprehensive two-phase computational fluid dynamics (CFD) simulations are conducted to study the dependence of slip performance and cavitation occurring inside the pore on the pore's geometrical features. A transient hydrodynamic model by employing extended Reynold's equation incorporating the slip coefficients derived from the CFD model is also presented. The study is particularly useful for the ring-liner interfaces of an IC engine.

8:30 – 9 am | Connecting Discontinuous and Continuous Tribological Models

Guytri Kastane, Institut Pprime, Montpellier, France, Mathieu Renouf, University of Montpellier, Montpellier, France, Noel Brunetiere, Institut Pprime, Futuroscope Chasseneuil Cedex, France

Modelling mixed lubrication necessitates considering asperities contact and wear as well as fluid flow between rough surfaces. This can be done by using the discrete element method (DEM) for the solids interaction coupled with continuous lubrication models based on the Reynolds equation solutions. One key-point in this approach is the information transfer between the discontinuous and continuous models. In this first part of the coupling, we are interested in the surface topography transfer between the models . An initial rough profile is discretized with a DEM approach. Then the profile is reconstructed from the discrete elements model using different reconstruction techniques. The error between the reconstructed and the initial rough profiles is analysed considering particles size, the surface statistical properties and the reconstruction method. The impact of this error on the solid and fluid models solutions is analyzed to define a reconstruction strategy.

9 – 9:30 am | On the Surface Lift-Off Transition in Rough Surface EHL Contacts

Jonny Hansen, Marcus Björling, Roland Larsson, Luleå University of Technology, Luleå, Sweden

The pumping and churning losses in transmission assemblies are minimized when gears are operated in low viscosity lubricants. Therefore, in order to improve gear efficiency, it is of crucial importance to gain knowledge about the underlying mechanism that governs elastohydrodynamic (EHL) contacts ability to form a separating oil film. This study was set out to explore the necessary requirements for EHL contacts to achieve a state of full film separation. A ball on disc device, arranged for electrical contact resistance (ECR) measurement, was operated under a wide variety of heavily loaded rolling/sliding conditions. Friction and ECR-signal were simultaneously monitored to capture the contact performance until surfaces achieved lift-off by adequate surface modification due to running-in. Special emphasis was set on post-test surface analysis to reveal whether any surface roughness parameter could provide insights in the pre-requisite for surface lift to take place.

9:30 – 10 am | Novel Insight into Tribology of Carbon Black Soot Particles in Engine Oil

Deepak Halenahally Veeregowda, Angela Tortora, Ducom Instruments Europe B.V, Groningen, Groningen, Netherlands

In this study, we have tested the friction and wear response of carbon black (surrogate for engine soot) on different steel surfaces, using the high frequency reciprocating rig and SEM – EDX. Chemisorption of ZDDP on the steel surface prior to friction test resulted in severe wear but the shear-induced chemisorption of ZDDP on the steel surface showed the lowest wear. Changes in wear was related to the concentration of Zn and P, which represents antiwear phosphate film on the surface. Chemisorption of ZDDP encouraged the CB to remove the anti-wear phosphate films, that triggered severe micro-pitting and grooves on the disk surface. However, there were no grooves or micro pitting on steel due to shear-induced chemisorption of ZDDP. As it retained the anti-wear phosphate film against attack by CB. We confirm that preconditioning the steel has showed a profound effect on the soot wear mechanism. It can give important clues in formulating the soot wear resistant lubricants.

10 – 10:30 am | Break

Session 1C • Legends C

Engine and Drivetrain I

Special program on electric vehicles

Session Chair:
Babak Lotfizadehdehkordi, ExxonMobil Chemical Co., Baytown, TX

Session Vice Chair:
Martin Webster, ExxonMobil Research & Engineering, Annandale, NJ

8 – 8:30 am | Efficiency and Emission of EVs in Comparison to IC Engines: A Life Cycle Analysis

Ali Erdemir, Argonne National Laboratory, Lemont, IL, Kenneth Holmberg, VTT Technical Research Centre of Finland, Helsinki, Finland

Electric vehicles (EVs) are considered as the new paradigm for future transportation needs due to their higher efficiency and lower emissions than traditional internal combustion (IC) engines. While energy losses due to rolling friction, aerodynamics, and braking are inherent in EVs as well, thermal and frictional energy losses are reduced substantially in EVs. We provide a side-by-side comparison of the energy consumption in IC vs EV cars. The energy efficiency for the IC case is about 21% while in the case of EVs, it could be 3.6 times higher (or about 77%). The friction-related losses excluding braking and rolling friction are 16.5% for the IC and only 6% for the EV car. We also carried out lifecycle analyses including not only the tank-to-wheel (mostly related to driving the vehicle), but also the well-to-tank plus the manufacturing, maintenance, and recycling stages thus providing a global picture comparing the overall efficiency and environmental impacts of both cases.

8:30 – 9 am | An Insight into E-Mobility

Dean Tomazic, FEV North America Inc., Auburn Hills, MI

Besides its zero emissions advantage, BEV's offer excellent drivability at superior efficiency. In contrast to ICE powertrain emissions and fuel economy challenges, BEV's have to overcome unique design and control challenges as system optimization is targeted over performance based value proposition. Hence, the BEV engineering community is developing novel solutions to optimize thermal management of batteries, E-Motors and power electronics. In this presentation, the authors will provide an insight into ongoing trends in electrified mobility including a deep dive assessment of opportunities and challenges that are ahead of the industry. The presentation will also provide an insight into how the design, controls and calibration are playing a role in BEV powertrain thermal management.

9 – 9:30 am | Automotive Fluids for Electrified Vehicles

Scott Halley, The Lubrizol Corp., Wickliffe, OH

The global focus on vehicle emission and greenhouse gas reductions has created an electrified vehicle spectrum ranging from traditional Internal Combustion Engines (ICE) through to Electric Vehicles; including hybrids, plug-ins, battery electric, and fuel cell powered vehicles. Driveline components and their respective fluids often receive attention as they are the integrators the propulsion system and the wheels. Fluids for these applications need to deliver the proper level of durability with electrical, thermal, and material compatibility properties in mind. Thermal management on electrified vehicles can also present some interesting challenges, particularly for engines and electrical systems. Batteries, for example, operate more efficiently when held within a narrow temperature range, while ICEs on certain electrified vehicles may operate at lower than traditional operating temperatures. Each of these systems can be enhanced using carefully selected fluid technologies.

9:30 – 10 am | Open Discussion

10 – 10:30 am | Break

Monday, May 20 | Technical Sessions

Session 1D • Music Row 1

Gears I

Session Chair:
Jeremy Wagner, Deere & Co,, Denver, IA

Session Vice Chair: Sean McIntyre, Penn State University, Wayne, PA

8 – 8:30 am | Complex Esters – A New Oxidatively Stable Lubricity Additive

Kevin Duncan, Croda, East Yorkshire, United Kingdom

Heavy duty applications such as automotive and industrial gear oils, and MWF's require higher viscosities with additional lubricity additives to cope with severe, hostile environments. Traditionally complex esters have been used successfully in such applications, even with efficient lubrication a side effect on mechanical motion is heat. The presence of excessive temperature can lead to potential oxidation and subsequent breakdown of the molecule, impairing the performance and lifetime of the lubricant. Including an oxidatively stable ester in a finished lubricant gives the potential to extend life-cycles and reduce machine downtimes whilst simultaneously having no impact on properties such as elastomer compatibility and frictional performance. Croda has developed an oxidatively stable complex ester and compared it to commercially available alternative esters, in order to understand their influence in real life demanding applications, where potential oxidation could be a critical factor.

8:30 – 9 am | Efficiency Testing for Industrial Gearboxes

Paul Norris, Jakub Jelita Rydel, Chip Hewette, Helen Ryan, Afton Chemical Corp., Bracknell, Berkshire, United Kingdom

Industrial gear efficiency has attracted a growing level of interest in recent years. Gearboxes are designed to be >90% efficient, so the prize is perceived to be small. However, with millions of gearboxes deployed worldwide small reductions in energy losses could yield huge cumulative energy savings globally. In order to expand on work that has already been published in the Industrial Gear efficiency space, a number of experiments were conducted utilising MTM, MPR and FZG techniques to evaluate the relative impacts of friction modifiers and thickener choice, as well as the impact of mineral base oil versus synthetic base oil. Results, conclusions and a review of work previously done in this area will be presented.

9 – 9:30 am | A Short-Term Hot Hardness Evaluation of Advanced Aerospace Gear Steels

Cody Wassel, Aaron Isaacson, Sean McIntyre, Todd Palmer, Penn State University, Wayne, PA

The primary heat removal mechanism in rotorcraft gearboxes is the lubrication system. If lube system failure occurs and oil is no longer supplied to the gears and bearings, component temperatures can quickly exceed their design limits resulting in material property degradation. This work examines the short-term hot hardness characteristics of various carburized aerospace gear steels. Each alloy was heated in intervals of 50°C and held at temperature for 30 minutes prior to testing. Hardness tests were performed using a Rockwell test procedure with a 100 kilogram load and a 1/8-inch alumina ball indenter. The indentation depth was measured and converted to Rockwell C. For each alloy, the experimental hot hardness data is presented. Equations to predict the short-term hot hardness are discussed.

9:30 – 10 am | A New Thermally-Coupled Model for Prediction of Gearbox Power Losses

Kharthik Chakravarthy, Amir Kadiric, Imperial College London, London, United Kingdom

This paper presents a numerical approach for prediction of power losses in a simple dip-lubricated spur gearbox using a thermally coupled lubrication model. To provide the crucial link between the frictional heat generation in the contact and gear bulk temperatures, a multi-physics FE approach, with coupled fluid, phase and heat transport equations, is used to model the heat flows in the gearbox. The method employs a two-phase, phase field transport equation to track the interface between air and oil during the gear meshing. Churning losses are evaluated directly through viscous and pressure effects. The tooth bulk temperatures from the multi-physics model are then used in an EHL lubrication model to predict frictional losses in gear teeth contacts, while bearing losses are calculated using existing models. Gearbox efficiency predictions are compared for a range of operating conditions and different gear oils.

10 – 10:30 am | Break

Session 1E • Music Row 5

Commercial Marketing Forum I

8 – 8:30 am | Open Slot

8:30 – 9 am | Chevron Phillips Chemical Company's Synfluid® Metallocene Polyalphaolefins (mPAOs) Grease Applications

Ken Hope, Chevron Phillips Chemical Co., The Woodlands, TX

Synfluid® mPAOs have been around for several years but new applications are continuing to develop. This presentation will provide a brief overview of mPAO key properties and then present recent developments for using Synfluid® mPAOs in greases. We will highlight low temperature advantages of mPAO in lithium and aluminum complex greases and the thixotropic nature of mPAO 65 in a polyurea grease.

9 – 9:30 am | Dow: Seek Together with Dow!

Andrew Larson, The Dow Chemical Co., Midland, MI

Dow is one of the most collaborative partners for lubricant formulators and marketers at the intersection of chemistry and tribology. As a key raw materials provider to the industry, Dow is a partner in solutions formulation, helping to meet the performance and regulatory challenges encountered at end-users. Dow continues to expand their product portfolio to meet the evolving needs of the industry. Please join us at STLE to learn more about our recent portfolio additions.

9:30 – 10 am | Functional Products: Cost-Effective Formulating with Functional Products

Daniel Vargo, Functional Products Inc., Macedonia, OH

Functional Products Inc. continually works to develop new tackifier, thickener, and additive technologies for all sectors of the lubricant market. However, we also provide start to finish formulation services to help customers achieve rapid success with their own product development. This forum will cover successful strategies for cost effective solutions to specialty markets. These approaches from the lab have helped to refresh old formulations or lower the cost of entry for customers seeking new markets.

