Overview

Wednesday, May 18, 2011

Registration
6:30 am – 5 pm – 2nd Floor Foyer

Speakers Breakfast
7 – 7:45 am – Salon A-C

Exhibits and Student Posters
9:30 am – Noon – Exhibit Hall

Education Courses (8 am – 5 pm)
Advanced Lubrication 301 – 302
Basic Lubrication 102 – 305
Metalworking – 309/310
NLGI Grease Course 101 – 303
Synthetic Lubricants 204 – 301

Technical Sessions (8 am – Noon)
SB Nanotribology V: Nanolubricants II – 203
SC Lubrication Fundamentals V – 204
SD Material Tribology II – 205
SE Seals I – 206
SF Tribotesting I – 207
SG Fluid Film Bearings V – 209
SH Gears I – 210
SI Surface Engineering I – 211
SJ Environmentally Friendly Fluids I: EFF Applications – 212
SK Non-Ferrous Metals I: Biobased Lubricants Options for Industry – 213
SL Power Generation I – 214

Commercial Marketing Forum V – Salon D/E

Technical Sessions (1:30 – 6 pm)
6A Wind Energy I – 202
6C Lubrication Fundamentals VI – 204
6D Materials and Nanotribology Joint Session
In-Situ Techniques, Modeling and Multi-Scale Phenomena – 205
6E Seals II – 206
6F Tribotesting II – 207
6H Gears II – 210
6I Surface Engineering II – 211
6J Environmentally Friendly Fluids II: Panel Discussion
Biodegradability, Environmentally Friendly Certification for Biobased Lubricants in the US and Europe and USDA Bioacceptability – 212
6K Non-Ferrous Metals II: Surfaces and Chemicals – 213
6L Power Generation II – 214

Commercial Marketing Forum VI – Salon D/E

Exhibit Hours:
Monday: Noon – 5 pm
Tuesday: 9:30 am – Noon & 2 – 5:30 pm
Wednesday: 9:30 am – Noon

Please check the errata in your registration bag to verify course times. Some times might change slightly.
## SESSION 5B  
**Nanotribology V**

**Room 203**
- **9:00 – 9:30 am**  
  Active Nanoparticles-Based Novel Lubricant Additives to Improve Energy Efficiency and Durability, D. Demydov, p. 94
- **9:30 – 10:00 am**  
  Experimental Studies on the Tribological Behaviour of Engine oil (SAE15W40) with the Addition of CuO Nanoparticles, R. Krishnan, p. 94
- **10:00 – 10:30 am**  
  Nanodiamond-based Nanolubricants, M. Ivanov, p. 94
- **10:30 – 11:00 am**  
  Experimental Analysis of Stable CuO Nanoparticle-Enhanced Lubricants, H. Ghadeinia, p. 94
- **11:00 – 11:30 am**  
  Single Asperity Friction and Temperature Dependent Properties of Boundary Lubricant Additive Films, J. Bares, p. 94
- **11:30 am – Noon**  
  Evolution of ZDDP-derived Reaction Layer Morphology with Rubbing Time, A. Naveira-Suarez, p. 96
- **12:00 – 1:00 pm**  
  Exploratory Research Work on Tribological Effects of Nanofluids, G. Molina, p. 96
- **1:00 – 2:00 pm**  
  Ionic Liquids as Lubricants; P. Sutor, p. 97
- **2:00 – 3:00 pm**  
  Amplitude Reduction in EHL Circular Contacts Under Rolling Sliding Conditions, T. Lubrecht, p. 97
- **3:00 – 4:00 pm**  
  Evolution of ZDDP-derived Reaction Layer Morphology with Rubbing Time, A. Naveira-Suarez, p. 96
- **4:00 – 5:00 pm**  
  EHL of Large Length/Diameter Ratio Profiled Needle Roller, X. Shen, p. 97

## SESSION 5C  
**Lubrication Fundamentals V**

**Room 204**
- **9:00 – 9:30 am**  
  Grid Generation in HL and EHL Using AMG, T. Lubrecht, p. 96
- **9:30 – 10:00 am**  
  A Simplified Mass-Conserving and Continuous Cavitation Model, N. Brunetiere, p. 96
- **10:00 – 10:30 am**  
  Collision and Surface Interactions of Particles in Lubricated Interfaces, C. Barbosa, p. 96
- **10:30 – 11:00 am**  
  EHL of Large Length/Diameter Ratio Profiled Needle Roller, X. Shen, p. 97
- **11:00 – 11:30 am**  
  Effect of Density Flow Factor on Thermal Elastohydrodynamic Lubrication of Infinite Line Contact Rough Surfaces, H. Khan, p. 97
- **11:30 am – Noon**  
  Active Nanoparticles-Based Novel Lubricant Additives to Improve Energy Efficiency and Durability, D. Demydov, p. 94
- **12:00 – 1:00 pm**  
  Ionic Liquids as Lubricants; P. Sutor, p. 97
- **1:00 – 2:00 pm**  
  Amplitude Reduction in EHL Circular Contacts Under Rolling Sliding Conditions, T. Lubrecht, p. 97
- **2:00 – 3:00 pm**  
  Evolution of ZDDP-derived Reaction Layer Morphology with Rubbing Time, A. Naveira-Suarez, p. 96
- **3:00 – 4:00 pm**  
  EHL of Large Length/Diameter Ratio Profiled Needle Roller, X. Shen, p. 97

