Overview

Please check the errata in your registration bag to verify course times. Some times might change slightly.

THURSDAY, MAY 23

Registration (7 am – Noon) Second Level Omni Foyer

Thursday Speakers Breakfast (7 – 7:45 am) – Legends A

STLE Certification Exams (8:30 am – 12:30 pm) – Mockingbird 2

Thursday Technical Sessions (8 am – Noon)

- 7A ● Rolling Element Bearings III – Legends F
- 7B ● Biotribology II – Music Row 1
- 7C ● Power Generation I – Music Row 5
- 7E ● Tribochemistry – Materials & Nanotribology – Joint Session II – Music Row 3
- 7F ● Synthetic and Hydraulic Lubricants III – Music Row 2
- 7G ● Grease I – Cumberland 1
- 7H ● Materials Tribology IV – Cumberland 2
- 7I ● Contact Mechanics I – Cumberland 3
- 7J ● Surface Engineering III: Surface Texturing – Cumberland 4
- 7K ● Lubrication Fundamentals VIII – Cumberland 5
- 7L ● Condition Monitoring II – Cumberland 6

Lunch on your own (Noon – 1:30 pm)

Thursday Technical Sessions (1:30 – 6 pm)

- 8A ● Rolling Element Bearing IV – Legends F
- 8B ● Biotribology III – Music Row 1
- 8C ● Power Generation II – Music Row 5
- 8D ● Seals I – Music Row 4
- 8E ● Tribochemistry II – Materials and Nanotribology – Joint Session – Music Row III
- 8G ● Grease II – Cumberland 1
- 8H ● Materials Tribology V – Cumberland 2
- 8I ● Contact Mechanics II – Cumberland 3
- 8J ● Surface Engineering IV – Cumberland 4
- 8K ● Engine and Drivetrain V – Cumberland 5
- 8L ● Condition Monitoring III – Cumberland 6

Beverage Break (10 – 10:30 am) – Second Level Omni Foyer

Beverage Break (3 – 3:30 pm) – Second Level Omni Foyer

TIME	SESSION 7A Rolling Element Bearings III Legends F	SESSION 7B Biotribology II Music Row 1	SESSION 7C Power Generation I Music Row 5
8 – 8:30 am	Hoot Noise of Rolling Element Bearings: Are Non Linear Vibrations the Key Theory?, H. Grillenberger, p. 130	Lubricity of Synovial Fluid Constituents for Hydrogel Cartilage Model, Y. Sawae, p. 131	The Tribological Performance of Gas Turbine Lubricants, J. Airey, p. 132
8:30 – 9 am	"Reliving Pain" – Highest Performance at Toughest Conditions/The Development of a New Ball Bearing Type with Integrated Tilt Compensation, T. Kreis, p. 130	Size of Worn Region Predicts Fluid Pressures During Human Slips, K. Beschorner, p. 131	Oxidation Life and Sludge of Turbine Oil by Dry-TOST Test, D. Sun, p. 132
9 – 9:30 am	Investigations on Cage Dynamics in Rolling Bearings by Test and Simulation, S. Schwarz, p. 130	Role of Poroviscoelastic Relaxations in Rate-Dependent Cartilage Microfracture, G. Han, p. 131	There are No "Varnish-Free" Turbine Oils, M. Hobbs, p. 132
9:30 –10 am	Effect of Microgravity and High Temperature on the Dynamics of Ball Bearing, Y. Liu, p. 130	Competitive Rates of Cartilage Rehydration, D. Burris, p. 131	High Performance New Hybrid Turbine Oil Made by Mineral Oil and PAG, H. Sekiguchi, p. 132
10 – 10:30 am	**Break**	**Break**	**Break**
10:30 – 11 am	Measured Lubricant Rheology Based Traction Model for Rolling Bearings, P. Gupta, p. 130	Tribocorrosion of Duplex Treatments on Ti-6Al-4V in Ringer's Solution, B. Strahin, p. 131	
11 – 11:30 am	Experimental and Numerical Investigation of Hydraulic Losses in Rolling Bearings, A. Gonda, p. 130	Raman Spectroscopic Analysis of the Biochemical Reaction of Hyaluronic Acid in Joint Replacement, R. Rufaqua, p. 132	
11:30 am – Noon	The Effectiveness of Ball-On-Disc Tests at Simulating Friction in Greased Rolling Bearings – A Direct Comparison of Experimental Results, N. De Laurentis, p. 131	Agarose Hydrogel as a Carrier for Hyaluronic Acid with the Lubrication Efficiency of the Sustained Release, M. Hafezi, p. 132	

	SESSION 8A Rolling Element Bearing IV Legends F	SESSION 8B Biotribology III Music Row 1	SESSION 8C Power Generation II Music Row 5
1:30 – 2 pm	A Mathematical Emulation of Bair's High Pressure Visualization Cell and Improved EHL Traction Analysis for Heavily Loaded Rolling Contacts, C. Pan, p. 146	Invited Talk: Contact Mechanics for Characterization of Hydrogel Material Properties, M. Oyen, p.148	Fluorescence Spectroscopy for Online Condition Monitoring of Machinery Lubricants, P. Suresh, p. 149
2 – 2:30 pm	Numerical and Experimental Performance Analysis of an Aircraft Engine Roller Bearing Using under Race Lubrication Method, R. Kerrouche, p. 146	Shear-Induced Cellular Death Response, S.Hart, p. 148	Consequences of Incorrect EHC Fluid Maintenance and Opportunities for Improvement, P. Dufresne, p. 149
2:30 – 3 pm	Real-Time Modeling of Thermal Interactions in Cryogenic Ball Bearings, P. Gupta, p. 146	Mitigating Cartilage Strain and Shear by Simulating Activity Regimes with In-Situ Cartilage Explants, S. Voinier, p. 148	Understanding EHC Fluid Condition Monitoring, K. Brown, p. 149
3 – 3:30 pm	**Break**	**Break**	**Break**
3:30 – 4 pm	Modeling Heat Generation in Turbine Engine Rolling Bearings, J. Taketa, p. 146	Static Friction Phase Diagram for Hydrogels, R. Espinosa-Marzal, p. 149	Evaluation of Turbine Oil Performance, J. Mehta, p. 149
4 – 4:30 pm	Thermal Conductivity and Flash Temperature of Bearing Steel, T. Reddyhoff, p. 146	Effect of Shoe Outsole Backing on the Coefficient of Friction, A. Iraqi, p. 149	Power Generation Business Meeting
4:30 – 5 pm	Measurement of Free Volume of Lubricants from Pressure Dependence of Bulk Modulus, B. Zhang, p. 148		
5 – 5:30 pm	Investigation of the Synthetic Stiffness for Elastohydrodynamically Lubricated Cylindrical Roller Bearings, Z. Xiao, p. 148		

	SESSION 7E Tribochemistry II	SESSION 7F Synthetic and Hydraulic Lubricants III	
	Music Row 3	**Music Row 2**	
	Formation and Nature of Lubricious Carbon Containing Tribofilms, Q. Wang, p. 134	Novel Functionalized Polyalkylene Glycols and Their Synergy with Primary Anti-oxidants, M. Greaves, p. 136	**8 – 8:30 am**
	Interactions Between Tri-Cresyl Phosphate Lubricant Additive and Iron Oxide Explored Using Statistical Analysis of Reactive Molecular Dynamics Simulations, A. Khajeh, p. 134	From Jet Engine Oils to High Temperature Industrial Lubricants: High Performance Anti-oxidants for Synthetic Esters, S.Lucazeau, p. 136	**8:30 – 9 am**
	Reactive Molecular Dynamics Simulations of Thermal and Tribochemical Film Growth from Di-tert-butyl Disulfide on an Fe (100) Surface, K. Mohammadtabar, p. 134	Time-Resolved Oxidative Degradation of Ester-Based Lubricants Identified by Mass Spectrometry, N.Doerr, p. 136	**9 – 9:30 am**
	Surface Absorption and Chemical Reaction of Additives Studied by Molecular Dynamics, H. Washizu, p. 134	Hydraulic Lubricant Performance, a Corrosion and Oxidative Perspective, R. Kumar, p. 136	**9:30 –10 am**
	Break	**Break**	**10 – 10:30 am**
	Impact of Nanodiamonds on ZDDP Tribo-Film Formation at Stainless-Steel Contacts, B. Acharya, p. 134	Hybrid Antifoam Technology for Lubricating Oils, E. Galgoci, p. 136	**10:30 – 11 am**
	In-Situ Raman Spectroscopic Characterization of ZDDP Tribofilms, C. Garcia, p. 134	Ionic Liquid Additized Environmentally-Friendly Hydraulic Fluids, X. He, p. 136	**11 – 11:30 am**
	Effect of ZDDP on Hydrogen Absorption in Two Synthetic Oils, M. Ratoi, p. 136	Hydrocarbon-Mimicking Ionic Liquids as Low Vapor Pressure Triboimprovers, E. Nyberg, p. 137	**11:30 am – Noon**

SESSION 8D Seals I	SESSION 8E Tribochemistry III		
Music Row 4	**Music Row 3**		
Impact of Natural Surface Texture on the Lubrication of Mechanical Face Seals, N. Brunetiere, p. 150	Synthesis and Characterization of Novel Ni-Matrix Composites, S. Gupta, p. 152		**1:30 – 2 pm**
Wear and Surface Fatigue of Rubbers for Static Seals in Reciprocating Sliding Contact, J. Sugimura, p. 150	Tribofilms in Wet Clutch Applications, D. Williams, p. 152		**2 – 2:30 pm**
Frictional Properties of Diamond Coated (and UNCD® coated) Silicon Carbide and Tungsten Carbide Mechanical Seal Faces, M. Lapansie, p. 150	Analysis of the Tribochemical Absorbed Films on Steel Surfaces Lubricated with 1,3-Diketone, S. Zhang, p. 152		**2:30 – 3 pm**
Break	**Break**		**3 – 3:30 pm**
Effect of Combined Mechanical Stress and Salt Spray Aging on Dynamic Friction Behavior of O Rings, J. Wu, p. 150	Effect of Lubricants on Friction Properties of the Steel/PEEK Contact, G. Tatsumi,p. 152		**3:30 – 4 pm**
Dynamic Behavior of a Fractional Viscoelastic Seal with Solid Contact, A. Leenders, p. xxx	Electric Field Effect on the Lubrication Performance of CuS Nanoparticle Additive, C. Liu, p. 152		**4 – 4:30 pm**
Simulation of Mixed Friction Between a Surface Textured Seal and a Smooth Rod, M. Brase, p. 150			**4:30 – 5 pm**
Seals Business Meeting			**5 – 5:30 pm**

THURSDAY >>

TIME	SESSION 7G Grease I Cumberland 1	SESSION 7H Materials Tribology IV Cumberland 2	SESSION 7I Contact Mechanics I Cumberland 3
8 – 8:30 am	Back to the Basics: Fundamental Building Blocks of Grease Formulation, J. Kaperick, p. 137	Mechanisms of Abrasive Wear in WC/Co Hardmetals, M. Gee, p. 138	Indenting Soft Swollen Elastomers with a Microparticle, J. Pham, p. 140
8:30 – 9 am	A New Preformed Polyurea Thickener for Grease, Z. Jia, p. 137		Transparent Hydrogel Indentation and Slip Mechanics Through In-Situ Particle Inclusion and Exclusion, A. Dunn, p. 140
9 – 9:30 am	Film Thickness in a Grease Lubricated Ball Bearing, P. Lugt, p. 137	Nickel MAX-Phase Composites for High Temperature and High Sliding Applications, N.Murthy, p. 138	Small Forces, Large Noise: Scaling Nano-Indentation to the Micro Scale, C. O'Bryan, p. 140
9:30 –10 am	Effect of the Alkyl Chain Length of ZDDP Combined with Amine Phosphate on Wear Rates as Studied by Profilometry, N. St. Pierre, p. 137	Effect of MoS_2 on the Tribological Performance of AA7075/Si3N4 Composite, Mir Irfan Ul Haq, p. 138	Eliminating the Challenges Associated with Physically Oscillating Contact Instruments, D. Garcia, p. 140
10 – 10:30 am	**Break**	**Break**	**Break**
10:30 – 11 am	How Reliable and Sensitive Is the New Indentation/ Retraction Method in Measuring Tackiness of Industrial Greases?, E. Georgiou, p. 137	Influence of Operational and Surface Conditions on the Tribological Performance of Self-Lubricating Polymer Composite Bearing Materials Used in Hydropower Applications, K. Berglund, p. 138	Shape Memory: The Contact Mechanics of Photonic Crystal Structure, K. Schulze, p. 142
11 – 11:30 am	Simulation of Grease Flow in Speed Reducer of Robot, A. Shishikura, p. 138	Tribological Behavior of Self-Lubricating Polymer Composite Bearing Materials During Long-Time Dry Sliding, M. Rodiouchkina, p. 140	The Tribomechadynamics of Jointed Interfaces: New Observations and Their Ramifications, M. Brake, p. 142
11:30 am – Noon	Effect of Rheological Properties of Grease on Rotational Torque of Ball Bearings Caused by Stirring Resistance, Y. Yamashita, p. 138		Method for Calculating the Contact Between Roller End Face and Ring Flange In Multi-Body Simulations, S. Wirsching, p. 142
	SESSION 8G **Grease II** **Cumberland 1**	**SESSION 8H** **Materials Tribology V** **Cumberland 2**	**SESSION 8I** **Contact Mechanics II** **Cumberland 3**
1:30 – 2 pm	Grease Evaluation for the Continuous Caster Bearings: Development of an Innovative Technique to Accurately Measure Water Content . . . , K. Mistry, p. 154	Environmental Sensitivity and Aging of Composite Solid Lubricant Coatings, M. Dugger, p. 154	Theoretical and Finite Element Analysis of Static Friction Between Multi-Scale Rough Surfaces, R. Jackson,p. 156
2 – 2:30 pm	Use of High Temperature Oven Aging to Determine COF of Candidate Greases as Oil Loss within the Grease Occurred, B. Johnson, p. 154	Improving Tribological Performance of PDA/PTFE Thin Film by Incorporating Ag Nanoparticles in the PDA Underlayer, D. Choudhury, p. 155	Investigating the Effect of the Evolution of the Radius of Curvature During Elastic-Plastic Contact of Asperities, E. O'Neill, p. 156
2:30 – 3 pm	A New Anti-Wear Grease Containing Nanoparticles, Y. Chen, p. 154	Improved Wear Life of 60NiTi by PDA/PTFE + Graphite Solid Lubricant Coatings, D. Choudhury, p. 155	When Does Roughness Affect Elastic-Plastic Contact?, S. Ahadzie, p. 156
3 – 3:30 pm	**Break**	**Break**	**Break**
3:30 – 4 pm	When Your Supply of Grease Ceases and You Need a Replacement, What Do You Do?, M. Moneer, p. 154	Tribological Behavior of the WSC Coated Silicon Carbide in Vacuum and Air, K. Simonovic, p. 155	An Elastoplastic Finite Element Study of Unidirectional Cylindrical Sliding Contact for Steel/Steel and Inconel617/Incoloy800H, H. Yang, p. 156
4 – 4:30 pm	Biolubricant Enhancement Using Combined Raw Carbon Nanostructures, A. Pérez, p. 154	Low Friction Behaviors of Ag-Doped -Fe_2O_3@SiO_2 Coatings Under a Wide Range of Temperature Conditions, Q. Zeng, p. 155	Feasibility Study of Impedance Analysis for Measuring Rolling Bearing Loads, T. Schirra, p. 156
4:30 – 5 pm	Grease Business Meeting	Study on the Tribological Properties During Drilling of CFRP with Carbide Tool, X. Liang, p. 155	A Study of Noise Prediction in Interior Materials of Automotive During Friction Process, J. Park, p. 156
5 – 5:30 pm		Tribological Behaviors of Highly Oriented Pyrolytic Graphite . . . in Macroscale, P. Wu, p. 155	Contact Mechanics Business Meeting

SESSION 7J Surface Engineering III Cumberland 4	SESSION 7K Lubrication Fundamentals VIII Cumberland 5	SESSION 7L Condition Monitoring II Cumberland 6	
The Effect of Graphene as Additive on the Anti-Corrosion of Polyurethane Coating, H. Tan, p. 142	Impact of Solvent Dilution Technique on Soft Particle Detection by Laser Particle Counter, L. Wang, p. 144	Root Cause Analysis of Varnish Generation in Lube Systems, J. Mehta, p. 145	**8 – 8:30 am**
Friction Properties of Milling Micro-Textured Surface on Al-Si Alloy Under Sliding Boundary Conditions, C. Guo, p. 142	Influence of Base Oil Ageing on Viscosity Modifiers Behavior, E. Gendreau, p. 144	Development of an Oil Split Test Method for Emulsions without the Use of Strong Oxidizing Acids, J. Lewis, p. 145	**8:30 – 9 am**
Numerical and Experimental Studies on Friction Reduction by Surface Modification in TEHL Contacts, M. Marian, p. 143	Lubrication of a Stretchable Sheet at the Tool Tip-Sheet Interface in Single Point Incremental Forming (SPIF), T. He, p. 144	Identification of Unknown Elements in a Lubricant Sample and High Throughput Wear Metals Analysis by ICP-OES, A. Wassmuth, p. 145	**9 – 9:30 am**
The Effect of Texture Shape on the Frictional Resistance Under Unidirectional Sliding, P. Pawlus, p. 143		Determination of Total Base Number in In-Service Lubricants Using FT-IR, A. Bohman, p. 145	**9:30 –10 am**
Break	**Break**	**Break**	**10 – 10:30 am**
Mastering the Art of Honing, D. Chobany, p. 143	Effects of Bearing Material Choice and Engine Oil Viscosity on Journal Bearing Durability in Stop/Start Environments, J. Xu, p. 144	In-Situ Analysis of Degraded Gear Oils Using Ultrasonic Reflectometry, T. Brenchley, p. 145	**10:30 – 11 am**
Texture and Microstructure Refinement in Surface Severe Plastic Deformation of Strain Hardening Materials, C. Saldana, p. 143	Benchtop Level Testing of Lubricants and Surfaces for Reciprocating Applications: High Frequency Reciprocating Rig, G. Ramirez, p. 144	Oxidation Analysis of Lubricants Using Ambient Pressure Differential Scanning Calorimetry (DSC) Techniques to Determine Antioxidant Performance, K. Schomburg, p. 145	**11 – 11:30 am**
Bi-Gaussian Stratified Feature of Impregnated Graphite Surfaces after a Laser Treatment, S. Hu, p. 143	Ball Milled Graphite Nanoplatelets as a Biolubricant Additives for Friction and Wear: An Attempt to Develop a 'Green' Lubricant, E. Omrani, p. 144	Fast and Efficient Quality Control of Lubricants and Its Foaming Tendency by FoamDDI . . . Fully Automatized Detection Imaging Apparatus, A. Mendez, p. 146	**11:30 am – Noon**

SESSION 8J Surface Engineering IV Cumberland 4	SESSION 8K Engine and Drivetrain V Cumberland 5	SESSION 8L Condition Monitoring III Cumberland 6	
Tribological and Physical Properties of PTFE Micro-powder-Filled NBR Rubber Under Water Lubrication, Y. Han, p. 157	The Effect of MoDTC on Friction Between Piston Ring and Cylinder Liner with Several Surface Treatment, K. Yamamoto, p. 158	Single Lubricant Solution for Natural Gas and Diesel Engines, I. Goldmints, p. 159	**1:30 – 2 pm**
Experimental Comparison of Conventional and Textured Dynamic Seal Surfaces, J. Bothe, p. 157	Computational Fluid Dynamics (CFD) Modeling of Torque Converter and Experimental Validation, F. Qureshi, p. 158	Oil Conductivity as an Early Indicator of Oil Oxidative and Additive Thermal Degradation Processes, J. Duchowski, p. 159	**2 – 2:30 pm**
The Deterioration Characteristics and Mechanism of Polishing Pads and Slurry in Chemical Mechanical Polishing (CMP) of Fused Silica, C. Kang, p. 157	Numerical and Experimental Analysis of Lubricant Transport, R. Ravendran, p. 158	Correlating Acoustic Emission Signals with the Tribological Behavior of Steel, T. Reddyhoff, p. 159	**2:30 – 3 pm**
Break	**Break**	**Break**	**3 – 3:30 pm**
Chemical Mechanical Polishing Behavior of PS/Sio_2 Nanospheres with Different Shell Thickness on Fused Silica, X. Zhang, p. 157		Using SEM/EDS Technology for Wear Debris Analysis, M. Villalba, p. 159	**3:30 – 4 pm**
Dynamical Characterization of Micro Cantilevers by Different Excitation Methods in Dynamic AFM, X. Tan, p. 157		Detecting WEC Formation in an Electrical Environment Using Electrostatic Monitoring Techniques, L. Wang, p. 159	**4 – 4:30 pm**
Ultralow Friction of Concentrated Polymer Brushes Sustained by Surface Texturing, M. Miyazaki, p. 157			**4:30 – 5 pm**
The Unsatisfied Effect of Plateau Honing on the Friction and Wear of Cylinder Liners, E. Kim, p. 158			**5 – 5:30 pm**

Session 7A • Legends F

Rolling Element Bearings III

Session Chair:
T. Slack, American Roller Bearing Company, Morganton, NC

Session Vice Chair:
N. Londhe, The Timken Company, Canton, OH

8 – 8:30 am | Hoot Noise of Rolling Element Bearings: Are Non Linear Vibrations the Key Theory?