10 – 10:30 am | Break


Safer. Cleaner. Greener.
CAPMUL®
Multifunctional Emulsifiers
Add functionality to your formulation with ingredients that are safe for people and the environment.
Visit Us at STLE Booth # 412
CONTACT US TODAY!
sales@abiteccorp.com
www.abiteccorp.com
ABITEC
AN ABF INGREDIENTS COMPANY

Session 1G • Music Row 3

Wind Turbine Tribology I

Session Chair:
Rohit Voothaluru, The Timken Co., North Canton, OH

Session Vice Chair:
Harpal Singh, Sentient Science Corp., Idaho Falls, ID

8 – 8:30 am | Comparison of Ultrasonic Load Measurements on an Operational Wind Turbine Bearing with Those Predicted by Ricardo SABR

Benjamin Clarke, Gary Nicholas, Rob Dwyer-Joyce, The University of Sheffield, Sheffield, United Kingdom, Michael Wheeldon, Jonathan Wheals, Ricardo, Leamington Spa, United Kingdom

Bearing failures in wind turbines are amongst the most common and costly failures and cause large amounts of downtime; condition monitoring and further understanding of service conditions is therefore desirable. Ultrasonic methods for monitoring rolling element bearings have been developed in the lab and applied in the field and can monitor lubricant film thickness and contact load. This work compares ultrasonic load data from an operational wind turbine to those predicted by a SABR model of the drivetrain. A tapered roller bearing on the high speed shaft of a 600 kW turbine was monitored. SABR is a shaft, gear and bearing conception and design package based on engineering standards as well as Ricardo's experience. SABR predicted raceway loading was converted into element loading using SABR calculated loads and raceway stress distributions, along with Sjoväll's load integrals. Comparison of results showed good agreement between the ultrasound and SABR predicted loads.

8:30 – 9 am | Onsite Condition Monitoring for Offshore Wind Turbine Gearbox Lubricant Based on Colorimetry

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

Lubricant condition monitoring is very effective technology for the gearbox monitoring based on the understanding of gearbox breakdown mechanism due to wear. Monitoring both oxidative degradation and contamination of the gearbox lubricant are necessary because they affect on wear and life of gearbox. We have developed a novel on-site diagnosis method for the gearbox lubricant based on colorimetry. Oxidative degradation is monitored as enhanced absorption in the blue light region. On the other hand, contamination with water, dust and wear particle is monitored as enhanced absorption of entire visible light wavelengths. The threshold value of the oil degradation was determined by wear testing of used lubricant samples. Major economical advantage of introduction of this lubricant diagnosis technology is the extension of lubricant exchange interval.

9 – 9:30 am | Monitoring Load and Lubrication in a Wind Turbine Gearbox Rolling Bearing in the Field

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

Wind turbine gearbox bearings although having a moderate failure rate, will result in the longest downtime if failure occurred. Most of these failures are from bearing failure. Thus, monitoring these bearings will allow for better understanding of loading and lubrication condition, crucial information for bearing designers. Piezoelectric elements bonded onto the bearing surface can be used to send and receive ultrasonic signals. In this study, a high-speed shaft tapered roller bearing within an operational wind turbine was instrumented with ultrasonic sensors. The sensors were used to send ultrasonic pulses directly at rolling element – raceway contacts. When a wave is reflected from a contact, the flight path is reduced due to raceway deflection and the amplitude drops due to energy transmission into the roller. These two features were used to deduce the load and to investigate the oil film formation and then correlated with turbine operational parameters such as wind speed and power.

9:30 – 10 am | Characterization of White Etching Areas in Annealed AISI 52100 Processed by High Pressure Torsion Tests

Luis Wilches Peña, Ling Wang, Brian Mellor, University of Southampton, Southampton, Hampshire, United Kingdom, Alexander Schwedt, Joachim Mayer, RWTH , Aacheb, North Rhine-Westphalia, Germany, Walter Holweger, Schaeffler Technologies AG & Co., Herzogenaurach, Bavaria, Germany

The study of White Etching Areas (WEAs) has mainly focused on samples those from field bearings disassembled after failure and bearings subjected to rolling contact fatigue tests in laboratories under various accelerators. This study investigated WEAs formed in annealed AISI 52100 after being processed on a High-Pressure Torsion (HPT) test rig where high strain is rapidly applied to create severe plastic deformation in materials (1) (2). Result show that WEA similar to those in bearings are formed in the annealed AISI 52100 bearing steel discs at three different locations under a range of loads and number of turns. Detailed SEM/EBSD/EDS characterisation on the WEAs both on the surface and in the subsurface of the HPT processed samples suggests that non-metallic inclusions in the material were found to interrupt the plastic flow in the samples under HTP testing, which has promoted the dissolution of carbides into the refined ferritic matrix.

10 – 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 20 and Tuesday, May 21 from 3-4 pm in the Omni Nashville Hotel – Broadway Ballroom, with Evonik raffle at 3:30 pm. 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 120 companies.

Synergex™

How long will your **fluid last?**

Extend the life of your metalworking fluids with Synergex™ multifunctional amine additives. This range of lower-odor, lower-volatility products from Eastman offers excellent buffering and pH stability.

Visit us at STLE booth #311

Learn more at
www.synergexamine.com

EASTMAN

Session 1J • Cumberland 3

Nanotribology I

Session Chair:
Jianbin Luo, State Key Laboratory of Tribology, Beijing, China

Session Vice Chair:
Jonathan Leong, Singapore University of Social Sciences, Singapore, Singapore

8 – 8:30 am | Session starts at 8:30 am

8:30 – 9 am | Development of Next Generation Coolants Using Nanofluids for Meeting Future Cooling Challenges in EV and Hybrid Vehicle Applications

Simon Tung, Innovation Technology Consulting, Rochester Hills, MI

The development of advanced automotive technologies is hampered by a vital need for high performance cooling on electrical vehicles and power electronics. The conventional approach for enhanced cooling has reached its limits. Research using nanofluids has the high potential payoff to bring about a revolution in cooling technology. Nanofluid is a new class of heat transfer fluids created by dispersing solid particles smaller than 40 nm in oil-based fluid. The suspended nanoparticles remarkably improve thermal conductivity and heat transfer coefficient than the conventional coolants. In this investigation, experimental results show thermal conductivity and heat transfer coefficient have been enhanced. The effect of heat transfer has been measured as the volume fraction of the suspended nanoparticles. Heat transfer properties increase with the volume fraction of nanoparticles. Potential applications of nanofluids include the EV/hybrid vehicles, fuel cell, and the manufacturing operations.

9 – 9:30 am | Influence of Copper Oxide and Tungsten Carbide Nanoparticles on Micropitting Under Boundary Lubrication

Sougata Roy, Yosef Jazaa, Sriram Sundararajan, Iowa State University, Ames, IA

This work investigates the potential of metallic nanoparticles as additives on crucial drivetrain failure mode called 'micropitting'. Copper oxide (CuO) and tungsten carbide (WC) nanofluids were used as lubricants to observe their effect on micropitting life of AISI 8620 steel. The nanofluids consisted of 1% nanoparticles by weight and 1% by weight of oleic acid surfactant in Polyalphaolefin (PAO) base oil. Rolling contact fatigue tests were conducted using a micropitting test rig (MPR). Both the nanofluids exhibited increased micropitting life compared to the base oil (PAO). Tungsten carbide nanofluids showed significantly higher micropitting resistance behavior than the copper oxide nanofluids under the boundary lubrication regime. Post experiment surface characterization showed different mechanisms to inhibit micropitting and wear for the two nanofluids-the tungsten carbide nanofluid formed a tribofilm whereas the CuO nanofluids tended to fill surface cracks with the nanoparticles.

9:30 – 10 am | Synergistic Effects Between Silver and Palladium Nanoparticles in Boundary Lubrication

Chanaka Kumara, Harry Meyer, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Oil-suspendable dodecanethiol-modified Ag and Pd nanoparticles (NPs) have been developed as candidate lubricant additives. The tribological performance of the NP-containing oils was evaluated using a ball-on-flat reciprocating sliding configuration at boundary lubrication at 100˚C. While either the Ag or Pd NPs by themselves possessed good friction reduction and wear protection abilities, a combination of the Ag and Pd NPs (0.10-0.25 wt% of each) exhibited promising synergistic effects by further reducing the friction (by 37%) and wear (by 80%) compared to using either alone. Morphology and chemical composition of the top and cross-section of the worn surface were characterized and revealed an Ag, Pd and S rich, ultra-thick (up to 3 μm) tribofilm. Galvanic replacement reactions between the Ag and Pd NPs have been evidenced and are believed to provide a stronger electron donation ability and consequently to enhance the lubricating performance

10 – 10:30 am | Break

Session 1K • Cumberland 4

Metalworking Fluids I

Session Chair:
E. Jon Schnellbacher, Lawrence Technological University, Allen Park, MI

Session Vice Chair:
Jill Myers, The Timken Co., North Canton, OH

8 – 8:30 am | Computational Study Aimed at Determining the Kinetics of Branched Esters Against Aminolysis

Mark Fennimore, Quaker Chemical Corp., Conshohocken, PA

The performance of MWFs relies on the chemical and physical properties of esters. Esters in MWFs function primarily as lubricants; however, their behavior can influence other aspects of the fluid's performance including emulsion stability, foam and product shelf-life. As such, esters are chosen to optimized performance across as many parameters as possible to suite customer needs. Problems arise due to reactions that occur between the ester with other components in the MWF, e.g. reactions with amines producing amides. Amides have different properties compared to their ester counterparts resulting in deleterious changes to the product. Experiments have shown that aminolysis formation is strongly correlated to the structural features of the ester, particularly substitution near the active site. Computational analysis with Transition State Theory was used in the present investigation to elucidate the structural motifs that give rise to aminolysis resistance in esters relevant to MWFs.

8:30 – 9 am | An Innovative Edger Rolling Oil for Steel Plants

Pankaj Bhatnagar, N Sivasurian, S Paul, R Mahapatra, D Saxena, S S V Ramakumar, Indian oil Corporation Limited, Faridabad, Haryana, India

Historically water was used for hot rolling in Indian Steel Industries. This trend has changed during last few years and steel plants are using hot rolling lubricating oil dispersion in water through roll bite lubrication system. The hot rolling oil dispersion in water is being used for the Hot Strip Mill of few Steel Plants in India, where oil is contributed as lubricant and water as coolant and users are increasing. The paper deals with the development of an edger rolling lubricant for Hot Strip Mill in authors laboratory comprising combination of specialty additives having excellent lubricity, antiwear and EP characteristics and its extensive field trial for establishing the product performance in one of the most reputed Indian Steel Plant. The paper also discuss the analysis of data obtained during field trial. The developed edger rolling oil has provided reduced wear of roll with extended roll protection, defect elimination of edges, improved campaign length and energy savings.

9 – 9:30 am | Metalworking Fluids and Chloride Corrosion on Iron Alloys

John Burke, Alan Cross, Houghton International Inc., Norristown, PA

Water-diluted metalworking fluids are formulated to provide cooling and lubrication at the tool work piece interface, flush chips from the cut zone and fixtures, and provide interim corrosion protection. With extended reuse and recycling of fluids becoming more popular, the buildup of contaminants becomes inevitable and problematic. These contaminants can interfere with fluid performance in several ways. One type of contamination is from the chloride anion. It has been observed that as chloride levels increase, so does the corrosion on surfaces of iron alloys. The corrosion is manifested in the form of rust and pitting. This paper will demonstrate the effects of increasing corrosion effects on steel test panels with various levels of chloride contamination on different types of water diluted fluids such as synthetic, semi-synthetic and emulsifiable oils.

9:30 – 10 am | Polyalkylene Glycol as Performance Wear Lubricant Additive on Straight Oil

Eduardo Lima, The Dow Chemical Co., São Paulo, Brazil

Additives typically called anti-wear or lubricity promoter's acts on preferential adsorption compounds on metal surfaces, forming a monomolecular film strongly adhered to the metal, which avoids contact between moving parts. Straight oil metalworking fluids users keep demanding higher lubricity and stability levels to attend continuous metal materials evolution proposals following developments from automotive and machinery industry. This study has shown positive results with oil soluble polyalkylene glycol use, in comparison with an elected fatty base benchmark, as making possible additive reduction up to 5 (five) times lower and with superiority results on proposed methodologies and related lab tests conditions adopted.

10 – 10:30 am | Break

Session 1L • Cumberland 5

Nonferrous Metals I

Session Chair:
Rick Pruhs, Quaker Chemical Corp., Waverly, IA

Session Vice Chair:
Girma Biresaw, USDA-ARS-NCAUR-BOR, Peoria, IL

8 – 8:30 am | Static Multiple Light Scattering as a Tool to Characterize Stability and Size of Nonferrous Fluids

Mike Gould, Christelle Tisserand, Formulaction, Worthington, OH

Nonferrous rolling emulsions are well known systems but their formulation evolved over the years asking to the formulators to remain continually innovative to keep expected performances. Different physico-chemical factors are responsive of their efficiency like stability, droplet size. In this study, we propose to present a review of non ferrous emulsions systems and some results of physical analysis studies with Static Multiple Light Scattering technique. This method provides a non-intrusive optical characterization of a native sample without dilution. An infrared light source illuminates the sample and the backscattered and transmitted light intensity signals are collected simultaneously by two sensors over the whole samples height and repeated over time. The resulting spatial and time dependent signals T and BS are directly linked to the fundamental properties of the emulsion (particles mean size, concentration), as well as physical instabilities (flocculation, creaming).