## SESSION 6A  
**Wind Energy I**

**Room 202**
- **9:00 – 10:00 am**  
  Investigation of Image-based Particle Shape and Size Analysis Techniques for Wind Turbine Gearbox Lubricants, S. Sheng, p. 108
- **10:00 – 11:00 am**  
  Wind Turbine Gearbox Oil Water Testing and Analysis, J. Leather, p. 108
- **11:00 – 12:00 pm**  
- **12:00 – 1:00 pm**  
  Surface Characterization with Functional Parameters, A. Spencer, p. 110
- **1:00 – 2:00 pm**  
  A Deterministic Multiscale Method Modelling Surface Texturing Effects in Hydrodynamic Lubrication Regime, S. Pei, p. 110
- **2:00 – 3:00 pm**  
  A Theoretical Investigation of Surface Texturing Effect on the Stribeck Curve, S. Pei, p. 110
- **3:00 – 4:00 pm**  
  Field Experiences Using Advanced Oil Contamination Control to Increase Gearbox Life and Reliability, W. Needelman, p. 110
- **4:00 – 5:00 pm**  
  Design for Intrinsically Lubricated Nylon Gears, M. Fox, p. 112
- **5:00 – 6:00 pm**  
  The Role of Additive Adsorption in Controlling Wet Clutch Friction, M. Ingram, p. 112

## SESSION 6C  
**Lubrication Fundamentals VI**

**Room 204**
- **9:00 – 10:00 am**  
  Grid Generation in HL and EHL Using AMG, T. Lubrecht, p. 96
- **10:00 – 11:00 am**  
  A Simplified Mass-Conserving and Continuous Cavitation Model, N. Brunetiere, p. 96
- **11:00 – 12:00 pm**  
  Collision and Surface Interactions of Particles in Lubricated Interfaces, C. Barbosa, p. 96
- **12:00 – 1:00 pm**  
  EHL of Large Length/Diameter Ratio Profiled Needle Roller, X. Shen, p. 97
- **1:00 – 2:00 pm**  
  Effect of Density Flow Factor on Thermal Elastohydrodynamic Lubrication of Infinite Line Contact Rough Surfaces, H. Khan, p. 97
- **2:00 – 3:00 pm**  
  Active Nanoparticles-Based Novel Lubricant Additives to Improve Energy Efficiency and Durability, D. Demydov, p. 94
- **3:00 – 4:00 pm**  
  Ionic Liquids as Lubricants; P. Sutor, p. 97
- **4:00 – 5:00 pm**  
  Amplitude Reduction in EHL Circular Contacts Under Rolling Sliding Conditions, T. Lubrecht, p. 97
- **5:00 – 6:00 pm**  
  Evolution of ZDDP-derived Reaction Layer Morphology with Rubbing Time, A. Naveira-Suarez, p. 96
- **6:00 – 7:00 pm**  
  A Theoretical Investigation of Surface Texturing Effect on the Stribeck Curve, S. Pei, p. 110
### TECHNICAL SESSIONS TIME GRID

#### SESSION 5D  
**Material Tribology II**

**Room 205**

- Study of Wear Behaviour of Nylon 66 Blended with Graphite and MoS2 using Taguchi's Technique, S. Dinesh, p. 97
- Reducing Friction in Plastics, M. Fox, p. 97
- Tests of Solid Lubricants for Cryogenic and Vacuum Environment, T. Schneider, p. 98
- Experimental High Temperature Solid Lubricants, R. Colbert, p. 98

**Room 206**

- Sealing Suitability of Hard-turned Shafts Operating with Rotary Lip Seals, S. Jung, p. 98
- Two Dimensional Contact Analysis Between the Lip Seal and the Surface Textured Shaft Based on Linear Convolution and FFT Algorithm, W. Li, p. 98
- Visco-Elastohydrodynamic Analysis of Rotary Lip Seals, B. Yang, p. 99

**Room 207**

- A Screening Method for Deposit Forming Tendencies of Engine Lubricants, S. Kouame, p. 100
- Experimental Study of Grease Lubrication Regimes Using Ball-On-Cylinder Bearing, W. Wong, p. 100
- Tribometry Studies on the Effects of Lubricant Contamination With Biofuels, G. Molina, p. 100
- Friction and Wear Testing of Liquid and Solid Additives, J. Domeier, p. 100