Hannes Grillenberger, Mark Nichols, Stefan Kopsch, Christoph Schroeder, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany

Hoot Noise (HN) of rolling element bearings is a phenomenon know for decades. This noise phenomenon occurs in automotive applications almost exclusively at cold start conditions in winter. This is the usual regime, when lubrication conditions are below operating regime of the lubricant used close to the engine. Thus the current theory is HN to be excited by the lubrication. This is also based on tests which show in most cases that a change of lubricant is a counter measure – with drawbacks of normal grease properties at normal or high temperature operation. The presentation will show that hoot noise may be excited independent of a lubricant and at normal temperature by elementary test and simulation results. This generates the need for a wider view on HN. First theoretical approaches will be presented validated by test and simulation including mislubrication and non-linear oscillations.

8:30 – 9 am | "Reliving Pain" – Highest Performance at Toughest Conditions/The Development of a New Ball Bearing Type with Integrated Tilt Compensation

Thomas Kreis, Herbert Niedermeier, Gebr. Reinfurt GmbH & Co. KG, Rimpar, Bavaria, Germany

Deep-groove ball bearings, running under tilted conditions, are subjected to high constraining forces. The balls of the ball set move on elliptical orbits, with the consequence that they are driven with different circulation speeds depending on the ellipse position, which causes a permanent alternating stress to the cage. The consequences would be (1.) rapidly progressing cage wear, which will cause a premature bearing failure, (2.) reduced load carrying capacity in tilted position and noise abnormalities. The new GRW design ensures smooth rolling of each ball of the ball set, even under tilted conditions in the harsh environment of a dental miniature bearing. The presentation shows requirements of "Dental Turbine" application, kinematic basic function of the new design, simulation results on the dynamic bearing behavior, exemplary test results from lifetime and functional tests, resulting performance improvements.

9 – 9:30 am | Investigations on Cage Dynamics in Rolling Bearings by Test and Simulation

Sebastian Schwarz, Stephan Tremmel, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany, Hannes Grillenberger, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany

Rolling bearing cages perform a very high-frequency movement within their cage pocket clearance compared to the rotational speed under certain operating conditions. This is often accompanied by higher elastic deformation and noise. An unstable cage movement causes high contact forces and reduces the performance of the bearing used. The presentation gives an overview of the essential properties of the unstable cage movement derived by multi-body simulations. Relations between the cage movement and the boundary conditions in the simulation such as coefficient of friction and load are identified. Based on the simulation results, an index is defined that allows the calculated or measured cage movement to be classified into different types and objectively evaluates the cage dynamics. A comparison of the calculated and experimentally measured cage dynamics for different load cases is presented to validate the simulation results.

9:30 – 10 am | Effect of Microgravity and High Temperature on the Dynamics of Ball Bearing

Yuanqing Liu, Wenzhong Wang, Beijing Institute of Technology, Beijing, China

In the space environment, the bearing system is subjected to negligible gravity force. What's more, the operating temperature fluctuation is much large, which greatly changes the lubricant traction coefficient and affects the motion of bearing. In this paper, a dynamic model is developed for angular contact ball bearings to investigate the effect of operating microgravity and temperature on motions of balls and stability of cage. The friction coefficient between ball and raceways is determined based on the experiments, while the traction coefficient is obtained under different operating temperatures and loads. The results show that the microgravity increases the slip ratio of cage and reduces the stability of bearing; Under the higher operating temperature, the stability of cage is lower and the slip ratio of balls and cage is higher.

10 – 10:30 am | Break

10:30 – 11 am | Measured Lubricant Rheology Based Traction Model for Rolling Bearings

Pradeep Gupta, PKG Inc., Clifton Park, NY

A simple elastohydrodynamic traction model, based on measured lubricant rheology, is formulated for rolling bearing performance simulations. With the experimentally measured dependence of viscosity on pressure and temperature, the energy equation is integrated through the lubricant film to first compute average Newtonian traction with applicable thermal effects. Compressibility effects are modeled by implementing pressure and temperature dependence of thermal conductivity. Viscosity dependence on shear stress is then applied to model "shear-thinning" effects. At very high contact pressure and very low slide-to-roll ratios material creep effects, where the behavior of lubricated and dry contacts is similar, are implemented, while a shear stress limit is applied at very high slide-to-roll ratios. Traction predictions for a typical contact in a traction rig show good agreement with experimental traction data.

11 – 11:30 am | Experimental and Numerical Investigation of Hydraulic Losses in Rolling Bearings

Attila Gonda, Sauer Bernd, Technical University of Kaiserslautern, Kaiserslautern, Germany, Daniel Großberndt, Hubert Schwarze, Technical University of Clausthal, Clausthal, Germany

During the operation of an oil-lubricated rolling bearing losses are occurred, which can be divided into the contact losses resulting from mechanical friction and the hydraulic losses caused by the displacement of the lubricant. Different calculation approaches and methods can be used to calculate the contact losses, but the selection of available calculation approaches is limited to determine the hydraulic losses. Within the scope of the current research project, axially loaded rolling bearings in horizontal arrangement were investigated in order to better predict the influence of hydraulic losses on the total friction torque and to investigate the influence of the operating parameters (viscosity, rotational speed, oil quantity) on the hydraulic losses. The current results of the experimental and simulative investigations are presented.

11:30 am – Noon | The Effectiveness of Ball-On-Disc Tests at Simulating Friction in Greased Rolling Bearings – A Direct Comparison of Experimental Results

Nicola De Laurentis, Yuta Kanazawa, Amir Kadiric, Imperial College London, London, United Kingdom

The frictional behaviour of a series of model bearing greases was investigated by measuring the torque generated in greased thrust ball and cylindrical roller bearings. The findings were directly compared with friction results obtained using the same set of greases in a ball-on-disc laboratory tribometer. The grease samples were strategically formulated with the aim of focussing the study on the individual effect of thickener type, base oil viscosity and presence of a friction modifier on bearing torque, by isolating each of these parameters of influence in the grease composition. A strong correspondence was found between the torque generated in the bearings and the friction values obtained in the ball-on-disc tests as a function of grease composition. It was verified that, with appropriate analysis of the results, ball-on-disc tests are representative of full bearings and can be effectively used to screen the impact of grease formulation on bearing torque.

Session 7B • Music Row 1

Biotribology II

Session Chair:
Guebum Han, University of Wisconsin-Madison, Madison, WI

Session Vice Chair:
Marc Masen, Imperial College London, London, United Kingdom

8 – 8:30 am | Lubricity of Synovial Fluid Constituents for Hydrogel Cartilage Model

Yoshinori Sawae, Mayo Kubota, Hironori Shinmori, Takehiro Morita, Tetsuo Yamaguchi, Kyushu University, Fukuoka, Japan

Soft, permeable and highly hydrated hydrogel was used as a model of articular cartilage tissue and lubricity of macromolecules contained in synovial fluid for the cartilage model was examined. The friction coefficient between cylindrical glass and the hydrogel cartilage model was evaluated in test lubricants which contain proteins, phospholipids and hyaluronic acid (HA) with different concentrations. Results indicated that phospholipids and HA had clear lubrication effect for the cartilage model and showed excellent lubricity if they mixed together. On the other hand, proteins increased the friction coefficient under the severe condition with high load and low sliding speed.

8:30 – 9 am | Size of Worn Region Predicts Fluid Pressures During Human Slips

Kurt Beschorner, Sarah Hemler, University of Pittsburgh, Pittsburgh, PA, Vani Sundaram, University of Colorado-Boulder, Boulder, CO

Shoe tread is intended to mitigate under-shoe fluid pressures. As tread becomes worn, its performance can be compromised. Previous modeling studies have suggested that under-shoe lubrication behavior is sensitive to the size of the worn region. The goal of this study was to determine whether the size of the worn region on shoes can predict under-shoe fluid pressures. Forty-one participants were exposed to a liquid contaminant (90% glycerol) in their own used shoes. Thirty fluid pressure sensors, embedded in the floor, recorded under-shoe fluid pressures to quantify the peak pressure. The size of the worn region was the product of the length and width of the worn heel region. Linear regression assessed the impact of worn tread size on peak pressure. The worn region predicted the peak pressure for both slip-resistant and non-slip-resistant shoes ($p=0.003$). Thus, using the dimensions of the worn region appears to be a reasonable method for determining when worn shoes should be replaced.

9 – 9:30 am | Role of Poroviscoelastic Relaxations in Rate-Dependent Cartilage Microfracture

Guebum Han, Melih Eriten, Corinne Henak, University of Wisconsin-Madison, Madison, WI

The aim of this study is to investigate the potential role of poroviscoelastic relaxations in rate-dependent crack nucleation in cartilage. Crack nucleation was induced at different loading rates via displacement-controlled microindentation. A sudden drop in measured load signaled crack nucleation. Experimentally measured critical load, critical displacement, and mechanical work at crack nucleation decreased with increasing loading rate. The rate dependence of critical loads correlated well with the load relaxation response. Critical total work at nucleation was relatively low at fast loading rates as poroviscoelastic relaxations could not disperse mechanical energy, and thus, more work was directed to rupture of collagen fibers. This correlation between critical loads and poroviscoelastic relaxation response suggests that poroviscoelastic relaxations play a governing role in the rate dependence of crack nucleation in cartilage.

9:30 – 10 am | Competitive Rates of Cartilage Rehydration

David Burris, University of Delaware, Newark, DE

Cartilage, a porous fluid-soaked tissue, maintains thickness and function via a balance between load-induced exudation and movement-induced fluid recovery; yet, the competitive rates involved remain virtually unstudied. This paper quantifies the relevant rates of cartilage fluid loss and recovery. Under physiologically relevant conditions, tribological rehydration rates exceeded 1,000 nm/s, which exceeded exudation rates by ~1,000x and passive (unloaded) swelling rates by 100x, and was comparable to free-swelling rates. The results suggest that: (1.) tribological rehydration and free-swelling contribute synergistically to fluid and solute recovery in the joint; (2.) that active recovery is far faster than passive recovery; (3.) that fluid, thickness, and function are restored at least an order of magnitude faster than they are lost. The results clarify how relatively little activity is sufficient to maintain joint space and function while clarifying the relative contributions.

10 – 10:30 am | Break

10:30 – 11 am | Tribocorrosion of Duplex Treatments on Ti-6Al-4V in Ringer's Solution

Brandon Strahin, Gary Doll, The University of Akron, Akron, OH

Tribocorrosion is a major problem in many industries. In tribocorrosion, the material experiences simultaneous wear and corrosion. The result is not the sum of wear and corrosion together but is typically increased. In this study, the affect electrochemical tribocorrosion on various treated and untreated Ti-6Al-4V surfaces was examined. The surfaces examined were untreated, nitrided, thermally oxidized, a supplementary duplex treatment, and a complimentary duplex treatment. Tribocorrosion testing was performed using a high-frequency reciprocating rig while simultaneously performing impedance testing in simulated body fluid (Ringer's solution.) Measurements were taken using 25 m, 50 m, and 100 m distances and 2 N load. These data were then compared to tribological data collected in the dry condition.

7B

11 – 11:30 am | Raman Spectroscopic Analysis of the Biochemical Reaction of Hyaluronic Acid in Joint Replacement

Risha Rufaqua, Martin Vrbka, Brno University of Technology, Brno, Czechia, Dipankar Choudhury, University of Arkansas, Fayetteville, AR, Dušan Hemzal, Masaryk University, Kotlarska, Brno, Czech Republic, David Rebenda, Ivan Krupka, Martin Hartl, Brno University of Technology, Brno, Czechia

Hyaluronic acid is a nonprotein component of synovial fluid, which acts as a key reactant in the tribo-chemical mechanics of joint lubrication. In this study, the biochemical responses of hyaluronic acid were evaluated in an artificial hip joint. The experiments were conducted in the ball-on-cup configuration in a hip joint simulator, where the balls are made from respectively cobalt chromium molybdenum alloy and ceramics (biolox forte and biolox delta). The cups are of respectively polyethylene and ceramic. Raman spectroscopic method was used to analyze the biochemical responses. The results revealed that biolox delta ball could be involved in the chemical reaction with hyaluronic acid as it provides different spectra compare to others. Therefore, the results have significant information regarding hyaluronic acid reactivity within the joint replacement.

11:30 am – Noon | Agarose Hydrogel as a Carrier for Hyaluronic Acid with the Lubrication Efficiency of the Sustained Release

Mahshid Hafezi, Liquo Qin, Guangneng Dong, Qunfeng Zeng, Institute of Design Science and Basic Components, Xian, Shaanxi, China

Hyaluronic acid (HA) as a major constituent of bionic synovial fluid (BSF) has significant role in lubrication of human body joints. Those who mostly suffer from joint related disease prefer to try injection of synovia after total hip arthroplasty (THR). However affection of Metabolism process to the injected synovia is able to destroy prolonging the life time of the prostheses. In this study, injectable, thermosensitive agarose hydrogel as a carrier for hyaluronic acid has been investigated to extend the life time of the artificial joints. Experimental evidences reveal bioactivity, superior viscoelasticity and naturally amorphous network structure of the HA in combination with the large molecules of agarose could be released slowly to separate the contact surfaces and improve the lubrication with more than 30% reduction rate in coefficient of the friction. Novelty of the present work provides a survey to the long-term lubrication of artificial joints.

Session 7C • Music Row 5

Power Generation I

Session Chair:
Jatin Mehta, Fluitec International, Bayonne, NJ

Session Vice Chair:
Salvatore Rea, LANXESS Corp., Perkasie, PA

8 – 8:30 am | The Tribological Performance of Gas Turbine Lubricants

Jake Airey, Mark Simmons, Richard Greenwood, The University of Birmingham, Derby, Derbyshire, United Kingdom, Matt Spencer, Rolls-Royce Plc, Derby, Derbyshire, United Kingdom

This study aims to evaluate the performance of several different lubricant formulations over the range of conditions seen within Rolls-Royce's future concept gas turbine design called the UltraFan®. The design features a Power Gearbox (PGB) that allows optimisation of the speed of the fan system and the intermediate pressure (IP) turbine. The PGB presents a new tribological challenge for the lubricant as well the need to continue protecting other oil system components such as various bearing chambers and other gearboxes. Oils have been evaluated using a Micro-Pitting Rig (MPR) to explore how different types and concentrations of anti-wear additives in the lubricants formulation influence micropitting. Also, an MTM (Mini Traction Machine) was used to understand how the molecular structure of group V basestocks influence friction. Evaluation of different components in these lubricants will aid better understanding of how lubricants behave in specific engine environments.

8:30 – 9 am | Oxidation Life and Sludge of Turbine Oil by Dry-TOST Test

Daxin Sun, Yu Jiang, Chao Yang, Yanbo Zheng, Zhongguo Liu, Dalian Lubricating Oil Research & Development Institute, PetroChina Lubricant Co., Dalian, Liaoning, China, Peng Li, Dalian Lubricating Oil Research and Development Institute, Dalian, Liaoning, China

For power generation plants, long-term stable is very important for turbine oils. Due to the increased gas temperatures at the inlet of the turbine, sludge and varnish problems arise in the turbine bearings, pipelines and the hydraulic control system. Oxidation life and sludge of different types basestocks and additives are investigated by dry-TOST test. The results indicate that the oxidation duration of Group IV base stocks is longer than Group I-III, meanwhile the sludge of Group I basestock is much more than Group II-IV. The effect of antioxidants, rust inhibitors, metal deactivators, and EP additives are also investigated. Hindered phenolics and aromatic amines have a great impact on oxidation duration and sludge by Dry-TOST test. The sludge of amide derivatives is more than other additives with hindered phenolics.

9 – 9:30 am | There are No "Varnish-Free" Turbine Oils

Matthew Hobbs, Peter Dufresne, EPT, Calgary, Alberta, Canada

Varnish has recently received a great deal of attention due to its costly impact on critical equipment. End-users are, therefore, more aware than ever of the risks associated with varnishing. As a consequence, oil suppliers have developed new products which are marketed as "low-varnish" or even "non-varnishing" alternatives to their conventional offerings. Some of these lubricants contain additives designed to increase their varnish-holding capacities while others feature more robust or polar base fluids. Regardless of the formulator's strategy, it is important for end-users to understand that there are no "varnish-free" oils. Next generation products may be more resistant to varnishing but operators are still best-served to adopt multiple strategies to prevent varnish-related failures. Among these, ion exchange-based filtration provides a reliable means of removing varnish-causing breakdown products and, therefore, preventing varnish in a broad range of applications.

9:30 – 10 am | High Performance New Hybrid Turbine Oil Made by Mineral Oil and PAG

Hiroki Sekiguchi, Yuhei Shirakura, Junya Iwasaki, Idemitsu Kosan Co.,Ltd., Ichihara-shi,Chiba, Japan

For efficient electric power generation, long-term stable operation of turbine is required. As turbine operation temperature increases for efficient power generation, sludge and varnish have been generated easily. As the countermeasure of this issue, the highly refine mineral oil and the appropriate antioxidant have been used to reduce the generation of sludge and varnish. In the recent year, PAG has been used as base oil to dissolve them. By combining the both strengths, we developed high performance new hybrid turbine oils made by mineral oil and PAG.