8:30 – 9 am | Friction Reduction on Anodized Alumina by Impregnating Ashless Fillers

Svajus Asadauskas, Tadas Matijosius, Center for Physical Sciences and Technology, Vilnius, Lithuania

Due to exceptional hardness, paintability, corrosion resistance and other advantages, anodized coatings are widely utilized on frames, casings, railings, fasteners and many other aluminum items. In many cases they are exposed to friction, which leads to severe damage, because the anodized coatings are highly porous and brittle. Frequently fluoro-polymers are applied onto the anodized coating in order to reduce friction and wear. However, the procedure is labor intensive, involves heating above 300°C and requires expensive dispersions. In this study a number of ashless fillers were evaluated after impregnating them into the anodized coatings on industrial aluminum alloys. Their capability to participate in friction zone reactions resulted in dramatic reduction of wear and friction, often exceeding the performance of PTFE. A number of field tests with different final applications demonstrated excellent technological advantages of the investigated materials.

9 – 9:30 am | Update on Challenges in Machining Aluminum Alloys

Neil Canter, Chemical Solutions, Willow Grove, PA

Use of aluminum alloys in machining operations continues to be growing in importance in applications such as automobiles where lower vehicular weight is needed to improve fuel efficiency. This presentation will provide an update on the issues surrounding the machining of aluminum alloys with an emphasis on metal removal operations. Included in the discussion will be an update on the types of additive chemistries that are available to be used and the continuing need for better aluminum stain inhibitors. Current health & safety issues will also be examined as these concerns may limit the tools that formulators can use in developing suitable metal removal fluids.

9:30 – 10 am | Aluminum Staining: Achieving Performance without Sacrificing Fluid Longevity

Clayton Cooper, Nicole Clarkson, ANGUS Chemical Co., Buffalo Grove, IL

Aluminum staining can be affected by several factors in a metalworking fluid (MWF) formulation. To name some of the more common influences, high pH and soft water have been known to negatively affect staining. However, formulating at a lower pH can incite poor fluid longevity, and water quality at the end user is almost always out of a formulator's control. To combat poor aluminum staining, chemistries such as phosphate esters, as well as other products, are utilized. But what if there's more to the story? This presentation focuses on other pieces of the formulation which can be adjusted to achieve aluminum staining performance without sacrificing other fluid criteria, such as fluid longevity.

10 – 10:30 am | Break

Session 1M • Cumberland 6

Fluid Film Bearings I

Session Chair:
Alex-Florian Cristea, Waukesha Bearings Corp., Rickmansworth, Herfordshire, United Kingdom

Session Vice Chair:
Xuan Ma, Harbin Engineering University, Harbin, Heilonglian, China

8 – 8:30 am | On The Effect of Journal Kinematics on the Force Coefficients of a Test Squeeze Film Damper Supplied With an Air in Oil Mixture

Luis San Andrés, Xueliang Lu, Texas A&M University, College Station, TX, Wei Zhang, Tianjin University, Tianjin, China

Squeeze film dampers (SFDs) reduce vibration and enhance stability in rotating machinery. Operation at a high squeeze velocity draws air into the film to make a bubbly mixture that produces notable changes in the SFD performance. During tests an air in oil ISO VG 10 mixture of known gas volume fraction (GVF) and low pressure [0.1 barg] is supplied at the damper [c=0.3% D, L=0.36 D] top end, to atmospheric discharge at the bottom end. Single frequency loads and impact loads serve to identify force coefficients. When supplied with a liquid the SFD shows a direct dynamic stiffness (Kd) reducing with frequency. When supplied with a mixture Kd increases with frequency. The damping (C) identified from periodic loads decreases as the GVF increases from 0 to 1; C estimated from impact loads first increases with GVF to 0.4 and then drops with a further increase in GVF. Thus, the results show the kinematics of journal motion affect the force coefficients of a damper operating with air ingestion.

8:30 – 9 am | On the Static Load Performance of a Large Size, Heavily Loaded Spring Supported Thrust Bearing

Rasool Koosha, Luis San Andrés, Texas A&M University, College Station, TX

The paper describes a thermoelastohydrodynamic (TEHD) analysis for predictions of the static performance of a large size spring-supported thrust bearing (SSTB). The bearing pads include pockets for hydraulic lift and an internal cooling system with pipes laid out along the radial direction. Pressure induced deformations significantly enlarge the film thickness at the pads' leading and trailing edges. Pad thermal deformations are lesser, except at the pad trailing edge where cooling lines do not reach. Bearing operation transitioning from a nominal rotor speed to a low rotor speed while the bearing pads remain hot simulates a quick shut-down process. With a hot pad the predictions produce a much lesser fluid film thickness than that arising during a slow shut-down process where the bearing pads cool at a steady rate. The gradient of minimum film thickness versus rotor speed is much higher during the fast shutdown process which could lead to a sudden bearing failure.

9 – 9:30 am | WITHDRAWN Design of Numerical Optimization for Gap-Compensated Hydrostatic Bearing

Nenzi Wang, Yu-Wen Chen, Hsin-Yi Chen, Chang Gung University, Tao-Yuan, Taiwan

In this study, the objectives of the design of optimization are to develop an effective data sampling technique for selecting initial search population and stopping criteria at the end of the optimization. A gap-compensated hydrostatic bearing with several design variables is the design target. The goals are to minimize the bearing friction while maximizing the bearing stiffness. The particle swarm optimization method is chosen for easy implementation with high efficiency. A good sampling technique can speed up the search of the optimum design and properly-selected stopping criteria can minimize the search effort without sacrifice the solution accuracy. For a given total number of function evaluations, several cases with various population sizes and epochs are tested. The case with the best solution convergent rate can then be determined. This study illustrate the selection of an effective sampling technique for initial population and the stopping criteria of the bearing optimization.

9:30 – 10 am | The Performance of Small Centre Pivoted PTFE Thrust Bearings in Low to Medium Speed Applications

Stephen Dixon, John Butler, Paul Bruce, Michell Bearings Ltd., South Shields, Tyne and Wear, United Kingdom

PTFE faced thrust pads have proven to be a very robust and reliable solution for large, and sometimes problematic, hydrogenerator applications. In such applications the thrust pads can have a radial width in the order of 400-900 mm. However, there are numerous smaller machine types using hydrodynamic bearings requiring much smaller pads, typically less than 150 mm. For such applications, does PTFE also have advantages over the traditional Babbitt lining? This paper outlines recent work undertaken to assess the performance of two sizes of 'small' PTFE faced thrust pads across a speed range of 2.5-35 m/s, typical of vertical pump applications. Unlike hydrogenerators, which are predominantly unidirectional, pumps are very commonly subject to rotation reversals. For this purpose, the work focused mainly on centrally pivoted thrust pads which have the same performance characteristics in both rotation directions. Results are presented for 80 and 150 mm radial width thrust pads.

10 – 10:30 am | Break

PARTICLE COUNTS
FOR INDUSTRIAL FLUIDS

COME TALK
TO US AT
BOOTH 218

NEW!

HIAC PODS+ PORTABLE OIL DIAGNOSTIC SYSTEM

Battery Operation – *Carry it to the sample point!*

FLUID POWER CONTAMINATION CONTROL IN 60 SECONDS

- MAXIMIZE production uptime
- EXTEND equipment life
- IDENTIFY potential equipment problems
- FAST analysis
- SINGLE BUTTON operation

HIAC 8011+ LIQUID PARTICLE COUNTER

Lab Model for R&D – *Fast and easy to use!*

- NO DILUTION – 1 - 425 cSt viscosity
- CUSTOM RECIPES save time
- FAST <60 second sampling time
- MAXIMIZE uptime and performance
- MINIMIZE bubble impact
- PAPERLESS data transfer
- MULTIPLE standards

Extend the life of your equipment with liquid particle counting analysis.

www.beckman.com/liquid-particle-counters

BECKMAN COULTER
Life Sciences

Session 2A • Legends A

Materials Tribology II

Session Chair:
Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA

Session Vice Chair:
Tomas Babuska, Lehigh University, Bethlehem, PA

1:30 – 2:30 pm | Self-Organization in Materials Subjected to Severe Plastic Deformation: Relevance and Application to Wear Resistance of Metallic Alloys

Pascal Bellon, Robert Averback, University of Illinois at Urbana-Champaign, Urbana, IL

Materials are often subjected to plastic deformation during their fabrication and their service life. This plastic deformation can alter phase stability and modify properties. These nonequilibrium environments can also lead to self-organization, for instance through the formation of tribolayers during wear. We will show that in alloys, severe plastic deformation can lead to chemical self-organization at the nanoscale, at temperatures where thermal diffusion is or is not significant. Experiments, modeling and atomistic simulations indicate that this nanostructuring results from competing kinetic processes with distinct characteristic length scales. This perspective will be illustrated on alloys subjected to sliding and erosion wear, or processed by ball milling, accumulative roll bonding, and high-pressure torsion. We will show that self-organization reactions leading to the formation of nanolayers can be used to design materials with improved wear resistance.

2:30 – 3 pm | Adhesion, Self-Welding and Static Friction Coefficient of Ni Alloys at Elevated Temperature

Md Saifur Rahman, Andreas Polycarpou, Texas A&M University, College Station, TX

Metals contacting at elevated temperature increase the complexity of explaining tribological characteristics even for the super alloys like Inconel 617 and 800H. The presence of Helium gas as coolant and impurities in the Very high Temperature Reactor (VHTR) makes the scenario more confounding. The static friction coefficient (sCOF) is being investigated for the before mentioned alloys at high temperature helium environment. Alloy 800H showed sCOF as high as 3.74 at 750 oC, whereas Inconel 617 showed 2.28 at 950 oC in helium atmosphere. The possibility of getting the materials self-welded at high temperature were also investigated to explain the high friction behavior. The samples were self-welded under high contact pressure in atmosphere controlled furnace and welding strength were measured using micro tensile stage. Presence of high adhesion force between the alloy surfaces resulted in very high static friction coefficient.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | Understanding the Role of Protective Metal Oxides in Nanoscale Tribocorrosion

Alex Lin, Xiao-Xiang Yu, Laurence Marks, Northwestern University, Evanston, IL

Tribocorrosion is the degradation of a material due to the effects of simultaneous mechanical and chemical (corrosive or oxidative) damages. It is well-established that these modes of attack are not simply additive and that additional synergistic effects are often at work. In this study, direct observations of nanoscale tribocorrosion were conducted on NiCrMo and CoCrMo alloys. The general experimental approach is to first prepare electron transparent samples, then expose them to controlled oxidative or corrosive conditions, and finally use them as samples for in situ tribological experiments in a transmission electron microscope. By characterizing the structural and chemical changes of the protective oxide films in these alloys, fundamental changes in the adhesion of the films as a function of the growth and dissolution rates can then be revealed.

4:30 – 5 pm | Evaluation of Friction Performance and Wear Reduction of Boronized Steels

Brandon Wong, Philip Egberts, University of Calgary, Calgary, Alberta, Canada, Eugene Medvedovski, Endurance Technologies Inc., Calgary, Alberta, Canada

The purpose of this research is to examine the impact iron boride-based coatings obtained through thermal diffusion process for steels on the measured friction and wear coefficients under dry conditions and immersion in corrosive salt-water environments during sliding. Variables considered included the coating thickness as well as the deposition of BN-type layers as a boundary lubricant following the boronizing process. A custom-designed and constructed reciprocating tribometer with a 6-mm sapphire hemisphere countersurface and electrochemical capabilities was used for all experiments. Following the measurement of the friction coefficient, white light interferometry and optical microscopy were used to evaluate wear rates of the samples and sapphire countersurfaces. Although boronized steel samples showed increased COF, their wear rates were significantly reduced compared to bare steels due to significantly higher iron borides hardness; the BN-type boundary lubricant had minimal effect.