**Break**

- Understanding Environmental Effects of DLC and Preventing DLC Wear via Alcohol Vapor Lubrication, S. Kim, p. 98

**Break**

- Tribology Studies on the Effects of Lubricant Contamination With Biofuels, G. Molina, p. 100
- Friction Force Measurement in Reciprocating Tribometers, G. Plant, p. 102
- Elastohydrodynamic Lubrication of Oscillating Roller Contacts, K. Chen, p. 100

#### SESSION 6D  
**Materials & Nanotribology**

**Room 205**

- In-Situ Microtribology of Soft Materials, J. Vail, p. 112
- In-Situ Characterization of Nanoscale Wear of Sharp Silicon Asperities, T. Jacobs, p. 112
- Tribochemical Surface Monitoring of Tantalum in an In-Situ Electrochemical Atomic Force Microscope, D. Hutnik, p. 113

**Room 206**

- Mixed EHD Analysis of Lip Seals Based on Measured Seal Surfaces, Y. Liu, p. 114
- 1 kW Less Friction Due to Textured Sliding Faces, L. Hoerl, p. 114
- Mechanism of Combined Coning and Waviness Mechanical Face Seal for Nuclear Reactor Coolant Pump – Theoretical and Experimental Research, X. Wang, p. 114

**Room 207**

- Nanoscratch Test for Magnetic Recording Disks, T. Karis, p. 115
- Tribological Behavior of Different Thin-film Coatings, N. Demas, p. 115
- Evaluation of Sliding, Reciprocating, and Fretting Wear of Self-lubricating Coating Created by High Velocity Particle Consolidation, A. Segall, p. 115

**Break**

- Development of an Instrument for Studies of Charged Triboemission Transport in Gas Atmospheres, G. Molina, p. 113
- Atomic Stick-slip Friction Studied by Optimally-matched Experiments and Simulations, Q. Li, p. 113
- Atomic Stick-slip Friction Studied by Optimally-matched Simulations and Experiments, T. Dong, p. 113
- Study of Friction on Graphene Using Simulation, A. Udupa, p. 113

**Break**

- Factors Affecting Performance of Mechanical Seals in CANUS Reactor Shutdown Cooling Pumps, G. Staniewski, p. 114
- A Mixed Thermoelastohydrodynamic Lubrication Analysis of Mechanical Face Seal by a Multiscale Approach, A. Nyemeck, p. 114
- Optimization of Face Groove Parameters Based on an Integrated Performance Parameter for Dry Gas Seals, W. Huang, p. 114

**Break**

- Study of Friction in Military Braking Systems, E. Jun, p. 115
- Causes and Implications of Data Variability in Basic and Applied Tribotesting, P. Blau, p. 115

**Seals Business Meeting**

**Nanotribology Business Meeting**

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WEDNESDAY >>
Wednesday May 18, 2011

TIME

8 – 8:30 am
Effects of the Feedline Restrictor Orientation of a Hybrid Bearing Hydrodynamic Behavior, M. Braun, p. 102

8:30 – 9 am
Finite Element Analysis of the Influence of Thermal Deformation on a Water-lubricated Hybrid Bearing’s Performance, Y. Zhang, p. 102

9 – 9:30 am

9:30 – 10 am
Performance of an Orifice Compensated Non-recessed Hole-entry Hybrid Journal Bearing Operating with Micropolar Lubricant, S. Sharma, p. 102

10 – 10:30 am
Break

10:30 – 11 am
A Study of a Constant Flow Valve Compensated Non-recessed Hole-entry Hybrid Journal Bearing Operating in Turbulent Regime, N. Ram, p. 102

11 – 11:30 am
Experimental Study on Dynamic Coefficients for Spindle System Supported by High-Speed Hybrid Bearings, S. Ma, p. 103

11:30 am – Noon
Thermal and Expansion Effects of a Shaft on Lubrication of a Water-lubricated Hybrid Bearing for High Speed Spindle, W. Chen, p. 103

1:30 – 2 pm
Lubrication of Industrial Gears with Synthetic Gear Oils, W. Bartz, p. 116

2 – 2:30 pm
Influence of Aerated Lubricants on Gear Churning Loss – An Engineering Model, G. Leprince, p. 116

2:30 – 3 pm
Experimental Research on Reasonable Lubricant Quantity for Transmission Gears Used in High-speed Train, L. Ying, p. 116

3 – 3:30 pm
Break

3:30 – 4 pm
Gears Business Meeting

4 – 4:30 pm
Tribological Evaluation of Surface Texturing used in Air Conditioning and Refrigeration Compressor Surfaces, A. Polycarpou, p. 116