10 – 10:30 am | Break

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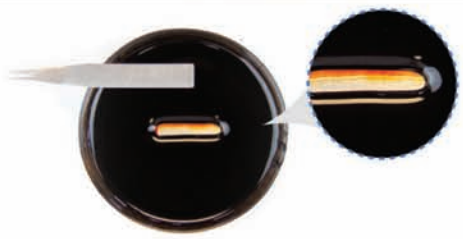

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Tuesday, May 21st · 11:00 AM

Session 7E • Music Row 3

Tribochemistry II

Materials Tribology and Nanotribology Joint Session

Session Chair:
Arnab Bhattacharjee, University of Delaware, Newark, DE

Session Vice Chair:
Nikolay Garabedian, University of Delaware, Newark, DE

8 – 8:30 am | Formation and Nature of Lubricious Carbon Containing Tribofilms

Qian Wang, Arman Khan, Hongxing Wu, Yip-Wah Chung, Northwestern University, Evanston, IL

Minimizing friction and wear at a rubbing interface continues to be a challenge and has resulted in the recent surge toward the use of coatings such as diamond-like carbon on machine components. The problem with the coating approach is the limitation of coating wear life. Here, we report a robust lubrication approach in which lubricious, wear-protective carbon-containing tribofilms can be self-generated and replenishable, without any surface pretreatment. Such carbon-containing films were formed under modest sliding conditions in a lubricant consisting of cyclopropanecarboxylic acid (CPCa) as an additive dissolved in polyalphaolefin base oil. Systematic reactive molecular dynamics simulations were conducted to explore the nature of the carbon tribofilm, analyze the related tribochemistry and reveal the atomistic mechanisms involved that lead to the formation of such tribofilm.

8:30 – 9 am | Interactions Between Tri-Cresyl Phosphate Lubricant Additive and Iron Oxide Explored Using Statistical Analysis of Reactive Molecular Dynamics Simulations

Arash Khajeh, Xiaoli Hu, University of California, Merced, Merced, CA, Stephen Berkebile, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD Ashlie Martini, University of California, Merced, Merced, CA

Tri-cresyl phosphate (TCP) is widely used as an anti-wear additive in lubricants because it reacts with ferrous surfaces to form protective films through chemical reactions between the TCP molecules and surfaces with a native oxide. To understand the reaction pathways that lead to TCP film formation, we used reactive molecular dynamics simulations to model the reaction pathways for TCP molecules interacting with an amorphous iron oxide surface at different temperatures. Multiple replica simulations were run at each temperature so that statistical analysis of the reactions and reaction pathways could be performed. This approach enabled characterization of the initial steps of TCP film growth and forms the basis of a fundamental understanding of anti-wear films that may ultimately lead to design of additives to produce faster forming and more robust tribofilms.

9 – 9:30 am | Reactive Molecular Dynamics Simulations of Thermal and Tribochemical Film Growth from Di-tert-butyl Disulfide on an Fe (100) Surface

Karen Mohammadtabar, Ashlie Martini, University of California, Merced, Merced, CA, Stefan Eder, Pedro Bedolla, Nicole Doerr, AC2T Research GmbH, Wiener Neustadt, Lower Austria, Austria

Di-tert-butyl disulfide is an extreme pressure additive that forms protective films to increase the lifetime of moving components. As film evolution between two sliding surfaces cannot be observed directly by common experimental approaches, we used molecular dynamics simulation with a reactive potential to model chemical reactions between di-tert-butyl disulfide and Fe (100). Thermal and shear-induced (tribochemical) films were grown to observe individual species and their reactions in the early stages of film formation. In order to mimic additive replenishment in a sliding contact, di-tert-butyl disulfide molecules were added iteratively to the model system. The film formation mechanisms – involving S-S breakage, Fe-S bonding and C-S breakage resulting in tert-butyl release – were analyzed in the context of previously reported results. Finally, tribological behavior was modelled for a single asperity sliding on the resultant iron sulfide films.

9:30 – 10 am | Surface Absorption and Chemical Reaction of Additives Studied by Molecular Dynamics

Hitoshi Washizu, University of Hyogo, Kobe, Japan

Molecular dynamics studies are carried out for the study of surface absorption process of additives. Formation process of organic monolayer of organic acids in hydrocarbon base oil on the charged metal surface are studied using all-atom molecular dynamics. We found that the base oil molecules made highly oriented (laid) adsorbed layer on the surface at first. Then the additive molecules is prevented to physically adsorb on the surface. The absorbing time is due to the structure of base oil. For surface coating, the sliding friction between ZrO2 and diamond like carbon (DLC) film including small amount of water and ethanol molecules between them, are studied. We found the transfer film formation in the Friction Fade Out phenomena. As a model system of absorption process of anti-corrosion additives on the metal surface, MD simulations of benzotriazole (BTA) molecules with copper slabs are done. A selective absorption phenomena is found.

10 – 10:30 am | Break

10:30 – 11 am | Impact of Nanodiamonds on ZDDP Tribo-Film Formation at Stainless-Steel Contacts

Biplav Acharya, Jacqueline Krim, North Carolina State University, Raleigh, NC

Nanodiamonds are known to improve tribological performance when added to lubricants and be beneficial and synergistic with TCP additives in oil-based lubricants. In particular they induce film formation on the oxide surfaces that are otherwise highly resistant to film formation. ZDDP forms a tribofilm at temperatures lower than TCP, assisted by various mechanisms distinct from that of TCP, particularly stress promoted mechanisms. Here we report on a study of nanodiamonds' effect on the stress promoted activation of ZDDP tribofilm formation at stainless-steel contacts. The tribofilm formation rates were measured in-situ with a quartz crystal microbalance (QCM) immersed in oil at different temperatures and in contact with a spherical ball with a variable normal force on it. The surface morphology, roughness, and thickness of the tribo-films were measured by AFM. Their chemical compositions were studied with EDS.

11 – 11:30 am | In-Situ Raman Spectroscopic Characterization of ZDDP Tribofilms

Carlos Garcia, Hugh Spikes, Janet Wong, Imperial College London, London, United Kingdom

Zinc dialkyldithiophosphates (ZDDPs) are lubricant additives that play a triple role as anti-wear agents, antioxidants and corrosion inhibitors. In their role as anti-wear agents, they help protect the rubbing surfaces by forming a mechanically protective film upon sliding contact. While the composition and properties of ZDDP tribofilms have been studied exten - sively through ex-situ measurements, the mechanism by which they form remains to be elucidated. It has been suggested that intermediate species could be identified by means of in-situ vibrational spectroscopy, however, the small volumes involved present a challenge to collect and measure the signal. In this presentation, we detail our attempt to overcome this challenge by a custom-built optical platform that allows the application of Raman spectroscopy on a lubricated contact. Preliminary results, correlated to friction and the process of tribofilm formation, will be presented. Remaining technical challenges are discussed.

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11:30 am – Noon | Effect of ZDDP on Hydrogen Absorption in Two Synthetic Oils

Monica Ratoi, Angelos Stavrinidis, Brian Mellor, University of Southampton, Southampton, Hampshire, United Kingdom, Vlad Niste, Hiroyoshi Tanaka, Joichi Sugimura, Kyushu University, Fukuoka, Japan

Bearing steels suffer from a degradation in mechanical properties when hydrogen diffuses into the steel from the contact surface. Previous work has reported that during rolling contact fatigue tests, the fatigue lives of the specimens is reduced significantly with the increase in the amount of hydrogen diffused into the steel. To mitigate this aspect different synthetic oils have been studied and two types, polyol esters and poly– –olefins found to generate tribofilms that reduce wear and hydrogen damage of bearing steels. The current study has investigated the effect of ZDDP addition to these oils on the RCF performance of bearings tested in air and hydrogen environments. The rolling contact fatigue life values were correlated with the amount of hydrogen species absorbed in the disc and ball specimens, the lubrication performance, i.e., wear track volume loss, surface and subsurface defects, tribofilms characteristics and chemistry.

Session 7F • Music Row 2

Synthetic & Hydraulic Lubricants III

Session Chair:
Patrice Cusatis, BASF Corp., Tarrytown, NY

Session Vice Chair:
Lauren Huffman, The Dow Chemical Co., Midland, MI

8 – 8:30 am | Novel Functionalized Polyalkylene Glycols and Their Synergy with Primary Anti-oxidants

Martin Greaves, Dow Chemical, Horgen, Switzerland

Thermal stresses on lubricants are expected to increase in the future as equipment is designed to operate under more severe conditions. Primary anti-oxidants (free radical scavengers) are frequently used in lubricant compositions. The inclusion of novel polyalkylene glycols (PAGs) as additives in combination with primary anti-oxidants in lubricant compositions can significantly boost the activity of the anti-oxidant and may lead to longer life fluids. The novel PAG additives have been carefully designed to include sulphur within the polymer backbone. A mechanism on their mode of action will also be proposed.

8:30 – 9 am | From Jet Engine Oils to High Temperature Industrial Lubricants: High Performance Anti-oxidants for Synthetic Esters

Siegfried Lucazeau, NYCO, Paris, France

The formulation of latest generation jet engine lubricants has led to the development of specific anti-oxidant systems that, used in fully synthetic esters, deliver increased stability and longevity, as well as improved control over deposit formation and coking. It is only relatively recently that such a technology was extended to industrial applications. As in jet engines, the combination of carefully selected neopolyol esters and specifically synthesized anti-oxidant systems delivers outstanding performance when evaluated through tests such as Micro-Coking Test at various temperatures, thermo-gravimetric analyses and dish tests – in addition to the standard fire safety tests. This technology may be used in high temperature chain oils, or even in greases. In addition, specific synergistic blends of classical anti-oxidants and aviation derived anti-oxidant systems have been examined in trimellitate esters as a cost-effective way of boosting performance of high temperature chain oils.

9 – 9:30 am | Time-Resolved Oxidative Degradation of Ester-Based Lubricants Identified by Mass Spectrometry

Nicole Doerr, Marcella Frauscher, Andjelka Ristic, Charlotte Besser, AC2T Research GmbH, Wiener Neustadt, Austria, Guenter Allmaier, Vienna University of Technology, Vienna, Austria

A commercial ester base oil used for hydraulic applications was blended with antioxidant and antiwear additives. In order to reveal the degradation products and processes caused by oxidation, a combined approach of artificial alteration, isotope labelling, and mass spectrometry (MS) was applied. Thereby, isotope labelling was performed with 16O2 and 18O2 to label the oxygen atoms, which were incorporated into the degradation products. Subsequently, the degradation products formed were unambiguously identified by MS. The time-dependent appearance/disappearance and abundance of both initial components and their degradation products allowed the description of oxidative degradation mechanisms. Emphasis was put on the correlation of oxygen consumption with the residual antioxidant contents. The role of antioxidant degradation products acting as indicators for critical lubricant conditions of lubricants is discussed.

9:30 – 10 am | Hydraulic Lubricant Performance, a Corrosion and Oxidative Perspective

Rajeev Kumar, Kathleen Cooper, ExxonMobil, Annandale, NJ

Performance considerations for hydraulic lubricants include how they interact with the metallurgy used within the equipment. Tests used to assess a lubricants suitability in hydraulic equipment for stationary & mobile applications, typically include assessments for wear and corrosion. Others however, are targeted towards an understanding of how the metallurgy contributes to catalytic oxidation of the lubricant. Both are at the core of the lubricant performance features for hydraulics that when robustly managed ensure a good service lubricant. This presentation will discuss standard hydraulic lubricant test methods importance to assessing corrosion and lubricant thermo-oxidation and their significance for hydraulic lubricants.

10 – 10:30 am | Break

10:30 – 11 am | Hybrid Antifoam Technology for Lubricating Oils

Ernest Galgoci, Justin Mykietyn, Münzing, Bloomfield, NJ

An antifoam is a critical part of a lubricating oil formulation. Although the criteria for choosing an antifoam may vary, the antifoam should generally exhibit strong surface foam control, persistence, air release, and compatibility with the lubricant. Because lubricant formulations can vary substantially, this produces a complexity that makes the choice of antifoam difficult to predict, the optimal choice of the antifoam is often best determined empirically. Fortunately, experiential knowledge and first principles can be used as guidelines to narrow the search. This paper will describe the theoretical framework of foam generation and stabilization, the thermodynamic and physical considerations of the action of antifoams, and the general formulation of antifoams used in lubricants. The discussion will focus on the performance of a hybrid chemistry approach, which delivers an excellent combination of foam control and air release relative to conventional chemistries alone.

11 – 11:30 am | Ionic Liquid Additized Environmentally-Friendly Hydraulic Fluids

Xin He, Huimin Luo, Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

Environmentally-friendly ionic liquids (ILs) are being developed as ashless additives for hydraulic fluids. Candidate ILs, at a treat rate of 0.5 wt.%, were blended into a non-polar mineral base oil, a hydrophilic polyalkylene glycol (PAG), and an oil-soluble PAG (OSP). Boundary

lubrication tribological tests were conducted on the IL-containing oils using a ball-on-flat reciprocating sliding configuration at 82 oC. Compared with a commercial primary zinc dithiophosphate (ZDDP), the ILs showed lower friction coefficient and wear volume. This attributes to the formation of a protective layer on the contact surface as revealed by characterization of wear scar morphology and composition. In addition to the superior lubricating performance, these ILs have advantages of higher thermal stability and lower toxicity than commecial hydraulic fluid additives.

11:30 am – Noon | Hydrocarbon-Mimicking Ionic Liquids as Low Vapor Pressure Triboimprovers

Erik Nyberg, Didac Llopart, Ichiro Minami, Luleå University of Technology, Luleå, Sweden

Tribochemically active lubricants are essential to high performance machine elements, such as gears and bearings. The past century has seen the development of a wide range of triboimproving lubricant additives (anti-wear and friction modifiers) to provide hydrocarbon base fluids with high performance capacity. However, for unconventional applications, such as mechanical devices in space missions, there is a lack of high performance triboimprovers. Near future space missions are projected to expand from scientific to engineering objectives, and consequently requests for radically increased tribological performances can be foreseen. In this work, we evaluate novel hydrocarbon mimicking ionic liquids as tribochemically active synthetic lubricants for use in mechanical devices that operate in space environments. Model scale tribotesting is combined with lubricant evaluation in actuator gearboxes typically employed in space robotics.

Session 7G • Cumberland 1

Grease I

Session Chair:
Cindy Liu, Kluber Lubrication, Londonderry, NH

Session Vice Chair:
Victoria Parker, Sasol, Westlake, LA

8 – 8:30 am | Back to the Basics: Fundamental Building Blocks of Grease Formulation

Joseph Kaperick, Afton Chemical Corp., Richmond, VA

This presentation explores the main performance areas for which grease additives are primarily used and some common questions and misunderstandings surrounding them. Data was generated using a variety of additives and testing from these different performance areas and includes discussion of (and some answers to) questions such as: Is there a difference between primary and secondary ZDDPs? Does the grease thickener help prevent rust? Are all rust tests equal? Is there really such a thing as synergistic combinations of antioxidants? Is EP performance in a grease really "all about the sulfur"? Is all sulfur created equal? Are all additive packages created equal? Does "one size fit all"? Does the grease thickener really interact with performance additives?

8:30 – 9 am | A New Preformed Polyurea Thickener for Grease

Zhe Jia, John Cuthbert, Nathan Wilmot, Bruce Hook, The Dow Chemical Co., Freeport, TX

Polyurea grease consists of a three-dimensional physical network incorporating a lubricating base oil, a thickener formed in situ between isocyanates and amines, and a variety of additives. The featuring urea functional groups will generate sufficient hydrogen bonding to hold base stock within the network for lubricating purpose. In this work, we proposed to develop a pre-formed polyurea thickener, with carefully designed chemical structure that allows the thickening agent to be compatible with the base oil at elevated temperatures and shearing conditions. The resulted product exhibits minimized handling complexity of toxic raw materials and inherent polyurea grease properties, including unique high temperature capabilities, enhanced shear stability and anti-oxidative characteristics. This preformed thickener, offering improved lubrication properties and EH&S and handling benefits for grease manufacturers, would be a promising alternative for conventional polyurea grease.

9 – 9:30 am | Film Thickness in a Grease Lubricated Ball Bearing

Piet Lugt, SKF Research and Technology Development, Nieuwegein, Utrecht, Netherlands, Hui Cen, Xuchang University, Xuchang, Henan Province, China

The film thickness for grease lubricated bearings is normally calculated using the base oil viscosity, where it is assumed that the bearing is running under fully flooded conditions. It is well known that this is not accurate since grease lubricated bearings are usually running under starved lubricated conditions leading to thinner films. Single contact measurements have shown that, in the case of starvation, the film thickness decreases significantly with increasing speed. It is shown in this paper that that effect is clearly different in full rolling bearings. This is shown for three types of thickener material and base oil. To quantify this starvation effect, the film thickness can be expressed as the ratio between the real film thickness and the calculated film thickness using the base oil viscosity, hb/hff. The measurements in this paper show that hb/hff > 1 for very low speeds but decreases with speed to values hb/hff <1. This decrease reduces with increasing speed.

9:30 – 10 am | Effect of the Alkyl Chain Length of ZDDP Combined with Amine Phosphate on Wear Rates as Studied by Profilometry

Nicole St. Pierre, Nye Lubricants Inc., Fairhaven, MA

The effect of the alkyl chain length on ZDDP was studied in combination with amine phosphate to potentially identify synergistic effects between the additives that lead to lower wear rates in various base oil chemistries. The fortified base oils looked at varying both the additive treat rate as well as the ratio of the additives which were analyzed using tribological tests such as 4 ball wear, SRV, and MTM. This wear study will utilize optical profilometry to look at the wear scars in the third dimension to see if there are noticeable differences in total wear volume that would differentiate the additive combinations best suited for mixed lubrication leading to better formulated products. The study will also allow us to analyze the data to identify two-way interactions between variables.

10 – 10:30 am | Break

10:30 – 11 am | How Reliable and Sensitive Is the New Indentation/Retraction Method in Measuring Tackiness of Industrial Greases?

Emmanuel Georgiou, Dirk Drees, Michel De Bilde, Falex Tribology NV, Rotselaar, Belgium, Michael Anderson, Falex Corp., Sugar Grove, IL

The tackiness of lubricating greases, used in various industrial applications is an important property to ensure good adherence and distribution to components, and maintain consistency of the lubrication layer. The new test method developed by Falex, to measure the adhesion and tackiness of greases, is based on indentation/retraction measurements. This method takes into account the effect of temperature, retraction speed and applied load. Until now, the sensitivity and repeatability were less studied. This presentation focuses on getting a better insight on sensitivity to additive levels, by testing formulated greases with a known concentration of tackifiers. The reliability of the

method is evaluated by statistical analysis of multiple tests. We believe that this information is of vital importance towards standardization of the method.

11 – 11:30 am | Simulation of Grease Flow in Speed Reducer of Robot

Akihiro Shishikura, Hideki Nakata, Kei Sakakura, Idemitsu Kosan Co., Ltd., Chiba, Japan

The grease flow in speed reducer (cyclo gear type) was observed by using an acrylic model. Only grease near the rotating part moved and the flow speed decreased with the grease hardness. We have already been reported that the particle method simulation (DEM-MPS) of grease flow is effective for flow analysis of grease and we applied this calculation method for this case. The observation result of the grease flow in the speed reducer well agreed with calculation result. In the case feeding iron powder as a tracer, the moving speed of the iron powder is remarkably slow, and it hardly moves in the reducer. This phenomenon also agreed well with the simulation result of grease flow. The bypass phenomenon of grease in speed reducer at grease-up operation can also be predicted by the calculation. Therefore, this flow analysis using DEM-MPS is effective for grease lubrication management of complex gear system.

11:30 am – Noon | Effect of Rheological Properties of Grease on Rotational Torque of Ball Bearings Caused by Stirring Resistance

Yurie Yamashita, Takeshi Tsuda, Kouji Yoshizaki, JTEKT Corp., Kashiwara, Osaka, Japan

In recent years, developing grease-lubricated ball bearings with low torque performance is required to improve energy efficiency, especially for industrial electric motors. Although many research reports have been published about the effect of grease on low torque performance of ball bearings, hardly any reports have studied about quantifying the grease factors affecting stirring resistance on bearing rotational torque. In this study, a new concept of "energy for viscous reduction property" measured with rotational-type rheometer was introduced, to consider rheological properties of grease during bearing rotation. Our results, obtained on urea grease with thickener made from single or multiple amine in several kinds of synthetic oils, suggested that the higher the energy for viscous reduction property, the lower the bearing rotational torque. Moreover, greases with thickeners composition containing a short carbon chain amine displayed improved low torque characteristic.