5 – 5:30 pm | Elevated Temperature Nanomechanical and Nanotribological Behaviors of Ni Alloys Surface Oxides: Part I-Experimental Study

Md Saifur Rahman, Andreas Polycarpou, Texas A&M University, College Station, TX, Sepehr Salari, Ali Beheshti, George Mason University, Fairfax, VA

In this study, the nano-tribological properties of the oxide and the top most layer of super alloys, Inconel 617 and Incoloy 800H are studied using experimental and finite element analysis. Part-I presents the experimental portion of the study. Hardness, elastic modulus of the materials along with creep behavior were investigated using nanoindentation, while coefficient of friction (COF), scratch depth and elastic recovery at elevated temperature were investigated using scratch method. Constant load hold method is used to extract the creep properties with consideration of thermal drift. The oxide layer on top of Inconel 617 exhibits better scratch resistance and lower COF compared to 800H. The mechanical properties of the oxide are extracted using nanoindentation and ramp loading scratch is used to identify the critical load for breaking into the oxide layer. Both alloys display plastic deformation with pile up around the scratch, however, oxide layer shows high elastic recovery.

5:30 – 6 pm | Elevated Temperature Nanomechanical and Nanotribological Behaviors of Ni Alloys Surface Oxides: Part II – Finite Element Study

Sepehr Salari, Ali Beheshti, George Mason University, Fairfax, VA, Md Saifur Rahman, Texas A&M University, College Station, TX

In this study, the nano-mechanical and nano-tribological properties of the oxide and the top most layer of Inconel 617 and Incoloy 800H are studied using experimental and finite element analysis. A comprehensive understanding of mechanical properties such as yield strength, creep parameters and stress-strain development is performed. Following part one of this presentation, FE analysis is used to extract the mechanical properties such as yield strength, shear strength and creep parameters of the oxide layer by a parametric study and fitting finite element results with the experimental nanoindentation values. In addition, a scratch model is built by using the extracted properties from nanoindentation simulations and validating the results with the experimental nanoscratch. The findings show that the oxide has higher hardness and elastic

modulus as compared to the substrate resulting in the oxide layers to contain mainly all the stress/deformation during the scratch of the surface.

6 – 6:30 pm | The Wear Mechanism of Flexspline Materials Regulated by Novel Amorphous/Crystal Oxide Form Evolution on a Frictional Interface

Caixia Zhang, Zhifeng Liu, Jianhua Wang, Institute of Advanced Manufacturing and Intelligent Technology, Beijing University of Technology, Beijing, China

Flexspline wear is a key factor leading to wear failure of harmonic drives. The tribological properties of three normal flexspline materials under grease lubrication conditions were investigated. A novel wear mechanism regulated by two oxide forms (amorphous FeOOH and crystalline Fe2O3) evolving on a frictional interface was proposed and the details were confirmed based on co-analysis of XPS, TEM, AFM and SEM. The amorphous FeOOH generated during sliding assists the oxide layer which therefore shows compact structure and better toughness, reducing friction at the interfaces, whereas the frictional crystalline Fe2O3, which tends to strip under the shear force without sufficient amorphous FeOOH around it, is the trigger for the loose and unstable oxide layer. The wear mechanism based on amorphous/crystalline oxide form evolution proposed provides novel research information for avoiding flexspline wear of harmonic drives.

Session 2B • Legends B

Lubrication Fundamentals II

Session Chair:
Marc Ingram, Ingram Tribology Ltd., Carmarthen, United Kingdom

Session Vice Chair:
Kenneth Garelick, Afton Chemical Corp, Richmond, VA

1:30 – 2 pm | Fluid Properties and Testing Parameters that Impact Lubricant Shear Stability

Sona Sivakova, Bart Schober, The Lubrizol Corp., Wickliffe, OH

Polymer shear stability is often described using the empirical value of shear stability index. For a long time, the shear stability index (SSI) of a polymer was viewed as a constant. But the shear stability index of a polymer can change based on the viscosity of the fluid being formulated and the API group of the base oil, as well as the temperature of the test. As the industry drives towards lower viscosity fluids, it has been observed that polymers blended into low viscosity fluids and highly refined or synthetic base stocks (like PAO) 'appear' more shear stable than in more conventional, higher viscosity, mineral base fluids. In this presentation/paper, we will investigate whether the perceived improvements in SSI due to trends toward lower viscosity lubricants, more refined base stocks and variations in test temperature are significant, whether they are maintained over more extended shear intervals and what this could mean for formulating durable low viscosity fluids.

2 – 2:30 pm | Hyperbranched Polymers for Shear Stable Viscosity Index Improvers

Lelia Cosimbescu, Pacific Northwest National Laboratory, Richland, WA, Robert Erck, Argonne National Laboratory, Lemont, IL, Deepika Malhotra, Pacific Northwest National Laboratory, Richland, WA

As fuel efficiency goals have pushed the boundaries of fluid viscosities lower and lower, well-designed VIIs that maintain lubrication and minimize friction and wear in a hot running engine are even more imperative. However, providing a high VI polymer is only part of the solution; another important parameter to consider is its shear stability. In the context of this work, the polymer's ability to resist mechanical shear-induced macromolecular degradation under shear conditions was investigated. Hyperbranched poly(alkyl methacrylate)s with and without polycaprolactone segments were designed and prepared via a core-first strategy, then evaluated with respect to their rheology, friction, wear, and shear stability performance. The focus of this work was to study the effect of architecture on mechanical shear stability, as it relates to hydraulic fluid performance. Furthermore, the effect of long versus short chain pendants on shear stability was evaluated.

2:30 – 3 pm | EHD Friction at Very High Pressure

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

A new high load minitraction machine is employed to measure the EHD friction properties of a range of low viscosity base fluids in sliding-rolling conditions up to mean pressures in excess of 4 GPa. Measurements are made over a range of temperatures, enabling the effects of shear heating to be distinguished and separated from shear thinning. The observed isothermal shear stress versus strain rate responses are compared with the main existing equations used to describe the shear thinning of simple liquids.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | Development of a Refined Full Cavitation Model Considering Vapor and Air

Yan Wang, Xuesong Li, Xiaodong Ren, Chunwei Gu, Tsinghua University, Beijing, China

Cavitation is one of the most common phenomenon in the fluid lubrication. Though there are many hypothesis on the cavitation mechanism and many cavitation models, the physical mechanism of the cavitation remains controversial. There are two major form of cavitation, namely, vapor cavitation, which supposes the cavitation is the result of the oil vapor and air cavitation, which supposes the cavitation is due to the dissolved air or bearing-outside air. This paper constructs a refined full cavitation model considering both the vapor cavitation and the air cavitation and validated the bearing with the open data. The vapor and air cavitation are analyzed in details in a plain journal bearing and a squeeze film damper (SFD). Results shows that the cavitation mechanism are various in different bearings. Cavitation in the normal plain journal bearing is mainly vapor cavitation and cavitation in the SFD is mainly due to the air entrainment.

4:30 – 5 pm | Multi-Scale Modeling of the Lubrication Between Rough Surfaces

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

In order to reduce friction during operation, many lubricated contacts work in the mixed lubrication regime. It is therefore necessary to have tools able to simulate this lubrication regime within a reasonable computation time along with enough accuracy. However, mixed lubrication involves several scales: the lateral scale of the asperities and the lateral scale of the domain as well as several scales in the through film direction. This is why a recently developed multi-scale approach is used in this paper and extended to include cavitation. The full contact domain is split in several sub-domains over which a deterministic approach is used because of its accuracy. The mass conservation between the sub-domains is ensured by a finite element macro-mesh based on the full domain scale allowing more efficient computations. As for the cavitation, the fluid is described as a homogeneous mixture of liquid and gas which density continuously varies with pressure.

2B

5 – 6 pm | Tribo-CAS Film with Unprecedented Lubrication and Wear Performance Characteristics

Kenneth Chao, Deere & Co., Cedar Falls, IA

We all know what Tribo means but maybe few of us are familiar with complex adaptive systems or CAS. The scientific description of complex adaptive system can be found online such as Wikipedia. Tribo-CAS is the first sucessful attempt to employ the powerful CAS theory in the field of tribology with unique performance capabilities never seen before. In a nutshell, Tribo-CAS Film is a surface matrix layer composed of individual solid particulates with certain natural mild-stickness among themselves. This powder layer can be applied to ordinary steel/metal surfaces via sandblasting method or equivalent, and adhere spontaneously to the surface without using extra adhesives. Because these individual particulates are not rigidly bonded they have the freedom to move around or self-organize continuously in a matrix form consisting of particle clusters and empty voids under liquid-lubricated contact, which is radically different from traditional surface coatings with rigidly bonded texture.

Session 2C • Legends C

Engine and Drivetrain II

Special program on electric vehicles

Session Chair:
Babak Lotfizadehdehkordi, ExxonMobil Chemical Co., Baytown, TX

Session Vice Chair:
Martin Webster, ExxonMobil Research & Engineering, Annandale, NJ

1:30 – 2 pm | Challenges and Opportunities with Lubricants for HEV/EV Vehicles

Arup Gangopadhyay, Ford Motor Co., Dearborn, MI

The projected growth of hybrid electric (HEV) and pure electric vehicles (EVs) in the near future brings changes in powertrain architectures. Engine, transmission, and axles will be assisted by electric motors and in some applications electric motors will be integrated in the architecture with less or no friction clutches. The electric motors will be in contact with the lubricant and the lubricant is required to cool the motors by taking heat away from it. Therefore, lubricant for electrified powertrains needs to function as an effective coolant, provide corrosion protection to copper windings, laminates, and rare earth magnetic materials while maintaining wear and oxidation protection, and trading off friction stability. This presentation will discuss these requirements and challenge the lubricant industry to meet these.

2 – 2:30 pm | New Challenges for Tribologists and Lubrication Engineers From Vehicle Electrification

Chris Shamie, Schaeffler Group USA, Brighton, MI

The automotive landscape is undergoing unprecedented transformation as vehicle propulsion becomes more and more electrified. What challenges must tribologists and lubrication engineers solve as the take-rates for pure internal combustion-powered vehicles fall and hybrids or battery electric vehicles rise? The problems of lubrication from the point-of-view of the gearbox / bearing development community will be presented.

2:30 – 3 pm | Chevrolet Bolt Fluid Test Development

Peter Lee, Craig Wileman, Michael Kader, Cole Hudson, Southwest Research Institute, San Antonio, TX

This research project sought to evaluate fluid performance by examining the total component efficiency of a 2017 Chevrolet Bolt electric motor gearbox. Using electrical input and mechanical output power instrumentation, the project aim was to determine where the greatest opportunities lie in reducing power losses across the HEV drivetrain component, define a cycle that simulates the component usage in the vehicle and examine the drivetrain component for fluid or part degradation over a defined customer equivalent mileage. The project completed an array of analytical fluid tests on two e-machine compatible fluids to quantify fluid properties that may affect performance of the electric motor. Motor drive electronics and controls were adapted to the Bolt electric motor gearbox and measurements of power loss and efficiency were taken for a narrow range of motor output with two compatible fluids. The experience developed within this research program is applicable to all current e-machines found in hybrid electric vehicles.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | Newly Developed Lubricants for the Challenges of Electric Drivetrains

Tobias Bender, Fuchs Lubricants Company, Wedel, Germany, Thomas Kraft, Gerd Jacobs, Erik Schuster, Rolf Luther, Bernhard Hagemann, Fuchs Schmierstoffe GmbH, Mannheim, Germany

After several successes with off-the-shelf fluids, FUCHS is developing a new generation of dedicated E-Motive fluids. As lubricants come into contact with many components, they must meet important requirements in terms of tribology and thermal management. With the increasing integration of electric components further special requirements arise for fluids and greases through new materials (e.g. copper, aluminum, and plastics), current-carrying components and high motor speeds. As part of the efforts in this area, FUCHS is currently working on water-based alternatives for transmission oils with a heat capacity that has been almost doubled in comparison to hydrocarbon-based lubricants. Apart from reducing the number of fluids used in an electrical drivetrain, this approach may also cover thermal management needs of the battery while significantly increasing the drivetrain's efficiency. Recent results from the development are presented and advantages and challenges discussed.

4:30 – 5 pm | Challenges and Outlooks for Transmission Fluids in Electric Vehicles

Torsten Murr, Shell Global Solutions Germany, Hamburg, Germany, Hong Gao, Shell Global Solutions, Houston, TX

Diverse and clean energy sources can contribute to meeting growing transport needs with reduced CO_2 emissions. Electrification will increase significantly and play an important role in the global future transportation. The presentation will explain the drivetrain electrification technology trends and new requirements on transmission fluids. The key properties will be demonstrated to address the challenges which the transmission fluids are facing in the electric vehicle applications. The outlooks for transmission fluids will be discussed for both hybrid and electric vehicles.

5 – 5:30 pm | Understanding Base Oils and Lubricants for Electric Drivetrain Applications

Yungwan Kwak, Atanu Adhvaryu, Xinggao Fang, Christopher Cleveland, Afton Chemical Corp., Richmond, VA, Susie Hurley, Afton Chemical Ltd., Bracknell, United Kingdom

The penetration HEV and EV technology into automotive powertrain designs is an evolving trend resulting from global regulations intended to reduce emissions of greenhouse gases and other pollutants and to improve vehicle fuel efficiency. In many HEV and EV hardware designs, drivetrain fluids contact the integrated electric motor, which requires electrical and thermal properties to be considered in addition to traditional fluid properties. This presentation will discuss new insights gained around electric and thermal properties of drivetrain fluids, with a

SYNTHETIC BASE STOCKS • ADDITIVE COMPONENTS & PACKAGES

MORE WAYS TO ADD VALUE

SPECIALTY CHEMICALS

Broader line of synthetic base stocks & additive components/ packages

MANUFACTURING

Expanded North American production

LOGISTICS

New, strategically located terminal

SERVICE

Enhanced technical and support resources

When you need to enhance your products, improve profitability and streamline your supply chain, call Soltex. We're continually expanding our resources to add more value to your products.

USA
+1 281 587 0900
+1 800 275 8580

CANADA
+1 613 966 8881

ARGENTINA
+54 9221 511 9100/9003

soltexinc.com/value

SOLTEX

Visit Us at STLE Booths # 517 & 519

specific emphasis on understanding the critical impacts of base oils. The successful utilization of this knowledge is demonstrated on a proof-of-principle basis to show that fluids with appropriate electrical and thermal properties can be designed to meet critical factors for electrification such as cooling capacity and electrical conductivity, while still maintaining essential performance features for conventional driveline fluids.

5:30 – 6 pm | **Open Discussion**

Session 2D • Music Row 1

Gears II

Session Chair:
Sean McIntyre, Penn State University, Wayne, PA

Session Vice Chair:
Jeremy Wagner, Deere & Co,, Denver, IA

1:30 – 2 pm | Softening Mechanisms in Carburized Aerospace Gear Steels during Short Term Exposure to High Temperature

Aaron Isaacson, Penn State University, State College, PA, Cody Wassel, Sean McIntyre, Penn State Applied Research Lab, University Park, PA, Todd Palmer, Penn State University, Wayne, PA

The loss of lubrication survivability of gears operating in rotorcraft gearboxes is highly dependent on the gear steel's resistance to softening during short term exposure to extremely high surface temperatures. The mechanism involved during the softening of a traditional carburized aerospace gear steel like AISI 9310 is quite different from that of more advanced, temper resistant steels like AMS 6308 (Pyrowear 53) and AMS 5930 (Pyrowear 675). This work examines each of these carburized materials after exposure to temperatures high enough to soften each sample below 20 Rockwell C. The softening mechanisms are identified and reasons for each are presented. Approaches to model the softening for each material system were also investigated.

2 – 2:30 pm | Fatigue Calculations for Rough Surface Contacts with Measured and Synthesized Run-In Surface Roughness

Hassneen Asadi, Pwt Evans, Alastair Clarke, Kayri Sharif, Cardiff University, Cardiff, United Kingdom

A procedure was developed to synthesise the running-in process based on measured as-manufactured profiles. Surface roughness profiles obtained from transverse ground test disks were used to simulate asperity modification during running-in. The surfaces were run against each other in an EHL analysis and the radius of curvature of asperity peaks increased to synthesise plastic deformation. The process was developed by comparison with the real run-in profiles and with observed changes in asperity peak radii of curvature. The synthesised and measured run-in surfaces were compared in various ways. Their geometry was examined in terms of form and asperity peak radii of curvature. Rolling sliding EHL contact analyses were run and their behavior in terms of peak asperity pressure and direct contact was assessed. The transient mixed EHL analysis results were used to apply surface loading to the rough profiles to obtain stress histories which were the basis of the fatigue modeling carried out.

2:30 – 3 pm | Influence of Specific Film Thickness and Surface Roughness Properties on Micropitting Damage

Amir Kadiric, Benjamin Wainwright, Pawel Rycerz, Imperial College London, London, United Kingdom

Micropitting is a type of rolling contact fatigue damage that occurs in rolling-sliding contacts as a result of cyclic stresses on the roughness asperity level. Despite its increasing occurrence in gear applications, the mechanisms behind micropitting are not well understood. It is well established that micropitting occurs at low specific film thicknesses (L ratio). However, the key issues that need answering are how the extent of micropitting damage is affected by the actual L ratio, and whether the spatial and height characteristics of surface asperities are just as significant as the L ratio itself. This work attempts to answer the above questions through systematic studies of micropitting using a triple-disc rolling contact fatigue machine, in parallel with rough surface contact simulations. In an attempt to understand the mechanisms at play, particular attention is paid to the continuous interaction of micropitting damage with the competing mechanism of mild wear.

3 – 4 pm | **Exhibitor Appreciation Break**

4 – 4:30 pm | Development of a CEC-Pitting Test Method for Gear Lubricants – Measures to Reduce Scattering and Micropitting Generation in Gear Pitting Tests

Christopher Illenberger, Institute of Machine Elements Gear Research Centre (FZG), TU Munich, Garching, Germany

The lubrication condition in the contact zone of two meshing gears has essential influence on the pitting lifetime of oil-lubricated gears. Mechanical and chemical stresses are mainly influenced by surface texture, lubricant film thickness and chemical-physical interaction between tooth flank surface and lubricant. To determine the performance of gear lubricants regarding the pitting load carrying capacity, standardized test methods are desired. Extensive testing has shown that the generation of micropitting can strongly influence the pitting lifetime leading to increased scattering, which impedes a reliable determination of the pitting load capacity of different lubricants. This complicates the discrimination between the pitting load capacity of the investigated lubricants. Measures to reduce scattering and to improve the test reliability have been investigated within the development work for a standardized CEC-Pitting test method, which is expected to be published in the near future.

4:30 – 5 pm | A Model for the Formation and Wear of Oxide Tribofilms on Aerospace Steels Under High-Speed Boundary Lubrication Conditions

Sean McIntyre, Penn State University, Wayne, PA, Stephen Berkebile, Nikhil Murthy, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

A model for the formation and wear of oxide tribofilms under high-speed boundary lubrication is presented. The rate of oxide film formation is modeled using an Arrhenius equation based on the maximum temperature of the contact, as well as the maximum temperature between interacting asperities in contact. Diffusion of oxygen into the metal is modeled using an unsteady quasi one-dimensional approach, with the flux of oxygen into the metal at the surface determined by the rate of oxide film formation. A model for the temperature and friction-dependent rate of wear and its effect on the thickness of the surface of oxide films is included. The friction coefficient is modeled using the surface concentration of oxide: more surface oxide produces a relatively low friction coefficient, while less surface oxide leads to higher friction due to bare metal contact.

5 – 5:30 pm | A Model for Gear Life with Surface and Subsurface Survival: Tribological Effects

Guillermo Morales-Espejel, SKF, Nieuwegein, UT, Netherlands

Based on well-established methods used in dynamic load capacity of machine components a concept model for gear fatigue life is presented. It applies the Weibull's weakest link of material strength and the L-P theory for bearing dynamic load ratings. The model introduces of a well-defined separation between the risk of surface initiated failures and the traditional subsurface fatigue of the gear contact. This opens new possibilities for the use of specialized endurance models to predict surface life of a gear contact. Comparison between experimentally obtained gear endurance and L10 predicted life, using the present theory, indicates the ability of the model to account for the gear endurance and the contribution of the surface to the performance. This new approach is of advantage for future progress in gear design. It introduces a new parameter that, in case of failure, defines the probability of it happening at the surface. This could represent a new way to assess micropitting risk.

5:30 – 6 pm | Industrial Gear Oil Models Based on High-Viscosity Naphthenic Base Oils and Viscosity Index Improvers

Thomas Norrby, Linda Malm, Nynas AB, Nynashamn, Sweden

Naphthenic base oils for industrial lubricants offer benefits with regards to solvency and low temperature properties. Naphthenic base oils do not, however, on their own have the required Viscosity Index (VI) required in the common ISO VG grades for many industrial lubricants. In, for example, Industrial Gear Oil standards such as ISO 12925-1 and DIN 51517-3, a minimum viscosity index of 90 or 85 is required. Therefore, to be able to formulate gear oils, we have created a set of model base fluids meeting these Viscosity (KV) and Viscosity Index (VI) requirements. We made a range if ISO VG classes from NYNAS T 110, BT 150, T 400 and T 600 with the addition of Viscosity Index Improvers (VII), Viscosity Modifiers (VM) or high VI base fluids. We managed to meet KV and VI requirements for ISO VG 150, 220, 320, 460, 680 and 1000. We intent to share these results with formulator eager to explore the span of opportunities offered by Naphthenic base oils in industrial lubricant applications.

6 – 6:30 pm | Gears Business Meeting

Session 2E • Music Row 5

Commercial Marketing Forum II

1:30 – 2 pm | Songwon Fuel and Lubricant Antioxidants

Wayne Sawyer, Songwon Industrial Group, Friendswood, TX

SONGWON is a leader in the development, production and supply of specialty chemicals. Founded in 1965 and headquartered in Ulsan, South Korea, it has become the second largest manufacturer of polymer stabilizers worldwide. The company has an extensive portfolio of aminic, phenolic, phosphite and thioester antioxidants for lubricants, in automotive and industrial applications. Aminic and phenolic antioxidants are primary antioxidants which retard oxidation in oil by reacting with and stabilizing free radicals. Phosphite antioxidants and thioesters are secondary antioxidants which decompose hydroperoxides formed in the oil. SONGWON manufactures antioxidants at its world-scale plant in South Korea. Backward integration of key raw materials, streamlined production and economies of scale help to ensure availability and reliable supply. Close cooperation with customers enables SONGWON to develop solutions for today and tomorrow to meet new and ever more demanding market requirements.

2 – 2:30 pm | ExxonMobil Chemical

Enabling Engine-oil Fuel Economy Through Base Stock Innovation

Michael Sheehan, ExxonMobil Chemical Company, Houston, TX

Aggressive CO_2 emissions and fuel economy standards continue to spur new developments in automotive lubrication. Formulators are challenged to develop ultra-low-viscosity lubricants for passenger vehicles while providing excellent durability and long drain intervals. Additionally, efforts are rapidly expanding to improve fuel economy in commercial vehicles. ExxonMobil Chemical continues to explore novel base stocks that meet the most challenging formulation demands. This presentation will highlight ExxonMobil's efforts to develop lower viscosity molecules without sacrificing critical properties such as volatility and oxidative stability. These solutions are targeted at providing formulators greater flexibility when developing 0W-8, 0W-12, and 0W-16 grades. The presentation will also explore base stock solutions that boost fuel economy in higher viscosity grades (e.g. 5W+). These solutions use novel molecules to expand fuel economy benefit beyond traditional formulations.