Session 7H • Cumberland 2

Materials Tribology IV

Session Chair:
M. Jones, Sandia National Laboratories, Albuquerque, NM

Session Vice Chair:
Pradeep Menezes, University of Nevada-Reno, Reno, NV

8 – 9 am | Mechanisms of Abrasive Wear in WC/Co Hardmetals

Mark Gee, National Physical Laboratory, Teddington, United Kingdom

Because of their combination of high strength and toughness, WC/Co hardmetals have remarkable wear resistance and are therefore used in applications where this property enables good performance. This presentation will focus on the understanding that has been achieved about the mechanisms of abrasive wear for WC/Co hardmetals. This understanding has been achieved through laboratory experiments that have been conducted including macroscopic wear tests such as the ASTM B611 and ASTMG65 tests, single and multipass scratch tests which aim to simulate the mechanisms that occur in abrasion, and experiments carried out in situ in the SEM which provide in operando information on how the mechanisms of damage relate to the microstructure of the WC/Co materials. The interpretation of the experimental results is aided by the microstructural characterisation of worn surfaces by techniques including high resolution SEM, EBSD and ECCI analysis, and FIB tomography.

9 – 9:30 am | Nickel MAX-Phase Composites for High Temperature and High Sliding Applications

Nikhil Murthy, Stephen Berkebile, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, Maharshi Dey, Matt Fuka, Surojit Gupta, University of North Dakota, Grand Forks, ND

MAX-phase materials are a promising group of materials for tribological application due to their high thermal stability and potential for adding lubricity to structural material. We used hot press sintering to synthesize MAX-phase metal composites attempting to improve the properties for high speed and high temperature conditions such as in turbomachinery applications. The friction and wear rates of pure nickel and Ni-MAX (90 wt.% Ni + 10 wt.% Ti3SiC2) specimens were measured with a ball-on-disk tribometer at low (1 m/s) and high (10 m/s) sliding speeds. The specimen were also tested using a reciprocating tribometer at temperatures ranging from 20 to 900 °C. The wear tracks of the specimen were inspected using scanning electron microscopy, electron dispersive spectroscopy, and laser scanning confocal microscopy to determine the morphology and presence of tribofilms. The coefficient of friction was generally lower and wear rate higher for the Ni-MAX composite than pure Ni specimen.

9:30 – 10 am | Effect of MoS_2 on the Tribological Performance of AA7075/Si3N4 Composite

Mir Irfan Ul Haq, Ankush Anand, Shri Mata Vaishno Devi University, Jammu, India

In this work, we examine the effect of MoS_2 on the friction and wear behaviour of AA7075/Si_3N_4 Composites. The percentage of Silicon Nitride was decided based on our previous work. Molybdenum Disulphide (MoS_2) was added in concentrations of 2 wt.%, 4 wt.% and 6 wt.%. The samples were fabricated via stir casting route as per the details in our recent work. The physical and microstructural evaluation of the composites was carried out prior to microhardness testing. The friction and wear behaviour of the cast composites was studied using a pin on disc machine with EN31 steel disc as the counter face material. The effect of applied load, MoS_2 content, sliding speed was studied on the friction and wear of the cast composites. The wear mechanisms in the worn out surfaces was studied using Scanning Electron Microscope. It was observed that MoS_2 plays a vital role in lowering the Coefficient of Friction at the contact due to its film formation capability.

10 – 10:30 am | Break

10:30 – 11 am | Influence of Operational and Surface Conditions on the Tribological Performance of Self-Lubricating Polymer Composite Bearing Materials Used in Hydropower Applications

Kim Berglund, Maria Rodiouchkina, Roland Larsson, Luleå University of Technology, Lulea, Sweden

In hydropower applications, self-lubricating polymer composite bearings has proven to be a good and environmentally friendly replacement for the traditionally used grease lubricated bronze bearings. However, in recent years, end users have experienced several bearing failures due to more demanding operating conditions due to integration of fluctuating renewable energy sources, e.g., wind and solar power, into the electric

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power systems. The aim of this work is to summarize and highlight important findings regarding the influence of various parameters on the tribological behaviour of these bearing materials using a linear reciprocating pin-on-disc configuration. Results indicates that low sliding speed and high nominal pressure offer the best performance for these bearing materials, with a reduction in frictional loses with up to 45% and almost three times lower wear. Furthermore, friction and wear can be reduced even more by optimizing the surface topography and hardness of the shaft.

11 – 11:30 am | Tribological Behavior of Self-Lubricating Polymer Composite Bearing Materials During Long-Time Dry Sliding

Maria Rodiouchkina, Leonardo Pelcastre, Kim Berglund, Roland Larsson, Luleå University of Technology, Lulea, Sweden, Jonna Lind, Åsa Kassman Rudolphi, Uppsala University, Uppsala, Sweden

Thermosets and thermoplastics containing PTFE are used in marine and hydropower applications due to their long service life and self-lubricity in dry and water-lubricated contacts. Their tribological performance is usually extrapolated from short, accelerated tests, which induces risks of inaccurate or incorrect interpretation. The aim of this study is to investigate the tribological behaviour and development of transfer layers during long sliding tests (160 hours), corresponding to years of operation. To mimic operational shutdowns, the tests were stopped every 20 hours to study the evolution of the surface topography and transfer layers. The wear rates of both materials decreased significantly with time. For the thermoplastic, COF decreased due to accelerated material transfer after 80 hours, highlighting the importance of long duration tests. The thermoset showed the highest transfer amount after 20 h and cause severe abrasive wear on the counter surface accompanied by a COF increase.

Session 7I • Cumberland 3

Contact Mechanics I

Session Chair:
Kyle Schulze, University of Florida, Gainesville, FL

Session Vice Chair:
Daniel Garcia, University of Florida, Gainesville, FL

8 – 8:30 am | Indenting Soft Swollen Elastomers with a Microparticle

Jonathan Pham, Justin Glover, University of Kentucky, Lexington, KY, Michael Kappl, Hans-Jürgen Butt, Max Planck Institute for Polymer Research, Mainz, Germany

Indentation of small particles into soft materials is important for many applications, from repellent surfaces to bioinspired adhesives. The mechanics of soft contact is typically defined by a balance of adhesion and elastic deformation, and often described by the Johnson-Kendall-Roberts (JKR) theory. For super soft materials on small length scales, JKR theory breaks down because liquid-like behavior emerges. Experimentally, this discrepancy has been shown mostly using crosslinked silicones. However, the majority of these materials possess a non-negligible amount of free molecules, leading to a self-swollen polymer network after preparation. We investigate indentation of soft silicones using a combination of confocal microscopy, atomic force microscopy, and fluorescent dyes. We confirm that JKR theory does not quantitatively agree with our experimental measurements, and explore the potential effects of free molecules in describing how a microparticle interacts with a soft surface.

8:30 – 9 am | Transparent Hydrogel Indentation and Slip Mechanics Through In-Situ Particle Inclusion and Exclusion (STLE Early Career Award Winner)

Alison Dunn, Christopher Johnson, Jiho Kim, Shabnam Bonyadi, University of Illinois at Urbana-Champaign, Urbana, IL

Many hypotheses exist to explain the coupled deformation and slip mechanics of interfaces where at least one surface is a transparent, high-water-content hydrogel. In this work we show versatile techniques of particle inclusion and exclusion microscopy in-situ with microindentation and sliding experiments of polyacrylamide hydrogels with > 90% water by mass. The particles are green fluorescent polystyrene spheres of 0.5 or 1 μm diameter. We identify time-dependent contact mechanics in migrating, stationary, and self-mated Gemini contact; our data suggests that for long times, Gemini contact approaches a constant-pressure contact model. Finally, we present for the first time asymmetric contact areas developed under slip as visualized by in situ particle exclusion which manifests as a flow field around the probe. The results of this work confirm the importance of in-situ microtribometry and begin to support mechanistic connections between hydrogel slip and deformation.

9 – 9:30 am | Small Forces, Large Noise: Scaling Nano-Indentation to the Micro Scale

Christopher O'Bryan, Kyle Schulze, Thomas Angelini, University of Florida, Gainesville, FL

Micro-indentation is a powerful tool for measuring moduli of soft materials; however, forces within the Hertz contact regime for thin samples are often below the detection threshold, requiring more sensitive techniques (e.g., colloidal-probe AFM). Alternatively, the Winkler model can be used with large-radius probes when sample thickness is known. However, uncertainty in sample thickness can lead to large errors in measured moduli. A method that enables micro-indentation for soft materials without knowledge of sample thickness would aid researchers lacking instruments like colloidal-probe AFM. Here, we present a micro-indentation method designed to measure the moduli of soft samples using a combination of roughened probes and data correlation analysis. This approach enables us to extract the moduli from indentation curves in which the measured load is larger than the noise. We demonstrate this method through indentation experiments of hydrogel samples of varying thickness and stiffness.

9:30 – 10 am | Eliminating the Challenges Associated with Physically Oscillating Contact Instruments

Daniel Garcia, Thomas Angelini, University of Florida, Gainesville, FL

The material properties of soft matter systems are measured with rheometers and tensile testing instruments whenever there exist few limitations on sample volume and fixturing where samples can be prepared specifically to work with the hardware of a given instrument. By contrast, indentation methods are advantageous for measuring material properties when sample preparation and geometry are highly constrained, which is often the case with tissue samples, hydrogel coatings, or soft objects with defined shapes like contact lenses. However, many soft matter materials exhibit frequency-dependent moduli, which are challenging to account for using the simple models of Hertz and Winkler. In this talk I will review our recent work to developed a Fourier-analysis method that leverages the Kramers-Kronig relations to extract frequency dependent elastic and viscous moduli from Force-indentation curves, eliminating the challenges associated with physically oscillating contact instruments.

10 – 10:30 am | Break

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10:30 – 11 am | Shape Memory: The Contact Mechanics of Photonic Crystal Structure

Kyle Schulze, Yongliang Ni, W. Gregory Sawyer, University of Florida, Gainesville, FL

The combination of stimuli-responsive polymer networks and photonic crystal structures has allowed for generation of functional material that have shape memory. These shape memory polymers exist in three states dependent upon their mechanical properties and applied stimuli: original, deformed, and recovered. Here we examine the shape memory of several PEG based PSMPC systems due to direct applied pressure and how it allows the system to transisition between these three states. Through in situ indentation measurements we observe the pressures that change the surface and bulk charactersistics that allow for an optical memory of the indent (much like a fingerprint scanner). We are also able to observe the links between the physical and chemical properties of the polymer used in conjunction with the mechanical properties of the overall structure and the overall response of the PSMPC.

11 – 11:30 am | The Tribomechadynamics of Jointed Interfaces: New Observations and Their Ramifications

Matthew Brake, Rice University, Houston, TX

Despite the prevalence of jointed structures, models of these assemblies are unable to predict the nonlinear dynamic properties (in terms of the amplitude dependent frequency and damping, and the evolution of damage within the interface). Recent research has demonstrated that several commonly held assumptions for modeling jointed structures are fundamentally incorrect. For instance, the dissipative mechanisms internal to an interface do not support the Masing hypothesis (i.e., that the hysteretic behavior of a jointed structure can be deduced from looking at only a quarter cycle of loading the joint). A series of experiments using novel electronic pressure film systems and high speed digital image correlation are used to compliment numerical insights into the physics of jointed systems. The ramifications of the findings are discussed in terms of a new generation of joint models.

11:30 am – Noon | Method for Calculating the Contact Between Roller End Face and Ring Flange In Multi-Body Simulations

Sven Wirsching, Stephan Tremmel, Sandro Wartzack, Design Engineering, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany, Christof Bohnert, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany

The contacts in rolling bearings like roller/flange contact under axial or combined loads are not extensively researched as them under pure radial loads, such as roller/raceway contact. To correctly compute friction in multi-body simulations for these contacts, one needs to calculate the pressure distribution in the contact, which is also vital for lifetime and load capacity. Afterwards the friction is computed. Current contact calculation methods normally work with the theory of Hertz, which leads to inaccuracies with higher-order geometries, like tori. The presented method discretizes a small area around the contact point. The analytically described geometries of both contacting bodies build a substitutive geometry via co-projection. A calculation with 2D bedding according to Winkler yields the pressure distribution. These results of the new method are compared with them, obtained by common simulation methods, such as the finite element method to assess accuracy and efficiency.

Session 7J • Cumberland 4

Surface Engineering III

Surface Texturing

Session Chair:
Zulfiqar Khan, Bournemouth University, Bournemouth, Dorset, United Kingdom

Session Vice Chair:
Kora Farokhzadeh, Bruker Nano Surfaces, San Jose, CA

8 – 8:30 am | The Effect of Graphene as Additive on the Anti-Corrosion of Polyurethane Coating

Hai Tan, Deguo Wang, Yanbao Guo, China University of Petroleum-Beijing, Beijing, China

Ocean is of the extraordinary riches where people are looking forward to. However, sea-water could enhance the corrosion of marine equipment. Various coatings (for example, polyurethane (PU) coatings) are spraying on the steel surfaces to enhance the anti-corrosion performance. In this paper, the corrosion behaviors of 4130 steel with or without PU coatings were discussed by electrochemical mean in the sea-water. And the graphene as the additive in different concentrations were also studied. A series of characterized methods were introduced to identify the corrosion behaviors and anti-corrosion performances of 4130 steel with or without coatings (in different concentrations of graphene), respectively. The results showed that the corrosion property of 4130 can enhanced obviously when sprayed the PU coatings. The graphene additive can further improve the anti-corrosion of PU coatings and in the graphene concentration of 0.6 % the PU/Graphene coatings worked best.

8:30 – 9 am | Friction Properties of Milling Micro-Textured Surface on Al-Si Alloy Under Sliding Boundary Conditions

Chao Guo, Qinghua Song, Zhanqiang Liu, Bing Wang, Key Laboratory of High Efficiency and Clean Mechanical Manufacture, Ministry of Education, School of Mechanical Engineering, Shandong University, Jinan, China, Long Chen, National Demonstration Center for Experimental Mechanical Engineering Education, Shandong University, Jinan, China

Texturing surfaces with different shapes to improve friction performance are generally investigated by using experimental approaches rather than theoretical analysis due to the complex boundary conditions. A comprehensive method is proposed to optimize textures and enhance lubrication in this paper. Considering the slip boundary of micro-gap flow, Reynolds equation is employed to solve slip velocity, and then the hydrodynamic lubrication effects are presented based on the Stokes equation using Galerkin finite element method. The influences of texturing geometry parameters on groove surface are investigated and discussed in detail. The results show that taper texture is more favorable to increase bearing capacity, and slip boundary makes the trend smooth. Finally, micro-milling cutters are used to machining different sizes of cylindrical, taper and hemispherical textures on Al-Si alloy 6061 surfaces, and friction experiments are performed to confirm the method presented in this paper.

9 – 9:30 am | Numerical and Experimental Studies on Friction Reduction by Surface Modification in TEHL Contacts

Max Marian, Tim Weikert, Stephan Tremmel, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

With the aim of improved energy efficiency of engine components, it is crucial to understand the underlying mechanisms of surface modification approaches, such as applying tribological coatings or microtextures. Within this contribution, TEHL simulations of the cam/tappet contact with modified surfaces are performed. Input data, like material and fluid parameters, geometries and load cases, are chosen according to the setup of a component test-rig, on which experimental tests are carried out to support the numerical findings. In particular, variants of amorphous carbon coatings and microtextures fabricated by laser ablation are investigated. Obtained insights indicate that coatings can reduce solid and fluid friction in all lubrication regimes. This corresponds to a shift of the Stribeck curve to the lower left. Conversely, microtexturing may reduce the fraction of solid friction while increasing fluid friction. This in turn resembles to a counterclockwise tilt of the Stribeck curve.

9:30 – 10 am | The Effect of Texture Shape on the Frictional Resistance Under Unidirectional Sliding

Pawel Pawlus, Slawomir Wos, Waldemar Koszela, Rzeszow University of Technology, Rzeszow, Poland

Tribological tests were carried out using a pin-on-disc tester under starved lubrication conditions. In order to achieve a conformal contact between sliding elements a special construction was used with self-aligning counter sample. During tests friction force were measured as a function of time. Disc surface texturing was performed with abrasive jet machining. Textured disc surfaces with two dimple patterns (spiral and radial) and four shapes (circle, oval, triangle and chevron) were tested. The contact area was lubricated by 0.08 ml of L-AN-46 oil. All tests were performed at ambient temperature, the normal force was 20 N, the sliding speed was 0.4 m/s, the number of revolutions was 10000. Tests revealed that in starved lubrication conditions both dimple shape and pattern affected the frictional resistance. In all cases surface texturing resulted in a decrease of the friction force. Chevron like oil pockets were the most universal shape independently of dimples array.

10 – 10:30 am | Break

10:30 – 11 am | Mastering the Art of Honing

David Chobany, Sunnen Products, St. Louis, MO, Wieslaw Grabon, Rzeszow University of Technology, Rzeszow, Poland, Boris Zhmud, Applied Nano Surfaces, BIZOL Lubricants, Uppsala, Sweden

Honing is a stock removal process intended to perfect bore geometry and size by removing a minimal metal layer while generating a finish pattern to provide optimum lubricant retention. The hone process produces extremely tight tolerances in straightness, roundness, size, and surface finish of cylindrical bores. The process expands abrasive stones of suitable grit and grade, under controlled pressure against the work surface while being rotated and reciprocated in the part. Combining these motions produces a cross-hatch pattern in the surface of the part being honed. In this presentation, we will show that the outcome of the honing process – not only in terms of the GD&T but also the tribology of the finished component – depending on a great number of parameters including the machine type, working conditions, tools, process fluid, and most importantly the operator experience. We will also demonstrate advantages of mechanochemical finishing versus conventional mechanical finishing.

11 – 11:30 am | Texture and Microstructure Refinement in Surface Severe Plastic Deformation of Strain Hardening Materials

Christopher Saldana, Georgia Institute of Technology, Atlanta, GA

In the present study, gradient microstructure and texture development in wedge-based high friction surface sliding of oxygen-free high conductivity copper was investigated. Microstructural response and evolution of crystallographic texture in severe surface plastic deformation was shown to be controllable in terms of both magnitude and gradient through control of the incident wedge angle and sliding parameters. Equiaxed ultra-fined grains and elongated grains were produced in the subsurface region, which is indicative of dynamic recrystallization at large strains in the subsurface. Subsurface regions exhibited a significant fraction of shear texture along 110 partial fibers. Texture evolution simulated using the visco-plastic self-consistent framework revealed variations in strain level controlling different mechanisms for rotation of these partial fibers. These results allude to fundamental limits in material processing by severe shear using scalable deformation configurations.

11:30 am – Noon | Bi-Gaussian Stratified Feature of Impregnated Graphite Surfaces after a Laser Treatment

Songtao Hu, Xi Shi, Zhike Peng, Shanghai Jiao Tong University, Shanghai, China, Tom Reddyhoff, Imperial College London, London, United Kingdom, Weifeng Huang, Xiangfeng Liu, Tsinghua University, Beijing, China

Graphite materials are increasingly applied to tribological pairs such as thrust bearings and mechanical seals due to its excellent self-lubrication. Laser technology is conducted as an effective effort to improve the lubrication by modifying surface topography and chemical composition. Researchers tried to explain the lubrication improvement arising from a surface-topography modification. However, current works are only focused on a single-stratum surface viewpoint, lacking a bi-Gaussian stratified surface perspective, which has been successfully used on plateau-honing and worn surfaces. In this paper, resin-impregnated graphite surfaces are processed by low- and high-energy laser treatments, leading to hydrophobicity and hydrophilicity, respectively. The bi-Gaussian stratified feature is disclosed on both laser-treated surfaces. Functional performance can be further optimized by controlling the bi-Gaussian stratified surface feature based on the choice of laser parameters.