2:30 – 3 pm | KAO Chemicals

Emulsifiers to Solubilizers – Spanning from Foam Control, Corrosion Inhibition to Fluid Longevity

Sabine Wohlfahrt, Kao Chemicals GmbH, Emmerich, Germany

KAO Chemicals is a well-established supplier for surfactant technology used in high-end technical applications such as metalworking. Surfactants, including emulsifiers, co-emulsifiers and solubilizers are key ingredients for cutting edge metalworking fluids. Core requirements of today's metalworking fluids are low foaming behavior, fluid cleanliness and longevity, all directly correlated with the (co-)emulsifiers used. KAO's AKYPO® ether carboxylic acid co-emulsifier and solubilizer products are essentials for longer lifetime metalworking fluids. Additionally, the KAO metalworking toolbox includes nonionic emulsifiers AMIDET, AKYPO® ROX/KAO FINDET MB and phosphate esters FOSFODET. All designed to meet the requirements demanded by today's market. Performance highlights will be illuminated by practically relevant tests on key parameters such as emulsifier efficacy, foam control, corrosion inhibition, hard water tolerance and fluid cleanliness.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | LANXESS

Introducing LANXESS Additin® RC 3502 – A Novel Organic Friction Modifier Designed to Not Only Reduce Friction, But to Deliver Sustained Performance and Antiwear Protection During the Operation of the Lubricant

Caroline Davison, University of Northumbria, Manchester, United Kingdom

Effective lubrication continues to play an important role in fuel efficiency and engine protection, but lubricant formulators are facing increased pressure from the continued move to lower viscosity engine oils coupled with the use of new materials of construction and powertrain electrification. With this in mind Lanxess has developed Additin® RC 3502, a metal free, SAPS free, non corrosive durable liquid additive that is fully compatible in all synthetic and mineral oils. The unique nature of this product 'boosts' additive-additive interactions directly at the frictional surfaces, where MoDTC friction modifier, antiwear and detergent additives work. These durable, compatible and synergistic benefits provide the freedom to formulate high performance lubricants without restriction or compromise.

2E

4:30 – 5 pm | **ANGUS Chemical Co**

A Natural Resource

Michael Lewis, ANGUS Chemical Co., Buffalo Grove, IL

Before the Internet, a cookbook was the best resource to find new recipes. Today, a quick Google search is all you need to find new ideas that fuel creativity in the kitchen. The challenges of formulating metalworking fluids are changing, but what about the resources available to you?

At ANGUS Chemical Co., we offer more than just versatile chemistries and tailored solutions. Over 70 years, we've honed our skills in manufacturing, applications testing, regulatory understanding and advocacy to help you cut through the clutter and achieve the target performance of your metalworking fluids quickly and easily. With perspectives ranging from formulation and regional regulations to end user education, ANGUS is a natural resource for formulators and manufacturers looking to solve their metalworking fluid challenges.

5 – 5:30 pm | **Evonik**

Novel Cost Saving Synthetic Solutions for the High-Tier Industrial Gear Oil Market

David Gray, Evonik Oil Additives, Horsham, PA

Environmental issues, social trends and changing regulations continue to drive the Industry to re-evaluate the current technologies and lubricants in all markets. The Industrial Gear Oil market has been relatively stable utilizing predominantly mineral oil based lubricants however established synthetic options are showing significant growth due to their longevity and superior performance. While the currently available synthetic options offer significant advantages in most areas, many users are struggling to justify the cost and formulation complexity for their Industrial Gear Oil applications. In response to this need, Evonik have developed NUFLUXTM synthetic base oils and tested them in a range of applications both on the bench and in the field. The author will discuss the concept, the development and the features and benefits of NUFLUXTM in addition to taking a critical look at recent field performance demonstrations in a range of applications.

5:30 – 6 pm | **BASF**

New Innovations and Developments in BASF Base Stock Technology

James Lansing, Gene Zehler, Jan Strittmatter, Edith Tuzyna, Frank Rittig, Michael Koch, BASF, Ludwigshafen, Germany

The market for synthetic base stock technology is constantly changing in response to industrial demands. As a leading Group V base stock provider, BASF has an extensive portfolio consisting of a variety of ester (under the trade name Synative®) and polyalkyene glycol (under the trade names Breox® and Plurasafe®) base stocks. Recent global trends have highlighted the need for key performance parameters, such as biodegradability, low toxicity, and enhanced frictional efficiency, while products are still expected to meet rigorous performance metrics. In response to market changes, BASF has developed several new ester, PAG, and unique hybrid base stocks. These new base stocks are designed to meet various commercial needs including cost attractive offerings, supply security, superior performance, sustainability needs, and more. Several new product offerings will be discussed during the presentation.

Session 2G • Music Row 3

Wind Turbine Tribology II

Session Chair:
Arnab Ghosh, Sentient Science, Idaho Falls, ID

Session Vice Chair:
Jonathan Leung, Georgia Institute of Technology, Atlanta, GA

1:30 – 2 pm | **Determining Mechanical Properties of White Etching Areas in Carburized 8620 Steel Using Spherical Nanoindentation**

Jonathan Leung, Richard Neu, Georgia Institute of Technology, Atlanta, GA, Vikram Bedekar, Rohit Voothaluru, The Timken Co., North Canton, OH

White etching areas (WEAs) are subsurface microstructural transformed regions found in bearing steels subject to rolling contact loading. Fatigue cracks are often found in conjunction with WEAs, and it has been suggested that the WEAs and fatigue cracks are related. However, the sequence of formation is still unclear. Determining the mechanical response of the WEAs through modeling and experiments is critical in providing clarity on their role in rolling contact fatigue. This work is focused on measuring the mechanical properties of WEAs using the Kalidindi-Pathak spherical nanoindentation protocols. The nanoindentation results show a significant increase in the indentation yield strength and reduction in indentation modulus. Using a "rule of mixtures" approach for closely packed nanocrystalline grains, the reduction in elastic modulus is shown to be associated with the presence of nanocrystalline grains within the WEAs.

2 – 2:30 pm | **Evaluating the Effect of Heat and Surface Treatments on the Formation of White Etching Cracks**

Benjamin Gould, Aaron Greco, Nicholaos Demas, Argonne National Laboratory, Argonne, IL

White etching cracks (WECs) have been identified as a mode of premature failure within wind turbine gearbox bearings. Though WECs have been reported in the field for over a decade, the conditions leading to these failures, and the process by which these failures culminate, are both highly debated. Because of the uncertainty regarding the formation mechanisms of WECs, multiple "solutions" have been implemented in the field. These range from heat treatments such as case carburization, to surface treatments such as black oxide coatings. The present work quantifies the effectiveness of these mitigation techniques using accelerated benchtop tests.

2:30 – 3 pm | **Effect of Lubricant Stability on White Etching Area Evolution Under Severe Dynamic Load Sliding Contact**

Sreeraj Kodoor, Linto Davis, P. Ramkumar, Indian Institute of Technology Madras (IITM), Chennai, Tamil Nadu, India

The lubrication engineers and tribologists are facing a key challenge on wind turbine gearbox (WTG) lubricant decomposition and followed by premature bearing failure called white etching cracks (WEC). Recently a new methodology, under pure sliding condition, is successfully replicated white etching areas (WEA) using the modified dynamic load Pin-on-Disc (PoD) within 40hr using low reference lubricant mixture for real-time hydrogenation. The objective of this work investigates the effect of different lubricants such as mineral oil, PAO and PAG synthetic base oils under extreme boundary lubrication on WEA formation during pure sliding condition of bearing steel using modified dynamic load PoD tribometer. Using the modified test rig, the experiments are conducted with contact pressure of 1.4GPa, sliding speed of 0.2m/s and 270 loading cycles/minute. The WEA evolution behaviour of synthetic lubricants and mineral oil are studied in detail using various metallographic inspection techniques.

YOU'RE INVITED!

74th STLE Annual Meeting & Exhibition
May 19-23, 2019
Omni Nashville Hotel
Nashville, Tennessee (USA)

Exhibitor Appreciation Hour

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

Omni Nashville Hotel

Refreshments will be served!

The trade show is a major component of STLE's Annual Meeting. In 2019 STLE is making it even easier for you to fit a visit to the exhibition into your personal itinerary with two hours of dedicated exhibit time—no need to worry about missing an education course or technical session!

Come view the newest products and services from the lubricant industry's leading companies. More than 100 exhibitors are in Nashville looking to do business with you.

As part of the Exhibitor Appreciation Hour, Evonik Oil Additives is holding raffles on Monday and Tuesday, May 20 and 21, at 3:30 pm in the exhibit hall. You must be present at **Evonik Booth 301** at time of drawing to win. Evonik is raffling three Bose Soundlink® around-ear wireless headphones II.

2019 Exhibit Schedule

Monday:	Noon-5 pm (Exhibitor Appreciation Hour 3-4 pm)
Tuesday:	9:30 am-Noon & 2-5:30 pm (closed for Presidents Luncheon - Noon-2 pm. Exhibitor Appreciation Hour 3-4 pm)
Wednesday:	9:30 am-Noon

Download the 2019 STLE 365 App. Annual Meeting section sponsored by **Palmer Holland/Focus Chemical.**

Exhibitors: To reserve a spot at the 2020 STLE exhibition at the Hyatt Regency Chicago in Chicago, Ill., contact Tracy Nicholas VanEe at (630) 922-3459, **tnicholas@stle.org**.

2G

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | The Role of Sulfur in Limiting Oil Drain Interval in Wind Turbine Main Gearbox Lubricants

Michael Blumenfeld, David Holt, Tabassumul Haque, ExxonMobil Research and Engineering, Annandale, NJ

The main gearbox lubricant is one of the most critical components of the modern geared wind turbine. These fluids are responsible for protecting gears and bearings under extremely high torque with severe and variable operating conditions. Despite its critical role, there is no industry consensus for identifying the "end of life" for a wind turbine gearbox lubricant. We conducted a review of used oil data and combined it with decades of up-tower experience to better understand the true failure modes of the main gearbox lubricant. Our results show that there is a significant lubricant failure mode that involves a reaction between certain sulfur-containing species and brass gearbox components which accelerates oil degradation in extended drain applications. In this paper, we will describe causes of lubricant failure, examine factors that influence lubricant failure timing, and present screener tests that predict lubricant failure in wind turbine gear oils.

4:30 – 5 pm | Initiation Mechanism of White Etching Cracks Under the Influence of Electric Current

Ling Wang, Viktorija Rumpf, University of Southampton, Southampton, United Kingdom, Alexander Schwedt, Joachim Mayer, RWTH Aachen University, Aachen, Germany, Walter Holweger, Schaeffler AG & Co. KG, Herzogenaurach, Germany

White etching cracks (WECs) formed at different stages have been created in DGBB 6206 bearings after being tested on an L11 bearing test rig at Schaeffler Technologies lubricated by a low reference oil under the influence of electrical current. The evolution of WECs in these bearings has been revealed through microstructural analysis using SEM, TEM, EBSD and EDX techniques and published at a previous STEL conference. Subsequent in-depth analysis of the WECs formed at their pre-stages has provided more evidence of WEC initiation mechanisms under electrical influence. Complimentary WEC experiments under different test conditions such as in-situ heating of WEAs, bearing tests without electrical current, with current and a high reference oil as well as on tests on FE8 without electrical current have been conducted to verify the WEC initiation mechanisms.

5 – 5:30 pm | Real Scale Test of an Innovative Sensor-Set for Early Risk Detection of White Etching Cracks at a 2.7-MW Wind Turbine Gearbox

Freia Harzendorf, Ralf Schelenz, Georg Jacobs, RWTH Aachen University, Aachen, Germany, Walter Holweger, Schaeffler AG & Co. KG, Herzogenaurach, Germany, Torsten Bley, Hydac Electronic GmbH, Saarbruecken, Germany, Soeren Barteldes, QASS GmbH, Wetter, Germany

A common challenge in windturbine drivetrain technology are unexpected bearing failures caused by so called White Etching Cracks (WEC). Lubricant composition, presence of additional electrical exposure and mechanical loading may lead to WEC. Despite of considerable effort in research root causes for such failures are not entirely understood. An elementary aspect of improving windturbines reliability is to detect these failures or their preliminary stages as early as possible. Therefore, an innovative sensor-set has been compiled which enables monitoring these influencing factors. For real scale tests it is applied to the high-speed-shaft bearing of of a 2.7 MW windturbine gearbox. The campaigns goal is to apply WEC-critical but realistic transient operational conditions. The innovative sensor-set is tested under realistic conditions to increase its forecasting abilities. These results entail a significant step towards early WEC risk detection and windturbine technology improvement.

5:30 – 6 pm | Wind Turbine Business Meeting

Session 2H • Music Row 2

Testing in Soft Tribology

Tribotesting & Biotribology Joint Session

Session Chair:
Alex Lin, Northwestern University, Evanston, IL

Session Vice Chair:
Gagan Srivastava, The Dow Chemical Co., Freeport, TX

1:30 – 2 pm | Relating Sensory Perception to the Tribology of Milk

Grace Hully, Izzy Roots, Tom Welham, PCS Instruments, London, United Kingdom, Philippa Cann, Marc Masen, Imperial College London, London, United Kingdom

In recent years there has been rapid growth in the variety and availability of non-dairy milk alternatives, driven by consumers' ever evolving demands. It has been shown that emulating the conditions within the mouth during food oral processing, and to quantify the differences and similarities in friction between different dairy and non-dairy milks would be a valuable tool in the future development of milk alternatives. In this study, we have used a Biotribology Machine (BTM) to measure real time friction over the full reciprocating cycle. Tests were performed looking at dairy milks of differing fat content and the differences between non-dairy milks and a typical semi-skimmed dairy milk. Results will be presented that show the effect of varying fat content across dairy products, in addition to the widely varying friction traces from popular non-dairy substitutes and the importance of being able to compare instantaneous friction events at any point in the reciprocating cycle.