Registration Available for STLE Certification Exams

All four of STLE's certification exams: Certified Lubrication Specialist™, Oil Monitoring Analyst I and II™ and Certified Metalworking Fluids Specialist™ will be conducted currently on Thursday, May 23 from 9 am to Noon in the Omni Nashville Hotel, Mockingbird 2. Individuals must be registered for exams in advance, however, onsite registration is available on a limited basis.

For more information, stop by the STLE Registration Desk in the Omni Nashville Hotel – Second Level Foyer. Registration and sign-in starts at 8:30 am, and the exams start promptly at 9 am.

- **Exam Fees: First exam: $440 (STLE member), $590 (Non-member)**
- **Retake exam $220 (STLE member), $295 (Non-member)**

Session 7K • Cumberland 5

Lubrication Fundamentals VIII

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

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

8 – 8:30 am | Impact of Solvent Dilution Technique on Soft Particle Detection by Laser Particle Counter

Lin Wang, David Holt, Derek Selby, ExxonMobil, Annandale, NJ

There are two types of particles found in lubricants, hard and soft. Hard particles such as dirt, are detrimental to equipment life. Soft particles, such as antifoam additives, are not detrimental to equipment life. Antifoam are designed to be insoluble in the lubricant to enhance their effectiveness and protect the equipment. Consequently, there is a need for an effective lubricant particle count method that can effectively discriminate between the harmful hard particles from the benign/useful particles. The laser particle count methods that are widely used today, unfortunately cannot discriminate between hard and soft particles thus providing inaccurate numbers that lead to unnecessary maintenance decision/work. We have found by use of appropriate solvents to pre-dilute the oils samples, it is possible to solubilize the soft particles. The careful selection of solvent and influence of antifoam chemistry is discussed here.

8:30 – 9 am | Influence of Base Oil Ageing on Viscosity Modifiers Behavior

Eliane Gendreau, Hugh Spikes, Janet Wong, Imperial College London, London, United Kingdom, Robert Taylor, Neal Morgan, Shell Global Solutions, London, United Kingdom

Effective viscosity modifiers are crucial for the improvement of fuel economy, as they enable the development of low viscosity lubricants. Viscosity modifiers are high molecular weight polymeric additives used to enhance the temperature-dependant viscosity of the oil. Their properties are also shear dependent. As the oil ages, its properties change and its viscosity may be impacted. This work investigates the influence of base oil ageing on viscosity modifiers. The quantification of shear thinning, which is the temporary or permanent decrease in viscosity at high shear rate, is examined. Fluid viscosity measurements will be presented, using friction and film thickness measurements. Local viscosity in the rubbing contact will be studied using fluorescence spectroscopy. The relationship between viscosity results from friction/film thickness measurements and those from fluorescence spectroscopy will be discussed.

9 – 9:30 am | Lubrication of a Stretchable Sheet at the Tool Tip-Sheet Interface in Single Point Incremental Forming (SPIF)

Tao He, Dohyun Leem, Xin Zhang, Newell Moser, Jian Cao, Qian (Jane) Wang, Northwestern University, Evanston, IL, Hirotaka Miwa, Toshikazu Nanbu, Murakami Ryou, Nissan Research Center, Kanagawa, Japan

Incremental forming is one of the rapidly developing manufacturing techniques for making complex sheet metal parts, in which a tool moves along a controlled path and forms the sheet blanks to a desired shape. Lubrication is considered as an effective way to reduce the tool tip-sheet friction; it may be significantly affected by sheet stretching during the forming process. The current work is focused on modeling the lubrication in SPIF, which includes the Reynolds equation considering surface stretching in different directions, tool tip surface elastic deformation calculated through influence coefficients (ICs) and the discrete convolution and fast Fourier transform (DC-FFT) method, and the sheet surface deformation obtained from finite element method (FEM). Cases are analyzed to reveal the influences of forming parameters, such as tool speed, cone radius, wall angle, and incremental depth, on the best design of SPIF lubrication.

9:30 – 10 am | Open Slot

10 – 10:30 am | Break

10:30 – 11 am | Effects of Bearing Material Choice and Engine Oil Viscosity on Journal Bearing Durability in Stop/Start Environments

Jun Xu, Infineum USA L.P., Linden, NJ, Emma Ravenhill, Infineum UK Ltd., Abingdon, Oxon, United Kingdom

Ever tightening limits of engine emissions have led to a trend towards lower and lower SAE viscosity grade oils. This decrease in viscosity presents a challenge for oil manufacturer and OEMs alike when considering the balance between fuel economy and engine durability. This problem is exacerbated by the introduction of stop/start technology which increases the level of boundary contact between engine parts. One of the engine contacts most affected by this change is the journal bearing. This paper investigates the effect of viscosity grade and journal bearing material choice on wear using a rig designed to mimic an engine's lifetime of stop/start events. It is clear from the results that with substantial decreases in viscosity grade that a solution is required, either via more complex journal bearing structures or novel oil additive chemistry.

11 – 11:30 am | Benchtop Level Testing of Lubricants and Surfaces for Reciprocating Applications: High Frequency Reciprocating Rig

Giovanni Ramirez, Kora Farokhzadeh, Steven Shaffer, Ivo Miller, Bruker Nano Surfaces, San Jose, CA

Development of new lubricants and surfaces to be employed in reciprocating systems such as engines and compressors always comes with challenges. Among them are how to precisely measure their wear and friction at the laboratory scale before performing more intensive component level tests. High frequency reciprocating rigs have been used for many decades to simulate those systems, and different standard protocols and configurations are conventionally used in lubrication research and development. Here we present an optimized tribometry setup enabling time effective screening of lubricants and materials at the benchtop scale using the UMT TriboLab. The samples can be tested under simulated conditions to rank the performance of lubricants and surfaces, while monitoring small changes in friction. We also present the critical importance of the calculation method employed to analyze the data obtained by high frequency reciprocating tests.

11:30 am – Noon | Ball Milled Graphite Nanoplatelets as a Biolubricant Additives for Friction and Wear: An Attempt to Develop a 'Green' Lubricant

Emad Omrani, Pradeep Menezes, University of Nevada-Reno, Reno, NV, Pradeep Rohatgi, University of Wisconsin-Milwaukee, Milwaukee, WI

Role of ball milled graphite nanoplatelets (GNPs) as an oil additive is investigated. The main objective of this study is to investigate and explain the enhancement mechanisms of GNPs at the contact surface during tribological testing. Effect of GNPs concentration and applied load are studied. Remarkably, the experimental analysis demonstrates the feasibility of the ball milled GNPs influential in a notable improvement in tribological performance of nanolubricants. The proposed mechanism to describe the effect of GNPs in boundary lubrication condition is "reduced direct metal-metal contact area" at the contact surface that is confirmed by cancerization of worn surface where a graphite nanoplatelets which

has low shear strength layers sits between two contacting surfaces and separates the two sliding metal surfaces with no actual contact between them. This means that there is less formation of asperity junctions between the two surfaces.

Session 7L • Cumberland 6

Condition Monitoring II

Session Chair:
Jatin Mehta, Fluitec International, Bayonne, NJ

Session Vice Chair:
Daniel Walsh, Spectro Scientific, Chelmsford, MA

8 – 8:30 am | Root Cause Analysis of Varnish Generation in Lube Systems

Jatin Mehta, Cristian Soto, Fluitec International, Bayonne, NJ

Varnish formation has plagued many lube systems. The formation of varnish is a common phenomenon, but still one uncovers various forms of varnish formed in the lubricating systems such as compressors, gas and steam turbines which are unusual and not derived due to the in-service fluid. This paper will showcase various root cause analysis of the deposit formation as observed in the real field scenario. This paper also describes how regular condition monitoring fails to detect early symptoms of the varnish formation in the system.

8:30 – 9 am | Development of an Oil Split Test Method for Emulsions without the Use of Strong Oxidizing Acids

Jon Lewis, Quaker Chemical Corp., Conshohocken, PA

Fluid concentration of in-use metalworking coolants is often monitored by acid split testing using strong oxidizing acids (such as nitric and/or sulfuric acids). While effective, this test method results in the generation of hazardous waste and has a high potential to result in severe chemical burns or inhalation of toxic fumes during the course of testing. An alternative oil split method was developed utilizing a combination of a magnesium sulfate (Epsom salts) solution and a quaternary ammonium chloride polymer to achieve the split. This new method provides similar splitting of a coolant's lipophilic components to the traditional acid split methods without the need for strong oxidizing acids. Implementation of this method for routine monitoring of metalworking fluids in Quaker's lab has resulted in a significant reduction in hazardous waste generation and improved worker safety.

9 – 9:30 am | Identification of Unknown Elements in a Lubricant Sample and High Throughput Wear Metals Analysis by ICP-OES

Autumn Wassmuth, PerkinElmer, Inc., Shelton, CT

When in service lubricants show an increase in concentration of key wear metals it can be an indication that maintenance is required. The elemental content of additives and contamination that signify that maintenance is needed are normally known and trended over time. For a lubricant with unknown composition, ICP-OES instruments can take an elemental fingerprint of the sample without calibrating for concentration. This elemental fingerprint can reveal what elements are present by allowing the user to see each element at multiple wavelengths simultaneously. During analysis the same simultaneous measurement of elements can lead to a measurement time that is less than the time required for sample uptake and washout. By adding a sampling valve to an ICP-OES instrument, the uptake and washout times are reduced allowing the sample to sample time to be around 25 seconds, without reducing data quality. While other advancements will increase sample throughput throughout the lab.

9:30 – 10 am | Determination of Total Base Number in In-Service Lubricants Using FT-IR

Ariel Bohman, PerkinElmer, Inc., Shelton, CT

The Total Base Number or TBN is a measure of the base reserve of a lubricant. This base reserve is used to neutralize acidic compounds that are generated as the result of combustion. These acidic compounds must be neutralized to prevent and reduce corrosion. Current wet chemistry methods involve the titrimetric determination of TBN which are time consuming and involve the use of hazardous chemicals which pose both safety and disposal concerns. FT-IR spectroscopy coupled with chemometric modelling can be used to develop a rapid and reagent-less method for the determination of TBN for in-service lubricants that can be implemented into existing infrared oil analyses. This presentation will discuss the development and implementation of chemometric models for the determination of TBN and provide examples of developed models for the analysis of in-service lubricant TBN.

10 – 10:30 am | Break

10:30 – 11 am | In-Situ Analysis of Degraded Gear Oils Using Ultrasonic Reflectometry

Tomos Brenchley, Michele Schirru, Rob Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom

Piezoelectric transducers can be used to measure the viscosity of oil by monitoring the amplitude of the reflection of an ultrasonic shear vibration that is in contact with the oscillating quartz. Applying this approach in an engine is restricted due to the harsh conditions which degrade the oscillator. Recent developments have overcome these limitations by making the sensor remote from the lubricant by employing a thin matching layer. This approach can be used to build a simple viscometer; in addition by exciting the transducer at different frequencies we can vary the shear rate applied to the oil. An oil was aged in an environmental unit assembly and was tested using this novel viscometer. Tests found the viscometer can measure the viscosity of lubricating oils and more specifically, the high frequency components of the ultrasonic spectrum can indicate the sudden change in base oil structure, while the lower frequency component is indicative of the whole lubricant performance.

11 – 11:30 am | Oxidation Analysis of Lubricants Using Ambient Pressure Differential Scanning Calorimetry (DSC) Techniques to Determine Antioxidant Performance

Keith Schomburg, PerkinElmer, Inc., Magnolia, TX

The ability to monitor oxidation properties in lubricants is an important laboratory analysis for any lubrication monitoring program. The oxidative stability of lubricating fluids is typically evaluated using Rotating Pressure Vessel Oxidation Test (ASTM D2272), Linear Sweep Voltammetry (ASTM D6971) and other oxidation analysis techniques. In most oxidation tests, copper is used as an oxidation catalyst. Recent studies show copper can be used for the oxidative analysis of lubricants using Differential Scanning Calorimetry (DSC) techniques. The use of copper as an oxidation catalyst in DSC has the effect of reducing the oxidation temperature allowing ambient pressure DSC techniques to be used for antioxidant studies. In this presentation, new and in-service lubricant samples were tested using copper and ambient pressure DSC techniques to determine the Oxidation Onset Temperature (OOT) and Oxidation Induction Temperature (OIT) values for evaluation of the remaining useful fluid life.

7L

11:30 am – Noon | Fast and Efficient Quality Control of Lubricants and Its Foaming Tendency by FoamDDI – An Upgraded, Fully Automatized Detection Imaging Apparatus

Aaron Mendez, Ayalytical Instruments, Houston, TX

We reported earlier at this forum the role of Digital Detection Imaging techniques in measuring the adverse effects of foam formation and foam stability on machinery, pumps and other equipment. Uncontrolled foam brake fluid films increasing wear and oxidation risks, cause cavitation in pumps, vary fluid flows, introduce pressure changes in hydraulic systems and promote loss of fluids. The foaming formation speed and its collapse can reliably be measured, plotted and displayed in real time since heating and cooling speeds have been optimized. The common tests used to evaluate luboils foaming tendency and foaming stability are ASTM D892 in all its three sequences and the High Temperature method D6082 which can now be easily performed with the benefits of being an unattended software-controlled procedure with potential for developments like air release and evaluation of antifoam performance tailored to specific lubricants. The new FoamDDI design allows for more efficient foam control.

Session 8A • Legends F

Rolling Element Bearings IV

Session Chair:
Nikhil Londhe, The Timken Co., Canton, OH

Session Vice Chair:
Anup Pandkar, Siemens Gamesa Renewable Energy, Orlando, FL

1:30 – 2 pm | A Mathematical Emulation of Bair's High Pressure Visualization Cell and Improved EHL Traction Analysis for Heavily Loaded Rolling Contacts

Coda Pan, Rensselaer Polytechnic Institute, Millbury, MA, Daejong Kim, University of Texas at Arlington, Arlington, TX, Michael Khonsari, Louisiana State University, Baton Rouge, LA

Observation of shear bands in rheological studies suggests existence of a shear stress threshold limitation in thin film flows of a Newtonian viscous fluid. The phenomenon is relevant to (1.) interpretation of experimental observations found in a High Pressure Flow Visualization Cell (HPFVC) and (2.) use of Barus viscosity law in EHL studies. The Mohr-Coulomb failure criterion, fashioned after the practice of soil mechanics, was suggested to identify a Limiting Shear Stress Threshold (LSST). LSST can also be associated with the theory of failure for ductile materials in terms of the threshold limitation of distortion energy. Two draft manuscripts are undergoing peer review for publication in STLE's journal, Tribology Transactions. Derivation of the LSST constitutive equation is described in the first manuscript entitled "Shear Bands in High Pressure Flow Visualization Cell." The second manuscript deals with "Influences of Barus-Newton Threshold on Ertel-Grubin Analysis."

2 – 2:30 pm | Numerical and Experimental Performance Analysis of an Aircraft Engine Roller Bearing Using under Race Lubrication Method

Rami Kerrouche, Salah Boukraa, University Saad Dahlab of Blida, Blida, Algeria, Azzedine Dadouche, Mahmoud Mamou, National Research Council Canada, Ottawa, Ontario, Canada

This paper studies the air-oil two-phase flow characteristics inside a cylindrical roller bearing as well as the temperature distribution and power loss. Numerical simulations have been performed to determine the oil distribution inside the bearing cavity and its effect on bearing temperature under different rotational speeds and oil flow rates. Under-race lubrication method was considered in this study. A commercially-available computational fluid dynamic (CFD) software was used to model the bearing and run the simulations. Experimental measurements of bearing temperature and friction torque have been carried out on a high speed rolling bearing test rig. The rig allows a smooth control of speed, load, and oil supply temperature to the test bearing. The rig runs at speeds up to 35,000 rpm with the capability of applying radial loads up to 4,500 N.

2:30 – 3 pm | Real-Time Modeling of Thermal Interactions in Cryogenic Ball Bearings

Pradeep Gupta, PKG Inc., Clifton Park, NY, Howard Gibson, NASA/MSFC, Marshall Space Flight Center, AL

Real-time modeling of thermal interactions in cryogenic ball bearings for liquid oxygen turbopump applications is based on classical differential equations of motion of bearing elements and step-wise time-averaging of transient heat generations. As the thermal interactions converge the time-varying temperature fields approach steady values. Bearing performance simulations are modeled in real-time over experimental time cycles. Steady-state solutions are independent of initial conditions as expected from stable time domain integrations. Model predictions of bearing heat generations are in good agreement with experimental measurements for both all steel and hybrid ball bearings. Under prescribed applied load and speed, while the ball/race contact stress is higher in a hybrid bearing, the contact heat generation is significantly lower in comparison to that in an all steel bearing, particularly under heavily loaded high-speed conditions.

3 – 3:30 pm | Break

3:30 – 4 pm | Modeling Heat Generation in Turbine Engine Rolling Bearings

Jared Taketa, Craig Price, Rolls-Royce Corp., Indianapolis, IN, Pradeep Gupta, PKG Inc., Clifton Park, NY

An updated dynamics model is presented to couple bearing element motion with thermal interactions in rolling bearings. Although lubricant churning and drag constitute majority of heat generation in most turbine engine bearings, lubricant traction becomes significant as the applied load increases. While churning and drag effects are based on classical laminar and turbulent flow theories, independently measured lubricant rheology, including shear dependence of viscosity, is used to model lubricant traction. Transient heat generations are time-averaged over thermal time step to compute time varying temperature fields in the bearing, which alter properties of bearing materials, operating bearing geometry and rheology of the lubricant. As the transient solutions converge to stable operating temperatures, bearing heat generation approaches the expected steady-state value. Heat generation predictions for both ball and rolling bearings are in good agreement with measured experimental data.

4 – 4:30 pm | Thermal Conductivity and Flash Temperature of Bearing Steel

Tom Reddyhoff, Hugh Spikes, Imperial College London, London, United Kingdom, Aaron Schmidt, Massachusetts Institute of Technology, Cambridge, MA

Calculation of flash temperatures of tribological components requires values of the thermal conductivity of the contacting materials. These values are rarely measured by researchers or designers, who instead rely upon values taken from the literature or from suppliers. This presentation describes measurement of the thermal conductivities of three materials of tribological interest 52100 bearing steel, zirconia and tungsten carbide. A Frequency Domain Thermoreflectance method is employed that is able to measure near-surface thermal conductivity from finished components including those with curved surfaces such as ball bearings.

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For most materials studied the thermal conductivity measured is close to that suggested by suppliers and in handbooks. However for AISI 52100 the value measured is less than half that generally stated in the literature. The possible reasons for this and its implications are discussed.