2 – 2:30 pm | Test Methods with Natural and Artificial Specimen for Biotribological Applications

Florian Rummel, Kartik Pondicherry, Anton Paar GmbH, Ostfildern, Germany

Tribological scenarios can be found in numerous biological and medical applications ranging from articular joints, catheters to the oral cavity. Understanding the behavior of such tribosystems is crucial for the development of life science and medical products. Within this study, the authors discuss as to how biotribological studies can be carried out with natural tissues, such as articular cartilage, or with the help of artificial substitutes such as polyvinyl alcohol (PVA) or artificial skin. This study covers novel test methodology which includes development of customized adapters to allow fixing of such tissues in order to evaluate their tribological behavior at low loads, covering sliding speeds from several nanometers up to around one meter per second. Results from different case studies are presented in the form of extended Stribeck curves and breakaway torque measurements.

2:30 – 3 pm | Finger-Pad Gripping: Understanding the Influential Factors

Raman Maiti, Wei Li, Zeng Lu, Stephen Matcher, Matt Carre, Roger Lewis, University of Sheffield, Sheffield, United Kingdom

Biomechanical properties of the human finger-pad are of great importance for research related to medical devices and sports. The aim of the paper is to understand the influence of external, topographical and physical properties on the friction of finger-pad using non-invasive optical coherence tomography (OCT) devices. Two optical devices, clinical (VivoSight®) and in-house (SDOCT), were used to measure the surface and sub-surface of the finger-pad sink. VivoSight and SDOCT system operated at an A-scan capturing rate of 20 kHz. The measured axial and lateral resolution of the SDOCT were 2.6 µm and 8 µm and VivoSight were 5µm and 7.5µm respectively. The finger-pad was dragged over a glass surface (0.2mm thickness) with the finger-pad facing upwards.

The forces on the finger were measured using multi-axial force plate HE6X6 from Advanced Mechanical Technological Inc. The different factors were influential in flattening/smoothening of the surface and sub-surface of the finger-pad skin.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | Open Slot

Session 2J • Cumberland 3

Nanotribology II

Session Chair:
Tevis Jacobs, University of Pittsburgh, Pittsburgh, PA

Session Vice Chair:
Zhijiang (Justin) Ye, Miami University, Oxford, OH & Hongyu Gao, Universität des Saarlandes, Saarbrücken, Germany

1:30 – 2:30 pm | Invited Talk: Molecular Behaviors in Thin Film Lubrication

Jianbin Luo, State Key Laboratory of Tribology, Beijing, China

The behavior of liquid lubricant molecules, especially the molecules near the solid surface is very important to the property of the whole tribo-system. Thin film lubrication (TFL) has been proposed to characterize the molecular pattern in lubrication film less than hundred nanometers, which effectively bridged the gap between elastohydrodynamic lubrication (EHL) and boundary lubrication. Unfortunately, to date, the molecular model of TFL which was proposed 20 years ago has not been well proven. Recently a new method based on surface-enhanced Raman spectroscopy developed in our group allows us to access the molecular behavior in a nano-confined film, along with both the packing and orientation of the liquid molecules in TFL regime. The presentation attempts to systematically review the major developments of TFL, including the state-of-art studies on experimental technologies, researches and applications.

2:30 – 3 pm | Why Many Liquids Appear to Solidify During Squeeze-Out – Even When They Don't

Hongyu Gao, Martin Müser, Universität des Saarlandes, Saarbrücken, Germany

Liquid lubricants exhibit load-carrying capacity when they are squeezed by solid walls, along with layering structure as well as increase of shear viscosity. The ever-increasing molecular ordering within the confined space can substantially affect the tribological performance of the system. Molecular dynamics simulation was carried out based on a simple tip-confining model system. This work aims to establish a network between confined-liquid behavior and the corresponding bulk properties. Specifically, solvation force and local stresses were first reported as functions of confine distance (d), where stress anisotropy becomes increasingly evident as d decreases. In addition, spacing between adjacent confined layers is comparable to the decay length of bulk liquid density oscillation. It suggests that the ability of a liquid to sustain non-isotropic stresses is not necessarily related to solidification but may be a natural consequence of liquid oscillating density correlation.

3 – 4 pm – Exhibitor Appreciation Break

4 – 4:30 pm | Dynamic Behavior of a Droplet Under Vibration Condition

Jing Xu, Jiadi Lian, Guodong Liu, Shaochao Fan, Jing Ni, Hangzhou Dianzi University, Hangzhou City, China

A 3D laser marking machine is used to fabricate the rough substrate with micro-texture surface. The dynamic change process of droplets on the micro-texture substrate is collected by high-speed micro-camera under vibration condition. The dynamic behavior of a droplet under vibration condition the friction mechanism are studied systematically. The experimental results show that when the micro-vibration of a certain frequency is applied on the micro-texture metal surface, with the alternating change of the contact angle difference between the droplets from the left to the right, droplets produce alternating shrinkage and elastic deformation of tension.

4:30 – 5 pm | Effect of the Dispersion of Nanoparticle Additives on Their Lubricity for Use in Metalworking Fluids (STLE Early Career Award Winner)

Shilpa Beesabathuni, Yan Zhou, Yixing Philip Zhao, Houghton International Inc., Norristown, PA

Nanoparticles are used as lubricity additives to reduce friction and wear as they can potentially outperform molecular additives, especially under high thermal and mechanical stresses. However, aggregation of the nanoparticle additives in lubricant oil adversely affects their tribological performance, because of a reduction in the effective particle concentration. In this study, we explore the effect of the dispersion of the nanoparticle additives on their tribological behavior in a base oil. A fully formulated metalworking lubricant was also applied as a comparison. The development of a well-dispersed and stable colloidal system is highly desirable to enhance the performance of nanoparticle additives.

5 – 5:30 pm | Interfacial Nano-Mechanics of Friction Modifiers

Kazushi Tamura, Kenji Sunahara, Hiroyuki Tatsumi, Motoharu Ishikawa, Idemitsu Kosan Co., Ltd., Ichihara, Japan, Masashi Mizukami, Kazue Kurihara, Tohoku University, Sendai, Japan

In recent years, with the tightening of environmental regulations, reducing energy loss are required in many fields of industry. Although friction modifiers (FMs) are promising lubricant additives to reduce friction and to improve energy efficiency, their mechanisms have not been fully understood. Here we analyzed the effects of FMs on shear characteristics of interfacially confined lubricants by using a surface force apparatus and resonance shear measurements. We found that interfacial confinement induced solidification of lubricant base oils and that FMs greatly inhibited this confinement-induced solidification. However, our analysis did not show substantial effects of FMs on the relationships between normal force and surface separation distance. These results suggest that inhibiting solidification plays a dominant role in FMs' friction reduction, regardless of their film-thickening ability.

5:30 – 6 pm | Study of the Nanoscale Wear Behaviors of Gallium Nitride Using Molecular Dynamics

Pengzhe Zhu, Beijing Jiaotong University, Beijing, China

In this work a series of molecular dynamics simulations of nanoscratching of gallium nitride (GaN) using a diamond indenter are conducted to investigate the anisotropic mechanical responses of GaN. The simulations are performed on the c-plane and m-plane GaN. Through the study of coordination and stress distribution, we explore the plastic deformation mechanisms of GaN, which are dominated by the nucleation and propagation of dislocations. We found the anisotropic deformation behaviors of c-plane and m-plane GaN in the scratching process. We also found that for a constant scratching depth, both the average friction force and friction coefficient for the c-plane are smaller those of m-plane of GaN. These results shed light on the application of semiconductor devices with required properties.

Session 2K • Cumberland 4

Metalworking Fluids II

Session Chair:
Jill Myers, The Timken Co., North Canton, OH

Session Vice Chair:
Emil Jon Schnellbacher, Lawrence Technological University, Allen Park, MI

1:30 – 2 pm | Comprehensive Investigations of Tribology Properties of Metalworking Fluid Chemistries on Multi-Metals

Yixing Philip Zhao, Houghton International Inc., Norristown, PA

Presently, there is a need in the metalworking fluids market for products which can machine metals such as steel, aluminum, titanium etc. A good lubricant not only needs to reduce friction, but also is expected to extend tool life, improve surface finish and increase productivity. These performance expectations require the development of next generation products with good tribological properties and enhanced performance. Tribology is the science of friction, wear and lubrication. However, in the metalworking fluid industry we have limited means to measure friction and even fewer ways to study wear and surface quality of parts and tools. In this presentation, we will discuss some examples of comprehensive tribological tests measuring friction and surface quality of different metals using several metalworking fluid emulsions. The investigation enabled us to better understand the effect of the chemistry of the fluids on the tribological properties of different metals.

2 – 2:30 pm | Go Figure: Using Analytics and Statistics in Metalworking

Emil Jon Schnellbacher, Formulas & Solutions, LLC, Allen Park, MI

Innovation and New Product Development struggles to make things better, faster, and cheaper. Is there a way to consistently formulate new products in a way that optimizes the constraints of: quality, time and money? Statistical models like Design of Experiment (DOE) are already used by some companies to optimize formulation in the laboratory phase of development. Not as many companies integrate analytics in the fuzzy-front-end of innovation to capture customer aspirations for new product selections. However, the use of analytics can assist in determining the voice-of-the-customer and developing better product specifications. By accurately determining the customer desires and needs, this minimizes guessing during the formulation and optimizes the likelihood of success during product launch. This paper presents a conceptual framework by using examples of this approach in optimizing formulation and new product development in metalworking fluids.

2:30 – 3 pm | Coolant Emulsion Properties and Field Performance of Metal Removal Fluids

Yixing Philip Zhao, Houghton International Inc., Norristown, PA

Over the last two decades, the products and chemistries of water based metal removal fluids have evolved significantly. The changes were driven by both market needs and technology innovation. The industry needs coolants to provide good performance such as good lubricity, enhanced cooling, biostability/long sump life, low foam, super detergency and dispersion, corrosion protection and better chip handling. On the technology side, new chemicals, better understanding of the chemistries and the adoption of sophisticated and systematic formulation methods have enabled us to develop robust and globally compliant [DC1] products with the above properties. In this presentation, we will first review current industry coolant performance requirements. We will then focus on important properties of coolant emulsions and their correlation to their performance in metal removal applications.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | New Innovations in Rust Preventive Sustainability

Amelia Hadler, Jennifer Clark, Gregory Moran, Eric Rodeheaver, Britt Minch, The Lubrizol Corp., Wickliffe, OH

Traditional rust preventives have proven invaluable when it comes to providing critical corrosion performance while maintaining a near-invisible film and a stable finished product. However, growing concern surrounding the sustainability of raw materials could threaten existing rust preventive formulations. In addition, there is increasing interest in products that provide more advanced corrosion performance while simultaneously maintaining the flexibility to be used in a wide array of diluents. This talk will explore the benefits of using innovative film-forming chemistries to address these challenges. A new rust preventive based on sustainable raw materials is introduced. When compared to conventional rust preventives, this product shows superior corrosion performance as well as premium solubility in multiple diluents including Group II and higher paraffinic base oils and high-flash point solvents.

4:30 – 5 pm | Parts Cleaning Fundamentals – Importance of Cleaning and Rinsing

Suresh Patel, Chemetall, New Providence, NJ

To increase the effectiveness of the finish or final product/assembly, parts must be cleaned prior to the subsequent process(es). If the cleaner does not fulfill its purpose of removing unwanted soils from the substrate, subsequent processing steps will be impacted negatively e.g. not produce a uniform conversion coating, and therefore inadequately protect the metal surface from corrosion. A high-quality metal surface preparation (cleaning and rinsing) combined conversion coating and the appropriate organic coating is essential for the durability of finished products. Rinse water quality and proper rinsing are as critical, yet often-over-looked step in the metal preparation process. A well-designed, lean cleaning and rinsing process can help improve product quality, thru-put, and higher profits! This paper will focus on different cleaning technologies (mechanical & chemical primarily) and issues specific to the parts cleaning industry.