4:30 – 5 pm | Measurement of Free Volume of Lubricants from Pressure Dependence of Bulk Modulus

Bo Zhang, Toshifumi Mawatari, Saga University, Saga-shi, Saga, Japan

The free volume of a liquid gives the liquid with fluidity. In spite of its paramount importance the only existing measurement technology of the free volume is for a solid and no for a liquid since the mobility of the free volume in the liquid. In this paper it is proposed that the free volume of a liquid may be measured through measuring the dependence of the bulk modulus of the liquid on the pressure. Since the volume of a liquid consists of the occupied volume and the free volume the bulk modulus can be expressed as 1/K=-dV/Vdp=-(dVf+dVo)/Vdp=f/Kf+1/Ko (1) where is the fractional free volume. Assuming that is independent of the pressure we have f=f0exp(-p/Kf) (2) K=KfKo/(Kf+fKo)=KfKo/(Kf+Kof0exp(-p/Kf)) (3) Equation (3) was used to extract the parameters of the bulk modulus of the free volume, the bulk modulus of the occupied volume and the initial fractional free volume for the lubricant KTF1. It was found that Kf=0.29 GPa, Ko=10 GPa, and fo=0.18.

5 – 5:30 pm | Investigation of the Synthetic Stiffness for Elastohydrodynamically Lubricated Cylindrical Roller Bearings

Zeliang Xiao, Xi Shi, Shanghai Jiao Tong University, Shanghai, China

The cylindrical roller bearing generally operates in elastohydrodynamic lubrication line contacts and its dynamic responses are closely related to the stiffness of lubricated contacts. The synthetic stiffness for elastohydrodynamically lubricated cylindrical roller bearing is derived from the oil film stiffness and contact stiffness of bearing. The oil film stiffness is calculated according to the relationship of pressure and film thickness of viscoelastic fluid while the contact stiffness of bearing is computed by using a contact mechanics approach. Effects of bearing applied load and rotation speed on the synthetic stiffness are investigated. The results show that the oil film stiffness is larger than the contact stiffness of bearing and the synthetic stiffness mainly depends on the latter. However, the oil film stiffness is of benefit to impact resistance and vibration reduction of bearings.

Registration Available for STLE Certification Exams

All four of STLE's certification exams: Certified Lubrication Specialist™, Oil Monitoring Analyst I and II™ and Certified Metalworking Fluids Specialist™ will be conducted currently on Thursday, May 23 from 9 am to Noon in the Omni Nashville Hotel, Mockingbird 2. Individuals must be registered for exams in advance, however, onsite registration is available on a limited basis.

For more information, stop by the STLE Registration Desk in the Omni Nashville Hotel – Second Level Foyer. Registration and sign-in starts at 8:30 am, and the exams start promptly at 9 am.

- **Exam Fees: First exam: $440 (STLE member), $590 (Non-member)**
- **Retake exam $220 (STLE member), $295 (Non-member)**

Session 8B • Music Row 1

Biotribology III

Session Chair:
Alison Dunn, University of Illinois at Urbana-Champaign, Urbana, IL

Session Vice Chair:
Jiho Kim, University of Illinois at Urbana-Champaign, Urbana, IL

1:30 – 2 pm | Invited Talk: Contact Mechanics for Characterization of Hydrogel Material Properties

Michelle Oyen, East Carolina University, Greenville, NC

Indentation techniques have recently been adapted for the study of hydrated materials, including biological tissues and hydrogels. Both natural and synthetic hydrogels have been characterized using indentation and nanoindentation across a wide range of experimental length-scales. The material response is shown to be greatly dependent on the chemical bonding within the hydrogel, i.e., whether the network is physically or chemically cross-linked. Hydrogels in particular are an attractive system for studying structure-properties relationships, as the water fraction can be systematically varied for a single polymer, and different polymers with the same water fraction can be compared. Based upon knowledge of the properties of each individual component, composite hydrogels can be created to mimic the overall response of complex biological materials to create multi-component tissue engineering scaffolds.

2 – 2:30 pm | Shear-Induced Cellular Death Response

Samuel Hart, Juan Urueña, Angela Pitenis, Padraic Levings, W. Gregory Sawyer, University of Florida, Gainesville, FL

The design of soft-implants is a very arduous task in which many factors must be considered to prevent or minimize a biological response. Yet, despite these efforts recent work has shown that sub-clinical inflammation may occur during soft contact lens wear in the eye. This study characterizes the contributions of frictional shear stress to sterile inflammation and cell death in vitro. Shear induced cell death was studied in human telomerase-immortalized corneal epithelial (hTCEpi) cells stained with apoptosis and necrosis markers. Additionally, actin, ZO-1, and nucleus stains provided further insight into the cytoskeletal and cellular death responses to shear stress. Tribological experiments were performed on a fluorescence microscope in which a soft hydrogel probe slid against cells to provide a range of shear stresses. It is evident that among the many factors considered during the design of soft implants, surface shear stresses must also be taken into account.

2:30 – 3 pm | Mitigating Cartilage Strain and Shear by Simulating Activity Regimes with In-Situ Cartilage Explants

Steven Voinier, Brian Graham, Axel Moore, Christopher Price, David Burris, University of Delaware, Newark, DE

Although the public understands regular exercise benefits overall health, recent epidemiological studies have also demonstrated cartilage integrity necessitates routine activity. One of the most likely contributors is articulation-induced cartilage rehydration: articulation actively restores hydration and its dependent biomechanical outcomes such as thickness, interstitial pressure, load support, mechanical stiffness, and lubrication. In this study, we leverage the tribological rehydration phenomenon to elucidate how both activity intermittency and volume affects the biomechanical functions of cartilage under well-controlled sliding conditions. We quantified the biomechanical response of explants in the cSCA configuration over size-adjusted 'equivalent days' of varying intermittent-activity patterns and total daily activity volume. Through this approach, we can deduce an optimal volume of intermittent activity pattern that maximizes interstitial pressure while minimizing shear stress.

3 – 3:30 pm | Break

3:30 pm – 4:00 pm | Static Friction Phase Diagram for Hydrogels

Rosa Espinosa-Marzal, Tooba Shoaib, University of Illinois at Urbana-Champaign, Urbana, IL

Investigating the mechanisms underlying soft-matter lubrication is pivotal in understanding the functionalities and complexities of bio-lubrication. Hydrogels are key components in biological tribosystems, including the articular and ocular lubrication systems. We present studies of the static friction by colloidal probe microscopy under a wide range of hold times, loads, compositions, sliding velocities and temperatures. The results of this experimental study let us construct a static friction phase diagram that should be universal for gel-like materials, including the components of biological tribosystems.

4 – 4:30 pm | Effect of Shoe Outsole Backing on the Coefficient of Friction

Arian Iraqi, Kurt Beschorner, University of Pittsburgh, Pittsburgh, PA

Footwear with high coefficient of friction (COF) against lubricated floor may mitigate slipping accidents. COF varies considerably across and within shoes brands. This variation may be due to the supporting midsole that affects contact area. This study investigated the effect of this support system on the COF. Eleven pairs of shoes with outsole tread were tested on a ceramic and laminate tile with canola oil using a robotic shoe tribometer. The contact area of the tread was used as a metric to identify between outsole backings that either fully or partially brought treads into the contact region. The outsole designs were similar between shoes with good and poor support system. The shoes with the good support system had 15.5% and 26.7% higher COF on ceramic and laminate tile, respectively, compared to shoes with poor support. The suboptimal design of shoe outsole backing negatively impacts COF by reducing the contact area.

Session 8C • Music Row 5

Power Generation II

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

Session Vice Chair:
Salvatore Rea, LANXESS Corp., Perkasie, PA

1:30 – 2 pm | Fluorescence Spectroscopy for Online Condition Monitoring of Machinery Lubricants

Pooja Suresh, Oleg Sosnovski, GasTOPS Ltd., Ottawa, Ontario, Canada

Lubricating oils contain antioxidant additives in order to protect the base oil from thermal oxidation, thereby preventing loss of lubricity and formation of oxidation products and deposits such as sludge and varnish. Monitoring the antioxidant levels provides early indication of oxidative degradation of the lubricant, allowing for condition-based maintenance ahead of potential damage to the equipment. This translates to lower cost of maintenance and improved equipment availability, which are key drivers for the power generation industry. Current techniques for measuring antioxidant additive content require expensive laboratory-grade equipment, sample preparation, consumables and operation by trained personnel, making them unsuitable for online monitoring. This presentation discusses the application of an alternative technique using fluorescence spectroscopy technology that allows for real-time, online monitoring of antioxidant additive levels.

2 – 2:30 pm | Consequences of Incorrect EHC Fluid Maintenance and Opportunities for Improvement

Peter Dufresne, EPT, Calgary, Alberta, Canada

EHC systems are one of the most critical hydraulic applications in power plants operating steam turbines. Despite their importance, common fluid maintenance practices often fail to keep the EHC fluid in acceptable condition. With a number of recent catastrophic failures, OEMs and insurance companies have become increasingly interested in oil quality to confirm that sites are operating within established industry specifications. Site managers, therefore, need to appreciate the implications of poor fluid condition and the importance of effective EHC fluid maintenance. Only then can they ensure that effective maintenance programs are in place with sufficient budgets established. This paper will review common issues observed and review opportunities that leverage technology to improve fluid quality in EHC applications.

2:30 – 3 pm | Understanding EHC Fluid Condition Monitoring

Ken Brown, Canoil, Mississauga, Ontario, Canada, Matthew Hobbs, EPT, Calgary, Alberta, Canada

Triaryl phosphate esters have been used as fire-resistant hydraulic fluids in the control systems of steam turbines for over 50 years. These fluids significantly reduce the risk of fire but their maintenance has been problematic at some stations. This is a combination of many factors ranging from system design to failure to keep up to date with current operating procedures and best maintenance practices. Some turbine manufacturers have also been slow to revise fluid condition monitoring requirements including recommended tests and their limits. This presentation will cover a number of root causes of fluid degradation in addition to more recent test methods and fluid conditioning/remediation options.

3 – 3:30 pm | Break

3:30 – 4 pm | Evaluation of Turbine Oil Performance

Jatin Mehta, Fluitec International, Bayonne, NJ

Significant advancements have been made in the last two decades in turbine oil formulations, utilizing superior base stocks and antioxidant chemistries. The result is that turbine oils used in even the most thermally stressful gas turbines can provide long-life and good performance provided they are maintained properly. Turbine oils are evaluated using various oxidations test under oxidative, thermal, hydrolytic and catalytic conditions. The test methods used in the industry are D943, D4310, and D7873 in additional to OEM specific tests. The Turbine Oil Performance Prediction test helps to determine the long-term performance of the turbine oil in steam and gas turbines. This paper will assess the oxidation resisitance, antioxidants stability, varnish potential/sludge formation and various performacne properties of the turbine oils. This paper will describe the performance of commercially available oils using Turbine Performance Prediction Tests.

4 – 4:30 pm | Power Generation Business Meeting

Session 8D • Music Row 4

Seals I

Session Chair:
Tom Lai, John Crane, Inc., Morton Grove, IL

Session Vice Chair:
Khalid Malik, Ontario Power Generation, Pickering, Ontario, Canada

1:30 – 2 pm | Impact of Natural Surface Texture on the Lubrication of Mechanical Face Seals

Noel Brunetiere, Institut Pprime, Futuroscope Chasseneuil Cedex, France

Some of the materials used for the seal faces exhibit porosity whose characteristics depends on their manufacturing process. The pore on the seal surface can be considered as dimple-like natural surface texture. Compared to artificial surface texture, their size and location are random. In this paper, the influence of these pores on the lubrication of mechanical face seals is numerically studied. The model solves the Reynolds equation coupled with a mass-conserving cavitation algorithm. The influence of the statistical parameters of the pore size and location distributions on the lubrication are analyzed.

2 – 2:30 pm | Wear and Surface Fatigue of Rubbers for Static Seals in Reciprocating Sliding Contact

Joichi Sugimura, Hiroyoshi Tanaka, Kyushu University, Fukuoka, Fukuoka, Japan

This paper describes a study on the effect of contact conditions on wear and surface fatigue of rubbers for high-pressure gas seals in reciprocating sliding. Reciprocating sliding tests are conducted with NBR and EPDM rubbers filled with different fillers and AISI 316L stainless steel in hydrogen, air and in vacuum by using a pin-on-disk type friction test rig. Fillers include carbon black and silica. The rubbers exhibit two different failure modes of wear and cracking depending on sliding conditions and filler materials. Some rubbers filled with larger carbon black and silica tend to be damaged by cracking rather than wear. The relationship of damage modes with the conditions and the mechanics involved in the deferent behaviors are discussed.

2:30 – 3 pm | Frictional Properties of Diamond Coated (and UNCD® coated) Silicon Carbide and Tungsten Carbide Mechanical Seal Faces

Mark Lapansie, Charles West, Jon Hohol, Advanced Diamond Techologies, Inc., Romeoville, IL

Hard ceramic mechanical seal face materials, such as silicon carbide and tungsten carbide (cemented carbide), are frequently used in pumping applications involving aggressive media or poor lubrication. However, high friction between these materials causes increased rotational torque and excessive heat generation. An ultrananocrystalline diamond (UNCD®) coating on these materials significantly reduces the coefficient of friction (CoF) in seal rotation, resulting not only in less torque and heat generation, but also reduced energy consumption and therefore reduced running costs. In this study, mechanical seal rings, both with and without UNCD coating, are evaluated in an apparatus which allows direct torque measurement of a multi-spring mechanical seal. The coefficient of friction (CoF) of each material pair in deionized water is reported, and a model of energy savings based on the coefficient of friction is proposed.

3 – 3:30 pm | Break

3:30 – 4 pm | Effect of Combined Mechanical Stress and Salt Spray Aging on Dynamic Friction Behavior of O Rings

Jian Wu, Haohao Li, Youshan Wang, Benlong Su, Zhibo Cui, Zhe Li, Harbin Institute of Technology, Weihai, Weihai, Shandong, China

Rubber seals has become one of the key components in industry sealing devices. However, environment becomes more severe due to ocean application fields. Thus, a combined salt spray and mechanical stress test platform was developed for studying aging process of rubber materials. Then, influence of mechanical stresses and salt spray aging on dynamic friction behavior of rubber materials have been investigated, and the coupled aging mechanism of rubber materials have been studied by Nicolet 380 ATR-FTIR and DSX510. Finally, a friction finite element model of O ring have been developed, which considered the effect of combined mechanical stress and salt spray aging. It can be seen that combined salt spray and mechanical stress aggravate rubber aging reaction; contact pressure decreases obviously, when aging time and tensile strain increases. The method based on accelerated aging test and finite element method provides a basis for design and optimization of rubber seals.

4 – 4:30 pm | Dynamic Behavior of a Fractional Viscoelastic Seal with Solid Contact

Arne Leenders, Leibniz University Hannover, Hannover, Germany

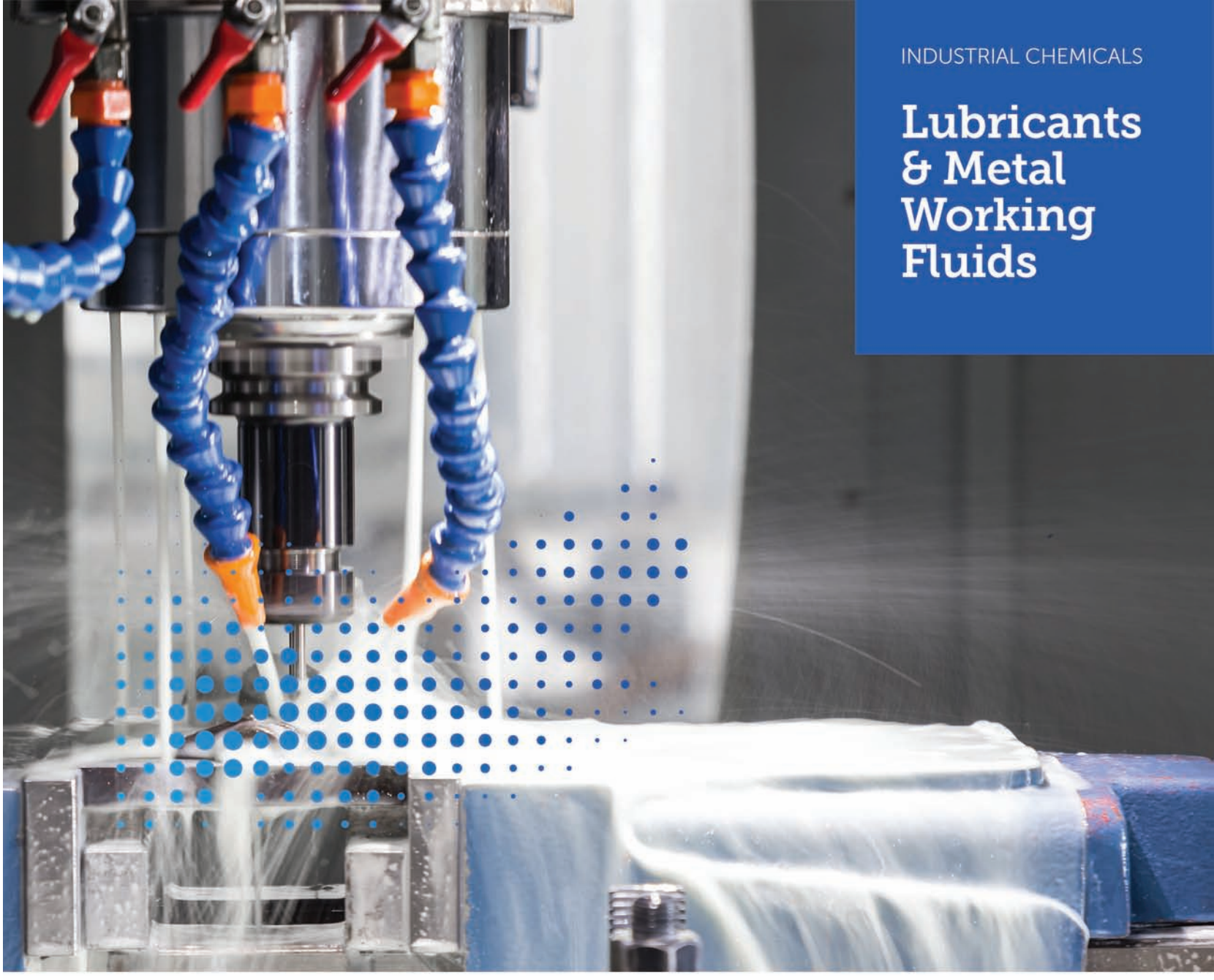
An important topic in computer aided simulations of seals concerns dynamical effects close to reality, like starting processes and states, where impulsive loads affect the seal. Aspects such as properties of the sealing material and also the nonlinear contact between seal and shaft have to be considered. Seals made of elastomers possess viscoelastic characteristics. The mathematical description of viscoelasticity is often made by Prony parameters. To describe the material with a lower number of parameters, that fit the measured material even better, we will use fractional derivatives. A seal must keep closed contact to the shaft under every operating condition. We will formulate the contact state as a linear complementarity problem. This method is able to handle contact with friction. Methods of model order reduction are used to lower the computational effort. This created simulation can be applied for transient effects of seals with unlubricated contact in an efficient way.

4:30 – 5 pm | Simulation of Mixed Friction Between a Surface Textured Seal and a Smooth Rod

Markus Brase, Matthias Wangenheim, Leibniz University Hannover, Hannover, Germany

Improved friction behavior is an important design objective in the development process of dynamic sealing systems. Surface texturing is one possibility to lower friction in the sealing contact by reducing the area of contact and increasing the lubrication gap. In this study, mixed friction between a surface textured seal and a smooth rod is simulated. The simulation model is based on a coupled fluid mechanics and contact mechanics analysis. The surface texture is applied to the seal surface in the form of deterministic micro-dimples. For the first time, a wide range of different dimple sizes is considered, which are suitable for mass production by injection molding or vulcanization. The impact of different dimple diameter, distances and depths on the friction force is analyzed. In order to find a surface with most friction reduction potential, mixed friction of the textured seals is compared to the corresponding friction of a smooth seal.