5 – 5:30 pm | Metalworking Fluids Business Meeting

Session 2L • Cumberland 5

Nonferrous Metals II

Session Chair:
Thomas Oleksiak, Novelis Global Research & Technology Center, Kennesaw, GA

Session Vice Chair:
Annie King, Houghton International Inc., Valley Forge, PA

1:30 – 2 pm | Thermal Behavior of Polyformates of Milkweed and Soybean Oils

Rogers Harry-O'kuru, James Xu, Girma Biresaw, USDA-ARS-NCAUR-BOR, Peoria, IL

Reprocessing of neat vicinal polyformate esters of milkweed, and soybean triglycerides in a silica drying column with mild heating resulted in a light reddish-orange gel formation of the column eluate on cooling. Analysis of the gel by 1H- and 13C-NMR showed products of possible elimination which include olefinic/aromatic moieties following possible elimination and rearrangement. A free carboxyl moiety in the gel matrix was observed. FT-IR of the gel suggested formation of olefinic species.

Trial runs to reproduce the column results by heating aliquots of the neat vicinal polyformate under N2 with and without silica gel generated a gas that discharged basic phenolphthalein solution. Further heating gave a tacky off-white polymer that was chloroform insoluble. In contrast, the vicinal polyacetate derivatives of milkweed and soybean oils were stable under similar reaction conditions.

2 – 2:30 pm | Development of Novel and Safer Dt-MPM Antioxidants and McIn Multifunctional Corrosion Inhibitors for Industrial Applications

Ashok Cholli, Polnox Corp., Lowell, MA

Lubricants and biolubricants are composed of base oil and additives. Key additives common to most formulations include additives like anti-oxidants, corrosion inhibitors, anti-wear additives, extreme pressure agents and emulsifier/demulsifier and other additives. The selection of lubricant additives is geared to address the desired lubricant performance related to the specific application and the oxidative-stability or the quality of the base stock oil used. Awareness of the toxicity issues related to the petroleum-based oils and additives that are used in the industrial lubricant products necessitated to develop and use environmentally acceptable lubricants. Polnox has been addressing the use of new and safer additives by developing novel technologies such as Dt-MPM™ antioxidants and McIn™ corrosion inhibitors for bio lubricants and lubricants without compromising their performance compared to commercial additives. Their effectiveness and benefits will be illustrated with examples.

2:30 – 3 pm | Effect of Isomerization on the Physical and Tribological Properties of Oleic Acid

Girma Biresaw, Robert Dunn, Grigor Bantchev, Rogers Harry-O'kuru, USDA-ARS-NCAUR-BOR, Peoria, IL, Helen Ngo, USDA-ARS-ERRC, Wyndmoor, PA

Isomerization is a powerful tool used by chemists to expand the physical and chemical properties of a wide range of organic molecules. Isomerization is widely applied in several industries to extend the application range of products and / or to formulate new line of products. Examples of industries that routinely apply isomerization in their product development include: lubricants, fuels, cosmetics, pharmaceuticals and food. Recently, a USDA patented procedure was used to isomerize oleic acid into iso-oleic acid. The two fatty acids are similar in the total number of carbons and double bond in their structure. However, the iso-oleic acid has a methyl substituted double bond randomly located along its chain. The effect of isomerization on the physical and tribological properties of these two fatty acids were investigated. The results of this investigation will be discussed in this paper.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | Scuffing Performance of Brass-Cast Iron Contact Pair in Hydraulic Fluid

M. Cinta Lorenzo Martin, Oyelayo Ajayi, Sheera Lum, George Fenske, Argonne National Laboratory, Lemont, IL, Girma Biresaw, Grigor Bantchev, Rogers Harry-O'kuru, USDA-ARS-NCAUR-BOR, Peoria, IL

Efficiency of hydraulic fluid power system can be increased by operating at higher pressures. Similarly, size reduction in the system will require higher power density and operation at higher pressures. Such operating conditions makes sliding components in hydraulic pumps susceptible to scuffing failure. This paper presents scuffing performance evaluation of bronze and cast-iron sliding contact pair in fully formulated commercial hydraulic fluid and several experimental composite fluids. Using a step load increase test protocol, scuffing was observed to occur in the commercial fluid and PAO basestock. Scuffing resulted in severe plastic deformation and roughing of the bronze material contact area. In composite fluids consisting of PAO and bio-based phosphonate ester fluid, only polishing wear was observed even after very high contact loads. Results of present study suggest composite fluids are potential candidates for scuffing prevention in hydraulic pumps operating at high pressure.

4:30 – 5 pm | Water Soluble/Dispersible Corrosion Inhibitors for Nonferrous Metalworking Fluids

Tiffany Meyers, Clariant, Mount Holly, NC

Aluminum alloys are increasing in use in many industries to reduce weight, leading to improved energy consumption and fuel efficiency. Corrosion inhibitors can be a valuable tool used for formulating synthetic, semi-synthetic and soluble oil fluids. These additives are effective in protecting aluminum and, at the same time, deliver additional functionalities which help metalworking fluid formulators address today's formulation challenges. During manufacturing and processing of these nonferrous materials (e.g. rolling, cutting, forming, grinding), a metalworking fluid could be exposed to components made of steel, copper or cobalt from contact with equipment and/or tools. A variety of water-soluble and water-dispersible corrosion inhibitors have been screened, evaluating performance criteria such as inhibition of staining on aluminum, steel protection, copper and cobalt leaching prevention, lubrication contribution, foaming tendency, and electrolyte stability.

5 – 5:30 pm | Synthesis and Detailed Characterization of Dimer and Trimer Acid Products Using Acid Zeolite Catalysts

Helen Ngo, Jianwei Zhang, Alberto Nunez, Robert Moreau, USDA, Wyndmoor, PA

Dimer and trimer fatty acids are synthetic biobased products used in many applications including polyamides, polyurethanes, adhesives, and lubricants. The industrial production of dimer/trimer acids is through dimerization of fatty acids with clay catalysts. However, clay catalysts cannot be recycled, which is an environmental concern. The structures of dimer/trimer acids, which can affect the synthesis and properties of the downstream products are poorly understood and inconsistent. This paper will focus on our efforts to overcome these concerns and ambiguities. Specifically, the advantages of using the recycled zeolite catalysts for a more environmentally friendly process will be discussed. Detailed structural information on the products verified by nuclear magnetic resonance and mass spectroscopy will also be presented. Ultimately, the goal of this new approach is to lead to an improved and more consistent material quality for the dimer/trimer acid industry.

5:30 – 6 pm | Nonferrous Business Meeting

Session 2M • Cumberland 6

Fluid Film Bearings II

Session Chair:
Troy Snyder, The University of Akron, Akron, OH

Session Vice Chair:
Michel Fillon, Institut Pprime, Futurocope Chasseneuil Cedex, France

1:30 – 2:30 pm | Adapting Fluid Film Bearing Technology for the New Context of Industry 4.0

Ilmar Santos, Technical University of Denmark, Lyngby, Denmark

Industry 4.0 can be defined as the overlay of several technological developments involving products as well as processes. Industry 4.0 is related to the Cyber-physical systems which describe the merger of digital with physical workflows. Cyber-physical systems combine mechanics, electronics, computation, and capacity of data storage and use the Internet as a communication medium. Industry 4.0 embraces a set of technologies enabling smart products. Smart products are characterized by the capability of performing computations, storing data, communicating and interacting with their environment. The Active Magnetic Bearing (AMB) is a typical smart machine element or smart product which is completely adapted to Industry 4.0 framework due to its intrinsic electronic sensing and actuation capabilities. Fluid Film Bearing (FFB) technology watches nowadays an exponential use of AMB technology in many rotating machines.

2:30 – 3 pm | Dynamic Experimental Research of Controllable Squeeze Film Damper

Chao Chen, Xiaojing Wang, Nie Zhou, Jun Liu, Jiaqi Zheng, Caizhi Zhu, Shanghai University, Shanghai, China

In order to decrease the vibration amplitude of rotor-bearing system, the concept for journal bearing with additional fluid film thickness in the bearing was proposed to alter the dynamic properties in this research. A new controllable squeeze film damper (CSFD) was brought out and the dynamic theoretical model of CSFD rotor-journal bearing system was established. Besides, the dynamic characteristics of CSFD journal bearing were studied by making use of a bearing test rig under different rotating speed, load and oil supply pressure. The experimental results demonstrate that, CSFD can suppress vibration and improve stability of rotor-bearing system. Besides, the reducing effects of the main bearing stiffness combined with CSFD were investigated which is basically consistent with the theoretical results. Under the same external condition, dynamic characteristic parameters have a positive correlation with the magnitude of the applied load.

3 – 4 pm | Exhibitor Appreciation Break

4 – 4:30 pm | A New Test Rig to Meet Industrial Applications: Startup and Performance of a Two Lobe Journal Bearing

Jean Bouyer, Pascal Jolly, Michel Fillon, Institute Pprime, Futuroscope Chasseneuil Cedex, France

This work aims to present the first tests operated on the brand new test rig of our team from Pprime Institute. It consists in a 315mm in diameter journal bearing subjected to speed up to 2,000 rpm and static loads up to 100 kN. Several problems due to the dimensions of the test rig and the solutions which were found will be presented. First tests on a babbitted two-lobe journal bearing will be described and the performance of the bearing will be detailed in terms of pressure, temperature, torque and film thickness measurements. The presentation will point out the real capabilities of the test rig.

4:30 – 5 pm | Ultrasonic Oil Film Measurements in Journal Bearings

Scott Beamish, Henry Brunskill, Andrew Hunter, Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

This paper describes the design and build of a journal bearing test platform which incorporates both shaft and bearing mounted ultrasonic arrays. These arrays produce high-resolution measurements of oil film thicknesses at a capture rate to 80,000Hz. Results have been validated against theoretical models, bench testing and in-line gap sensors to demonstrate accuracy. This versatile system has been designed to operate under a wide range of conditions including variable speed, load, oil type and temperature, thus making it suitable for many new and exciting applications. This work focuses on the rig design, sensor instrumentation, refining the ultrasonic measurement technique, validation and how the system is being applied to highly relevant industrial problems. Current investigations include misalignment, vibration, start-up, and comparison of environmentally acceptable lubricants (EALs) against traditional mineral oils.

5 – 5:30 pm | Development of A Gaseous Cavitation Model for Oil-Film Bearing Considering Thermal Effect

Aoshuang Ding, Xuesong Li, Xiaodong Ren, Chunwei Gu, Tsinghua University, Beijing, China

Thermal effect strongly influences the lubricant viscosity in bearings. In this paper, an original isothermal gaseous cavitation model has been corrected with the energy equation included based on the mixture heat capacity. For validation, in eight different cases at 2000 and 3500 rpm, the simulation results of the gaseous cavitation model with thermal effect considered are compared with the half-Sommerfeld model, the Rayleigh–Plesset model, the isothermal gaseous cavitation model and experimental data. Among the three models, the gaseous cavitation model with thermal effect considered provides the best performance and can simulate the thermohydrodynamic characteristics and cavitation features of the journal bearing accurately. Therefore, the gaseous cavitation model with thermal effect considered is a reliable cavitation model for oil-film bearings.

5:30 – 6 pm | Experimental Investigations of Oil Pockets Effect on the Lubrication Regime Transition of Journal Bearings

Jaroslaw Sep, Lidia Galda, Rzeszow University of Technology, Rzeszow, Poland, Artur Olszewski, Tomasz Zochowski, Gdansk University of Technology, Gdansk, Poland

To prevent the bearing destruction the specific surface texture can be created on the sliding zones. One of the roles of surface irregularities is to keep some oil in case of its shortage. The aim of this paper is to identify the characteristic parameters such as sliding velocity, Hersey number and friction coefficient when the transition of lubrication regimes occurs for different types of journal bearings. The study shows the results achieved in experimental investigations for journal bearings with the oil pockets on journal surface mating with smooth bearing and with texture on bearing surface co-acting with standard smooth journal. The obtained results are also compared with the tests effects of classical smoothly finished journal bearings. It was found that textured journal bearings moved from mixed to hydrodynamic lubrication faster and at lower speed in comparison to smooth journal bearings.

6 – 6:30 pm | Fluid Film Bearings Business Meeting