5 – 5:30 pm | Seals Business Meeting



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Session 8E • Music Row 3

Tribochemistry III

Materials Tribology and Nanotribology Joint Session

Session Chair:
Nikolay Garabedian, University of Delaware, Newark, DE

Session Vice Chair:
Istiaque Alam, University of Delaware, Newark, DE

1:30 – 2 pm | Synthesis and Characterization of Novel Ni-Matrix Composites

Surojit Gupta, Maharshi Dey, Matt Fuka, University of North Dakota, Grand Forks, ND, Nikhil Murthy, Stephen Berkebile, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

This paper reports the synthesis and characterization of novel Ni-MAX composites by adding 5 vol% , 10 vol% , 20 vol% and 30 vol% MAX (Ti3SiC2 Ti3AlC2, and Cr2AlC) particulates in the Ni-matrix. Detailed SEM investigation showed that the MAX Phases are dispersed well in the Ni-matrix with minimal interfacial reactions. The mechanical and tribological behavior of these samples were further characterized. From SEM investigations, it was construed that the tribology of these composites are governed by the formation of tribofilms. A comparative analysis of the effect of different MAX phases on mechanical and tribological behavior will be documented as a part of this study.

2 – 2:30 pm | Tribofilms in Wet Clutch Applications

Darryl Williams, Afton Chemical Corp., Richmond, VA

Anti-shudder durability performance in a clutch friction system is a key driver in current and future transmission fluid development. We have developed surface analysis techniques that have uncovered important relationships between the surface morphology and chemistry of wet clutch materials and anti-shudder durability. Recently it has been found that tribofilm formation on the steel plates in wet clutches play a role in preserving the surface of the steel during a durability test. This effect is related to preservation of the friction level and anti-shudder performance of the wet clutch. Characteristics of tribofilms formed in wet clutches will be described.

2:30 – 3 pm | Analysis of the Tribochemical Absorbed Films on Steel Surfaces Lubricated with 1,3-Diketone

Shumin Zhang, Chenhui Zhang, Xinchun Chen, State Key Laboratory of Tribology, Tsinghua University, Beijing, China, Ke Li, Intelligent Transport Systems Research Center, Wuhan University of Technology, Wuhan, China

The tribological properties between steel surfaces with a ball-on-disc geometry in a rotating contact using 1,3-diketone and polyalphaolefin (PAO2) lubricants are investigated. Compared with PAO2, an ultralow friction coefficient of 0.007 is achieved with 1,3-diketone. It is found that a tribochemical reaction occurs between diketone molecules and steel surfaces, which lowers the contact pressure dramatically. Moreover, chemically adsorbed films are formed on the rubbing surfaces, and can stably exist at low contact pressure. In addition, a well-developed conformal contact surface morphology is generated between two friction pairs, which can be helpful to the realization of ultralow friction. The results of this study reveals that 1,3-diketone lubricant has a good lubricating performance on steel surfaces, and can be extended to industrial applications for its enormous potential.

3 – 3:30 pm | Break

3:30 – 4 pm | Effect of Lubricants on Friction Properties of the Steel/PEEK Contact

Go Tatsumi, Monica Ratoi, Brian Mellor, University of Southampton, Southampton, United Kingdom, Yuji Shitara, Kiyomi Sakmoto, JXTG Nippon Oil & Energy Corp., Yokohama, Japan

Polymers and polymer-based composites are becoming preferred materials in many tribological applications because of their lightweight, reduced noise and self-lubricating properties. Poly-ether-ether-ketone (PEEK) has better mechanical properties and higher thermal stability than other conventional polymers and therefore is recommended for applications with severe conditions. PEEK can be used unlubricated but lubrication has the potential to further reduce friction and wear. To elucidate the effect of lubrication and especially that of some ubiquitous friction modifiers and anti-wear additives, this study carried out tribological tests using PEEK discs and steel balls with a smooth or rough surface. It was found that lubrication with poly-olefin significantly reduced friction in all lubrication regimes compared with unlubricated tests, regardless of the surface roughness. On the other hand, the effect of friction modifiers and anti-wear additives was dependable on surface roughness.

4 – 4:30 pm | Electric Field Effect on the Lubrication Performance of CuS Nanoparticle Additive

Chenxu Liu, Yu Tian, Yonggang Meng, Tsinghua University, Beijing, China, Ofir Friedman, Yuval Golan, Ben-Gurion University of the Negev, Be'er-Sheva, Israel

Active control of friction has been a goal pursued by scientists for many years. Here we use electric potentials to investigate the lubrication performance of CuS nanoparticle additive in ester lubricant for the friction pair of ZrO_2 ball and copper plate. When the potential of the copper plate is lower than -14 V, the friction coefficient decreases from 0.18 to 0.05 after an induction period of running-in, the time of which is shorter if the voltage is lower. The significant friction reduction is attributed to the excess of positively charged nanoparticles in the vicinity of the negatively charged surface.

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Session 8G • Cumberland 1

Grease II

Session Chair:
Scott Crawford, Primrose Oil Co., Dallas, TX

Session Vice Chair:
Wenyang Zhang, NanoMech, Inc., Springdale, AR

1:30 – 2 pm | Grease Evaluation for the Continuous Caster Bearings: Development of an Innovative Technique to Accurately Measure Water Content in These Greases

Kuldeep Mistry, Carl Hager, Nigel Los, Jill Myers, The Timken Co., North Canton, OH, Raj Shah, Koehler Instruments Co. Inc., Holtsville, NY, Hank Levi, Scientific Gear LLC, Fairfax, VA

The continuous caster is one of the most challenging environments for bearings from the ladle, down through the bender and segments, to the discharge area. Many critical positions are subject to high loads and low rotational speeds, often at elevated temperatures, in an environment heavily contaminated with water, steam and scale. The selection of the bearings, lubrication, seals, and maintenance practices, are critical to address a variety of customer requirements. In this study, we will discuss grease selection for the continuous caster bearings. The following grease performance attributes were included in this investigation, including: load carrying capacity, wear protection, water resistance, corrosion resistance, thermal stability and grease mobility. These properties are crucial for service life of the bearings and are very much dependent on the grease formulation. The other goal of this study was to develop an accurate procedure to measure the water content of lubricating grease.

2 – 2:30 pm | Use of High Temperature Oven Aging to Determine COF of Candidate Greases as Oil Loss within the Grease Occurred

Bryan Johnson, Arizona Public Service, Tonopah, AZ

Standby operation of a machine located in a high temperature environment required qualification prior to use. A simple innovative oven aging process was designed that would stress the grease chemically while also reducing its percentage of oil. A Pin and Vee block combination was used to test COF of the three candiadate greases as they were aged. The pins were drilled and a thermocouple added to allow continuous temeperature monitoring of the pin and vee tests as the COF was measured with increasing loads applied by the instrument. New grease samples from each of the three candiadates considered were tested at different temperatures to establish baselines prior to the oven aging. Aged candiate greases were then tested in a full scale valve stem/stem nut. The presentation will discuss details of the aging process used, the set up of the Pin and Vee instrument to include temperature measurements and the results from full scale testing of a valve stem/stem nut application.

2:30 – 3 pm | A New Anti-Wear Grease Containing Nanoparticles

Yan Chen, Xuezhen Wang, Abraham Clearfield, Hong Liang, Texas A&M University, College Station, TX

Galling wear is one of the common wear mechanisms in oil and gas exploration and metal forming. One way to reduce galling was to use grease lubricant. In this research, a new grease is developed containing - zirconium phosphate (ZrP) nanoparticles. Experiments showed that by adding those nanoparticles, the friction between steels (4130 against P530) was reduced by 10%. More significantly, the areas being galled were reduced by 80% with the addition of 0.5%wt particles. This presentation discusses mechanisms of anti-galling induced by adding nanoparticles.

3 – 3:30 pm | Break

3:30 – 4 pm | When Your Supply of Grease Ceases and You Need a Replacement, What Do You Do?

Michael Moneer, Peter Lee, Southwest Research Institute, San Antonio, TX

A very large gear set for an external crane was using a grease that was to be discontinued. In order to find a replacement that would do the job, rheological and characterization of the grease was undertaken using a rheometer and an MTM. This presentation will cover the work undertaken including the test profile developed for the MTM and results for different greases tested.

4 – 4:30 pm | Biolubricant Enhancement Using Combined Raw Carbon Nanostructures

Andrey Pérez, CINVESTAV, Querétaro, Mexico

We propose using high viscosity vegetable oils additivated with different unpurified or raw carbon nanostructures such as; MWCNTs, graphene oxide and nanopearls. We aim at meeting the requirements to replace traditional products derived from non-renewable sources while using carbon nanostructures to obtain desired friction coefficients. Unpurified carbon nanostructures containing nanoparticles such as Fe, Ni and Co constitute a simple option to improve the tribological properties of biolubricants; this approach avoids both purification and functionalization thus diminishing production costs. Tribological testing was performed using pin-disc, twin-disc and 4-Ball machines for a complex ester and a linseed oil additivated with raw carbon nanostructures. SEM/STEM characterization helped assess morphology and structure of carbon nanostructures and worn metal surfaces. XRD, FTIR and ICP analyses were used to characterize the carbon nanostructures used to additivate biolubricants.

4:30 – 5:30 pm | Grease Business Meeting

Session 8H • Cumberland 2

Materials Tribology V

Session Chair:
Brandon Krick, Lehigh University, Bethlehem, PA

Session Vice Chair:
Nikhil Murthy, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

1:30 – 2 pm | Environmental Sensitivity and Aging of Composite Solid Lubricant Coatings

Michael Dugger, Brendan Nation, John Curry, Sandia National Laboratories, Albuquerque, NM

Solid lubricants offer predictable friction and wear behavior over a wide range of temperatures, pressures and sliding speeds, but most also exhibit some form of environmental sensitivity. This can take the form of well-known variations in friction and wear behavior that are dependent upon the operating atmosphere, or long-term aging in the presence of species in the environment that alter the film's chemistry and performance. Many composite solid lubricants have been developed in recent decades to mitigate environmental sensitivity and aging. In the family of MoS_2-based materials, for example, this has included co-depositing the solid lubricant with Sb_2O_3, Ti, Au or other species. In this presentation several potential mechanisms of friction variation during aging will be discussed. The performance and composition changes exhibited by several composite films when exposed to an accelerated aging environment will be described.

2 – 2:30 pm | Improving Tribological Performance of PDA/PTFE Thin Film by Incorporating Ag Nanoparticles in the PDA Underlayer

Dipankar Choudhury, Isabelle Niyonshuti, Jingyi Chen, Min Zou, University of Arkansas, Fayetteville, AR

Polytetrafluoroethylene (PTFE) coating adhesion strength to a metallic substrate is poor. Polydopamine (PDA) can adhere PTFE to a substrate strongly and therefore PDA/PTFE coating has a significantly higher durability. In this study, various percentages (1 to 2 wt.%) of cubic-shaped silver nanoparticles (AgNPs) were incorporated in the PDA film, resulting in an increased roughness and thus adhesion strength of the PTFE coating to the PDA underlayer. Linear reciprocating tests revealed 3.5 times increase in the durability of PDA/PTFE coating by incorporating only 2 wt.% of AgNPs compared to PDA/PTFE. The wear progression and scratch tests revealed the fundamental mechanism of these improvements.

2:30 – 3 pm | Improved Wear Life of 60NiTi by PDA/PTFE + Graphite Solid Lubricant Coatings

Dipankar Choudhury, Charles Miller, Min Zou, University of Arkansas, Fayetteville, AR

The aim of the study is to fabricate a bioinspired polydopamine (PDA)/polytetrafluoroethylene (PTFE) + graphite particles (GrP) solid lubricant coating on 60NiTi substrates to improve the dry lubrication performance. The durability tests were conducted at 2-N normal load (contact pressure 586.7 MPa) in a linear reciprocating motion against 6.35-mm diameter Si3N4 balls and the scratch tests were performed using linearly increasing loads (0.5 to10 N and 10 to 18 N). The PDA/PTFE + 0.25 wt.% GrP coating increased the durability 2.4 times compared to the PDA/PTFE coating. The scratch tests showed an improvement of coating adhesion. The atomic force microscopy images revealed a morphological change in the PTFE + GrP fibrils. The transferred film of nickel and PTFE were identified on the counterface balls, and these films were enhanced when rubbed against PDA/PTFE + 0.25 wt% GrP coatings.

3 – 3:30 pm | Break

3:30 – 4 pm | Tribological Behavior of the WSC Coated Silicon Carbide in Vacuum and Air

Kosta Simonovic, Tomas Polcar, Czech Technical University, Prague, Slovenia, Albano Cavaleiro, University of Coimbra, Coimbra, Portugal

In this work, we explore the tribological properties of the PVD produced self-lubricating W-S-C coting [1] on the Silicon Carbide (SiC) substrate. Two series of coatings have been produced, both having thickness of 1.5 µm and for both of the coatings surface chemical composition (in at%) was measured by XPS. Series A (hardness 4.9 GPa) having the at. % of W, S and C at 38.7, 36.3 and 17.3, respectively, and Series C (hardness 7.6 GPa) having the at. % of W, S and C at 47.3, 24.0 and 23.5 respectively. Two types of tribological test have been performed. First one where load was set to 10N, sliding speed to 10 cm/s and number of cycles to 10000. Second type was the loading/unloading test in which the load was gradually increased in steps of 5N until the value of 20N was reached. Next, load was gradually decreased in 5N steps until it reached initial value of 5N. Each load step was tested for 500 cycles at 10 cm/s sliding speed. All of the tests have been performed both in air and vacuum.

4 – 4:30 pm | Low Friction Behaviors of Ag-Doped γ-Fe_2O_3@SiO_2 Coatings Under a Wide Range of Temperature Conditions

Qunfeng Zeng, Xi'an Jiaotong University, Xi'an, Shaanxi, China

In the present paper, the Ag-doped -Fe_2O_3@SiO_2 coatings deposited on the steel were prepared by sol-gel method. The results show that there is the core-shell microstructure in the Ag-doped -Fe_2O_3@SiO_2 coatings and Ag nanoparticles were distributed in coatings. The tribological properties were investigated by tribometer at temperatures of RT, 100˚C, 300˚C, 500˚C and 600˚C. It is found that the coatings exhibit low and stable friction (from 0.25~0.06) from RT to 600˚C. The coefficient of friction (CoF) of the friction pair decreases with the increase of temperature. XRD, Raman spectra and SEM measurements show that the anti-friction behaviors of the friction pair are owed to the soft noble metal Ag below 600˚C and involved in the transformation between -Fe2O3 and -Fe2O3 at 600˚C during sliding. The -Fe_2O_3 is beneficial to form low shear interface and achieve high temperature low friction. The core-shell microstructure of coatings inhibits -Fe_2O_3 changing into -Fe_2O_3.

4:30 – 5 pm | Study on the Tribological Properties During Drilling of CFRP with Carbide Tool

Xiong Liang, Wu Dan, Tsinghua University, Beijing, China

This paper investigated the tribological behaviors of carbon-fibre-reinforced polymer (CFRP) against tungsten carbide under dry friction conditions. The friction coefficient was measured and the effects of normal load, temperature and sliding speed on the friction coefficient were studied. The results show that the friction coefficient increased with the increase of normal load, but the effect of normal load on the friction coefficient seems to have a threshold. The effect of temperature on friction coefficient is not a simple linear relationship, which is mainly related to the fact that the resin matrix in CFRP melts at high temperatures and act as a lubricant. In addition, sliding speed and temperature have a comprehensive effect on the friction coefficient due to the friction heat during the sliding process.

5 – 5:30 pm | Tribological Behaviors of Highly Oriented Pyrolytic Graphite Under Wide Temperature Domain (10 K~295 K) in Macroscale

Pu Wu, Chenhui Zhang, Jianbin Luo, Tsinghua University, Beijing, China

With the development of superlubricity, the requirement for the accuracy of measuring super low friction force under different environment becomes more and more important. In this work, we built a unique home-made tribometer with high vacuum and ultra-low temperature test environment. The tribometer can regulate the temperature range from 5 K to 300 K, and the highest vacuum of the chamber is better than 5 x 10-5 Pa. The resolution of friction force is 7 x 10-5 N by using a dual frequency laser interferometry system and the maximum applied normal load is 1 N. In addition, experiments were performed to investigate the tribological behaviors of highly oriented pyrolytic graphite under wide temperature domain (10K~295K) in macroscale. And the lubricating mechanisms also have been analyzed through several characterization methods.

Session 8I • Cumberland 3

Contact Mechanics II

Session Chair:
Daniel Garcia, University of Florida, Gainesville, FL

Session Vice Chair:
Kyle Schulze, University of Florida, Gainesville, FL

1:30 – 2 pm | Theoretical and Finite Element Analysis of Static Friction Between Multi-Scale Rough Surfaces

Robert Jackson, Yang Xu, Auburn University, Auburn, AL, Xianzhang Wang, Tsinghua University, Beijing, China

The current work considers the multi-scale nature of roughness in a new model that predicts the static friction coefficient. This work is based upon a previous rough surface contact model, which used stacked elastic–plastic 3-D sinusoids to model the asperities at multiple scales of roughness. A deterministic model of a three-dimensional deformable rough surface pressed against a rigid flat surface is also carried out using the finite element method (FEM). The accuracy of the deterministic FEM model is also considered. A spectral interpolation is used to smooth the geometry in between the original measured nodes. The effects of normal load and plasticity index on static friction are then analyzed. The results predicted by the theoretical model are also compared to other existing rough surface friction contact models and the FEM results. They are in a good qualitative agreement, especially for higher loads and higher plasticity indices.

2 – 2:30 pm | Investigating the Effect of the Evolution of the Radius of Curvature During Elastic-Plastic Contact of Asperities

Eoghan O'Neill, Hamid Ghaednia, Gregory Mifflin, Matthew Brake, Rice University, Houston, TX

The study of elastic-plastic contact mechanics is fundamental to understanding the multi-scale behavior of mechanical systems. The evolution of the radius of curvature during elastic-plastic contact and its effects on contact parameters has been neglected in previous studies. The typical approach for the elastic-plastic regime is to apply the equivalent radius of curvature from Hertzian theory. To assess the applicability of this assumption, contact between two spheres is modeled with FEA. For two spheres, the ratio of the radii of curvature and the material models are varied; purely elastic, elastic-plastic, and rigid material models are considered. After normalizing the FEA data with Hertz and Jackson-Green contact models, trends are observed showing that the equivalent radius of curvature assumption does not satisfy the complexities involved in elastic-plastic contact. Finally, a new formulation for the evolution of the radius of curvature during elastic-plastic contact is proposed.

2:30 – 3 pm | When Does Roughness Affect Elastic-Plastic Contact?

Senyo Ahadzie, Hamid Ghaednia, Matthew Brake, Rice University, Houston, TX

Rough surface contact has been an ongoing challenge in mechanical engineering. The present work investigates the effect of surface roughness and lubrication in predicting the aftermath of low speed impact of aluminum samples by stainless steel spheres of multiple radii. The collisions were recorded with a high-speed camera and analyzed with MATLAB® to calculate coefficient of restitution. Following these experiments, optical profilometry was used to measure the peak plastic deformations of the plastically deformed regions. Results showed that for a given initial impact velocity of less than 3 m/s, coefficient of restitution varied by less than 10% for surface roughness ranging from 80 to 1500 grit for both lubrication conditions. However, roughness had a significant effect on the permanent deformation from the impacts: a 55% and 125% increase in the depth of the permanent deformation was observed for a change in roughness from 80 to 1500 grit for dry and lubricated impact conditions.

3 – 3:30 pm | Break

3:30 – 4 pm | An Elastoplastic Finite Element Study of Unidirectional Cylindrical Sliding Contact for Steel/Steel and Inconel617/Incoloy800H

Huaidong Yang, Itzhak Green, Georgia Institute of Technology, Atlanta, GA

The work employs a plane strain finite element analysis to investigate the unidirectional sliding contact between a deformable half cylinder and a deformable flat block. The sliding is displacement-controlled where the materials are identical steels, and then Inconel 617/Incoloy 800H. A normal interference (indentation) is applied, which is then followed by unidirectional sliding. The von-Mises stress, plastic strain, junction growth, normal force, tangential force, effective coefficient of friction (COF), and scars on the surface of the block are obtained during the sliding motion. The large plastic strain is found on the surface of the block, which forms a "pocket" shape under the surface. The direction of the growth is in the same direction of the tangential force that the weaker material experiences. The forces and the effective COF are found to stabilize after a certain sliding distance. Pileup is found on the surface of the block after a sufficient unidirectional sliding distance.

4 – 4:30 pm | Feasibility Study of Impedance Analysis for Measuring Rolling Bearing Loads

Tobias Schirra, Georg Martin, Marcel Neu, Eckhard Kirchner, Technical University of Darmstadt, Darmstadt, Hessen, Germany

Electrical properties of rolling bearings have been the key to measure lubrication film thickness for many years. Another usecase of this physical effect is determining the loads on rolling bearings by measuring the electrical impedance. Enhancing rolling bearings with a load-sensing function is beneficial in many applications. For example, it facilitates condition-based maintenance in transmissions by improved lifetime estimation through actual load data. The underlying electrical model of the rolling contact is a plate capacitor, whose capacity depends on the dimensions of lubrication film in the hertzian area. This paper investigates accuracy, limits and disturbances of the proposed load measuring system. The electrical model of the rolling contact has to be critically scrutinised and refined, taking disturbances into account, in order to increase the accuracy of a reliable in-situ measuring load sensor.

4:30 – 5 pm | A Study of Noise Prediction in Interior Materials of Automotive During Friction Process

Juho Park, Youngze Lee, Sungkyunkwan University, Suwon-si, Gyeonggi-do, The Republic of Korea

In this study, we aimed to evaluate the correlation between noise and friction variation through an analysis of data obtained from relative motion of headlining and panel. Tests were conducted using headlining and panel specimens cut from the actual vehicle, the effect of surface roughness and real contact area on noise is investigated by comparing textured headlining A with non-textured headlining B. In order to investigate the effect of friction variation and acceleration on the noise caused by stick-slip, the load was changed from 1800g to 4900g and the sliding distance was changed from 1 mm to 2 mm. Through experiments, we propose a method to predict and prevent noise generation by mapping various contact conditions according to the degree of stick-slip.

5 – 5:30 pm | Contact Mechanics Business Meeting

Session 8J • Cumberland 4

Surface Engineering IV

Session Chair:
Kora Farokhzadeh, Bruker Nano Surfaces, San Jose, CA

Session Vice Chair:
Suvrat Bhargava, TE Connectivity, Middletown, PA

1:30 – 2 pm | Tribological and Physical Properties of PTFE Micropowder-Filled NBR Rubber Under Water Lubrication

Yanfeng Han, Wei Feng, Jiaxu Wang, Chongqing University, Chongqing, China

Polytetrafluoroethylene (PTFE) and PTFE composites have shown excellent tribological performance as solid lubricants. In this work, PTFE was used to improve the tribological performance of nitrile butadiene rubber (NBR)The tribological and physical properties (friction coefficient, morphology, and wettability) of NBR filled with diffident percent of PTFE micropowders have been investigated. The experimental results indicate that the PTFE addition can improve the tribological properties of NBR under different lubricating conditions signficantly, and the improvement will be more effectively with increased percent of PTFE addition. NBR-PTFE composites exhibited better tribological behaviors under water lubricating condition because scanning electron microscopy (SEM) of the corresponding PTFE micropowder-filled NBR composites suggest that agglomerates morphology, dispersion and interfacial compatibility with NBR are the key factors influencing tribological and physical properties.

2 – 2:30 pm | Experimental Comparison of Conventional and Textured Dynamic Seal Surfaces

Johan Bothe, Leibniz University Hannover – Institute of Dynamics and Vibration Research, Hannover, Germany

Dynamic seals prevent mass transfer across system boundaries while allowing relative motion of the corresponding sealing surfaces. Dynamic seal friction decreases overall efficiency of machines, therefore reducing dynamic seal friction is economically and ecologically desirable. Textured sealing surfaces are a promising and economically feasible approach to reduce seal friction. For this presentation, a dynamic seal with a conventional sealing surface is compared experimentally to an otherwise identical dynamic seal with a textured sealing surface. The texture consists of dimples arranged in a grid and is applied to the sealing surface during seal production using textured moulds. Results include start-up as well as long-term performance.

2:30 – 3 pm | The Deterioration Characteristics and Mechanism of Polishing Pads and Slurry in Chemical Mechanical Polishing (CMP) of Fused Silica

Chengxi Kang, Guoshun Pan, Dan Guo, Xin Zhang, Tsinghua University, Beijing, China

The polishing pads and slurries are the essential consumable materials in chemical mechanical polishing (CMP). In our research, we studied the deterioration characteristics of the typical polishing pad and slurry in CMP of fused silica. With the polishing time increasing, the hardness of the pad increases, but the modulus of elasticity decreases. And the surface roughness of the pad increased first and then decreased after the extensive glazed areas appeared. Also, slurry pH and particle size of ceria decreased, but particle size of silica changed a little bit. Meanwhile, we investigated the chemical changes of the pad and slurry to illustrate the deterioration mechanism. The results show the quantity of the active sites of the pad is the decisive factor influencing the removal rate of fused silica. And the deterioration mechanism of slurry containing different kinds of polishing nanoparticles is not the same.

3 – 3:30 pm | Break

3:30 – 4 pm | Chemical Mechanical Polishing Behavior of PS/Sio$_2$ Nanospheres with Different Shell Thickness on Fused Silica

Xin Zhang, Dan Guo, Guoshun Pan, Chengxi Kang, Tsinghua University, Beijing, China

This work demonstrates the feasibility of core-shell structured PS/SiO_2 composite nanospheres as abrasives for planarization fused silica. The surface morphologies of PS/SiO_2 monodisperse nanospheres were characterized with scanning electron microscopy (SEM), transmission electron microscopy (TEM) and the atomic force microscopy (AFM). The mechanical properties of nanospheres were studied with nanoindentation on the basis of AFM. Meanwhile the elastic moduli of PS/SiO_2 and PS nanospheres were obtained with the JKR models. The chemical mechanical polishing (CMP) performance of FS when applied the as-prepared nanospheres with different shell thickness was characterized by 3D white light interference surface topography instrument. It's found that the material remove rate of the FS when applied PS/SiO_2 with shell thickness reducing has shown a trend of rising first and then falling down. And we have given a semi-quantitative explanation for this phenomenon using Hertz contact theory.

4 – 4:30 pm | Dynamical Characterization of Micro Cantilevers by Different Excitation Methods in Dynamic AFM

Xinfeng Tan, Dan Guo, Jianbin Luo, Tsinghua University, Beijing, China

An atomic force microscopy (AFM) experimental setup was modified to analyze the differences between the piezoelectric excitation and the photothermal excitation (PTE) for three types of cantilevers, including two aluminum (Al) coated cantilevers and one uncoated single-crystalline silicon cantilever. The results show the PTE is a direct and localized excitation method to yield smooth and clean frequency spectra without the coupling with mechanical components. The 1st and 2nd order flexural vibration amplitudes of coated cantilever are easily and efficiently excited by the PTE method, mainly due to the bimetallic effect and a high photothermal efficiency. The energy conversion and absorption efficiency comparison has been analyzed for different cantilevers by the PTE method. The spurious effects can be avoided by the PTE method which clearly reflects dynamic characteristics of the cantilever, and the scanning image quality can be improved.

4:30 – 5 pm | Ultralow Friction of Concentrated Polymer Brushes Sustained by Surface Texturing

Mayu Miyazaki, Takahiro Tsuchiya, Ken Nakano, Yokohama National University, Yokohama-shi Hodogaya-ku, Kanagawa, Japan, Chiharu Tadokoro, Saitama University, Saitama-shi, Japan, Shinya Sasaki, Tokyo University of Science, Tokyo, Japan, Keita Sakakibara, Yoshinobu Tsujii, Kyoto University, Uji-shi, Japan

Concentrated polymer brushes (CPBs) have been extensively studied in tribological fields because of their ultralow friction. By applying them to sliding surfaces, attempts are being made to improve the lifetime and efficiency of various mechanical systems. The authors utilized a parallel-grooved glass plate as a substrate, on top of which a PMMA-CPB was formed, and found that parallel grooves drastically improved the lifetime of PMMA-CPB, which shows an ultra-low friction under a sliding condition lubricated by MEMP-TFSI. To clarify the mechanisms of improving its lifetime and lubrication, further studies are being done to investigate mechanical properties of PMMA-CPB formed on grooved glass surfaces.

8J

5 – 5:30 pm | The Unsatisfied Effect of Plateau Honing on the Friction and Wear of Cylinder Liners

Eunseok Kim, Jaesang Yoo, Youngze Lee, SungKyunKwan University, Suwon-si, Gyeonggi-do, The Republic of Korea

To improve the performance of the engine, it is important to control interacting surfaces optimally in designing the surfaces of cylinder liners. The plateau honing technology has been used on the cylinder liners. It is a cross-hatch pattern of valleys for oil repository. However, the valley produced by honing functions hinders the formation of fluid dynamic pressure on interacting surfaces. The friction and wear tests with reciprocating motion were performed to compare the lubricity of sliding cylinder liner surfaces with different plateau honing marks on the different surface roughness. The effectiveness of different depth of profiles on the surface wear was compared with those of different surface roughness. From the tests the deep grooved honing marks, it was found that the severe interactions due to asperity contacts and formation of relatively thin films produced larger amounts of wear volumes than the test with the smooth surface.

Session 8K • Cumberland 5

Engine & Drivetrain V

Special Topics, Surface/Wear

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

Session Vice Chair:
Babak Lotfizadehdehkordi, ExxonMobil, Baytown, TX

1:30 – 2 pm | The Effect of MoDTC on Friction Between Piston Ring and Cylinder Liner with Several Surface Treatment

Kenji Yamamoto, Yifang Hsieh, Tsuyoshi Hiramatsu, ADEKA Corp., Tokyo, Japan

Authors pointed out the effect of MoDTC for improving fuel economy of passenger car especially with low viscosity engine oils, and indicated MoDTC generate MoS2 on rubbed surface with calcium and magnesium type detergent formulated engine oils in past study presented at STLE. Friction test and surface analysis are carried out to estimate the effect of MoDTC and surface treatment including DLCs, nitrides and metal plating for piston related friction. Friction test results with oscillating friction tester and floating liner apparatus will be shown with XPS surface analysis, and the effect of MoDTC on friction reduction and surface treatment for tribofilm generation will be discussed.

2 – 2:30 pm | Computational Fluid Dynamics (CFD) Modeling of Torque Converter and Experimental Validation

Farrukh Qureshi, David Whitticar, Michael Huston, The Lubrizol Corp., Wickliffe, OH, William Liou, Yang Yang, Western Michigan University, Kalamazoo, MI

The torque converter in automatic and powershift transmissions is used as the fluid coupling between the engine's output shaft and transmission's input. Torque converter efficiency is important from the standpoint of managing parasitic losses and is impacted by the fluid selection. This work explores the impact of transmission fluid physical properties on torque converter performance characteristics. A torque converter commonly used in construction machinery was selected for this study. Lubrizol worked with Western Michigan University's Center for Advanced Vehicle Design and Simulation (CAViDS) to develop a model based on torque converter design and fluid properties using computational fluid dynamics (CFD) approach. The efficiency and k-factor for this specific torque converter were measured at two laboratories, situated in Europe and United States. Development of this model, test results and comparison of predicted and measured results will be presented and discussed.

2:30 – 3 pm | Numerical and Experimental Analysis of Lubricant Transport

Rathesan Ravendran, Benny Endelt, Jesper deClaville Christiansen, Aalborg University, Aalborg, Denmark, Nikolaj Kristensen, Hans Jensen Lubricators, Hadsund, Denmark

This study present both theoretical and experimental investigation of the lubricant transport across the piston rings in a large two-stroke engine. The lubricant between the piston rings and cylinder liner is modelled using a one-dimensional Reynolds equation, which includes parameters of the geometry, viscosity, pressure and surface velocities. The experimental work is performed on a newly developed test rig with reciprocating liner and stationary piston rings. The lubrication oil is injected as a spray on the liner surface. This setup imitates the conditions inside the engine. Furthermore, proximity sensors are installed along the liner to measure oil film thickness. The paper presents unique findings of the quality and stability of the lubrication oil film on the cylinder liner, and how operating conditions influence the oil film. Test of different lubrication feed-rates, lubricant viscosities and injection strategies have been performed and the results are reported and discussed.

3 – 3:30 pm – Break

Authors and Presenters Invited to Attend Speakers Breakfast

Lead authors and education course instructors are invited to the Speakers Breakfast (Sunday through Thursday, May 19-23) from 7-7:45 am in the Omni Nashville Hotel – Legends D to meet with session and paper solicitation chairs (PSCs) for a continental breakfast on the days of their presentations. This is a great time to review the session schedule and note any last-minute changes Speakers should plan on attending.

Session 8L • Cumberland 6

Condition Monitoring III

Session Chair:
Kemberlee Snelling, TRICO Corp, Davison, MI

Session Vice Chair:
Jatin Mehta, Fluitec International, Bayonne, NJ

1:30 – 2 pm | Single Lubricant Solution for Natural Gas and Diesel Engines

Isabella Goldmints, David Brass, Infineum USA, Linden, NJ

The drive to lower fleet emissions, coupled with increased availability of natural gas, have led to recent interest in natural gas engines for heavy duty vehicles and have propelled developments in mobile natural gas engine hardware. Considering that most gas engine vehicles operate in mixed fleets with Diesel engines, they can present a challenge for fleet operators; requiring them to stock different lubricants and prevent misapplication. This challenge creates an opportunity for lubricant suppliers to provide a multifuel oil to protect both natural gas and Diesel fueled engines. Here we present a new multifuel oil additive technology, formulated to protect both natural gas and diesel engines, despite disparate lubrication requirements, and demonstrate its excellent performance in both as measured by multiple parameters such as oxidation and nitration resistance, wear protection and durability, cleanliness, and soot dispersancy in engine dyno and fleet field tests.

2 – 2:30 pm | Oil Conductivity as an Early Indicator of Oil Oxidative and Additive Thermal Degradation Processes

John Duchowski, Timo Lang, Valérie Diehl-Klein, HYDAC FluidCareCenter GmbH, Sulzbach, Saar, Germany

A suitable diagnostic property to be employed for online oil condition monitoring purposes has been long sought after. Several recent investigations of oil and additive degradation processes suggest that the oil electrical conductivity could lend itself for this purpose. It has already been reported that oil conductivity increased by nearly a factor of twenty in the course of two years for a hydraulic oil employed in a large automotive press. Similar observations were made on a hydraulic power unit driving a train break system. Most recently this behavior was observed on a free standing hydraulic test stand. The last case proves most intriguing because an increase in conductivity has been noted there in the form of a single, early indicator without concomitant changes in other fluid properties. In view of these observations, we propose that oil conductivity represents a potential candidate for online tracking of the oil ageing processes at an early stage in industrial systems.

2:30 – 3 pm | Correlating Acoustic Emission Signals with the Tribological Behavior of Steel

Tom Reddyhoff, Imperial College, South Kensington, United Kingdom, Zhe Geng, Suzhou Institute of Industrial Technology, Suzhou, China

Acoustic emission (AE) signals were recorded during reciprocating ball-on-disc tribological tests on 52100 steel under a range of conditions. Time domain AE signals were transformed to the frequency domain using a Fast Fourier Transform and parameters such as power, RMS amplitude, mean frequency, median frequency and energy were analysed and compared with the coefficient of friction and wear volume. Results suggest that different acoustic frequencies can reflect the friction and wear respectively. If frequencies are chosen correctly, the correlation between AE and friction signals can be very high (Pearson coefficients 0.8~0.9). SEM and Raman analysis of the worn surfaces revealed how oxide debris affect the friction, wear and AE and the interactions between them. Since an AE signal contains more information than the CoF and wear volume and is more sensitive to changes in wear mechanism, it can become a powerful tool to monitor tribological behaviour of in-service components.

3 – 3:30 pm | Break

3:30 – 4 pm | Using SEM/EDS Technology for Wear Debris Analysis

Mindy Villalba, SGS NA (Vallejo/Herguth), Vallejo, CA

The SEM-EDS is the ultimate tool for quickly resolving tough analytical problems effectively, timely and economically. Modern SEM-EDS instruments are operated using sophisticated software which allows for automated analysis and processes. These techniques are key in circumventing technical challenges generally involved with selecting the right tools to perform an effective analysis in a timely and economical manner. Based on current industry methods, (ISO 16232, 7-8), SEM technology has expanded its effectiveness in the lubricant/tribological industries across a variety of situations including deposit/wear/filter debris analysis, particle sizing/characterization, failure analysis, and metallurgical studies. This presentation will explore three case studies to show how SEM-EDS technology successfully resolved tough analytical problems though the use of the SEM-EDS tools: Particle Sizing and Characterization Tool, Wear Debris Analysis Tool, and Filter Debris Analysis Tool.

4 – 4:30 pm | Detecting WEC Formation in an Electrical Environment Using Electrostatic Monitoring Techniques

Ling Wang, Kamran Esmaeili, Terry Harvey, Neil White, Walter Holweger, University of Southampton, Southampton, Hampshire, United Kingdom

White etching crack (WEC) remains one of the most critical bearing failure modes. Recent publications suggest that electrical discharging, due to the presence of electrical current and a dielectric lubricant, is one of the drivers for WEC formation. To date, only limited research has been conducted to characterise the influence of operating parameters on the electrical discharges (EDs), their contributions to WEC formation and most importantly in developing a robust technique for the monitoring of EDs and WEC formation. Using electrostatic sensing techniques, this study investigates the influence of operating conditions such as load, speed, temperature and slip-to-roll ratios on EDs. The results show that responses of the electrostatic sensors are correlated with the electrical potentials measured across the two-disc contact on a TE74 twin-roller machine. Further experiments are being conducted to explore the feasibility of electrostatic sensors in detecting WEC bearing failures.

Call for Presentations

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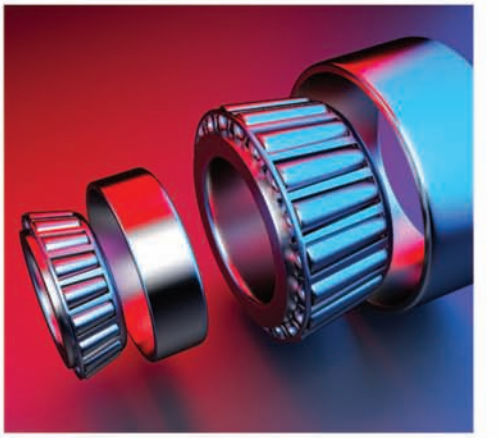

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If you are interested in presenting at STLE's 2020 Annual Meeting & Exhibition, submit a 100-150-word abstract at **www.stle.org**. Abstracts are due **Oct. 1, 2019.** Notification of acceptance will be sent in December 2019. While you do not need to prepare a full manuscript to be included on the meeting technical program, you are invited and encouraged to submit a manuscript for review and possible publication in STLE's peer-reviewed journal, Tribology Transactions.

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