4:30 – 5 pm
Diamond-coated Tools with Different Etching Treatments – Delamination Characteristics and Machining Performance, K. Chou, p. 118

5 – 5:30 pm
Effects of Surface Texturing on Friction and Wear Reduction Between Silicon Nitride and Steel Materials, A. Amanov, p. 118

5:30 – 6 pm
Surface Engineering Business Meeting until 6 pm
### TECHNICAL SESSIONS TIME GRID

**SESSION 5J**
**Enviro Friendly Fluids I**

Room 212
- Hydraulic Fluids from an Environmental View, G. Gaule, p. 105
- Design Considerations for an Environmentally Friendly Hydraulic Fluid, J. Burke, p. 105
- Changing to Enviro-Friendly Grease in Rail and Wheel Flange Lubrication, J. de Koker, p. 105

Room 213
- Biobased Products: Key Federal and State Policy and Regulatory Issues, S. Pfifferling, p. 106
- Development and Evaluation of Nonferrous Stain Inhibitors, T. Oleksik, p. 106
- Film-forming Properties of Vegetable Oil-synthetic Oil Blends in Elastohydrodynamic Conditions, G. Banichet, p. 107

Room 214
- Finding Varnish — Is There a Definitive Test?, E. Zabawski, p. 107
- Color Analysis of Membrane Patches using a Transmitted Light, T. Honda, p. 107
- In Turbine Oils, Minor Ingredients can have the Biggest Impact, A. Fentress, p. 107

**SESSION 5K**
**Non-Ferrous Metals I**

Room 212
- Aluminum Sustainability — A World of Opportunity, S. Larkin, p. 119
- Herringbone Status in Aluminum Cold Rolling, P. Deneuville, p. 119
- Analysis of Volatile Organic Content in Non-Ferrous Metal Forming Fluids by Thermo-gravimetric Analysis, J. Burke, p. 119

Room 213
- ASTM Standard Practice & Guide Updates Impacting Power Generation, A. Wardlow, p. 120
- Counting and Sizing Sub Micron Particles in Oil Provide the Basis for Novel Correlations with Other Test Results, G. Munson, p. 120
- Sub-Micron Particles Contribute Greatly as Charge Carriers and Charge Generators in Lubricating Oil Systems, Creating More Particles: A New Technology May Prevent this from Occurring, G. Munson, p. 120

Room 214
- Productivity Enhancements using Lubrizol Clean Hydraulic Oil Technology, D. Oesterle, The Lubrizol Corporation, p. 147
- Additive Technology for Extending Re-Regreasing Intervals and Improved High Temperature Protection, P. Zhu, The Lubrizol Corporation, p. 147

**SESSION 5L**
**Power Generation I**

Room 212
- Modern, Ester-based Hydraulic Fluids for Power Generation, N. Broekhof, p. 120
- ESTERS: Various Methods to Identify and Quantify These Additives, P. Mortreuil, p. 119
- Environmentally Friendly Fluids Business Meeting

Room 213
- Development and Evaluation of Water Soluble Renewable Resources Based Polymeric Lubricant Additive on the Lubricity, Misting & Foaming Potential of Metalworking Fluids that are Especially Designed for Aluminum, S. Erhan, p. 119
- The Effect of a Water Soluble Renewable Resources Based Polymeric Lubricant Additive on the Lubricity, Misting & Foaming Potential of Metalworking Fluids that are Especially Designed for Aluminum, S. Erhan, p. 119
- Determination of Dicarboxilic Acids in Rolling Emulsions, O. Seifert, p. 119

Room 214
- Steam Turbine Lubricant Development: A Case Study Approach, W. Hewson, p. 120
- Power Generation Business Meeting

**Commercial Marketing Forum V**

Salon D/E
- PAO Premium – A New Generation of PAO Technology for Tomorrow’s Lubricants, N. Stone, Chemtura, p. 147
- Productivity Enhancements using Lubrizol Clean Hydraulic Oil Technology, D. Oesterle, The Lubrizol Corporation, p. 147

**WEDNESDAY**

8 – 8:30 am
8:30 – 9 am
9 – 9:30 am
9:30 – 10 am
10 – 10:30 am
10:30 – 11 am
11 – 11:30 am
11:30 am – Noon
1:30 – 2 pm
2 – 2:30 pm
2:30 – 3 pm
3 – 3:30 pm
3:30 – 4 pm
4 – 4:30 pm
4:30 – 5 pm
5 – 5:30 pm
8 – 8:30 am
Active Nanoparticles-Based Novel Lubricant Additives to Improve Energy Efficiency and Durability
D. Demydov, A. Suresh, NanoMech, Inc., Springdale, AR, A. Malshe, University of Arkansas, Fayetteville, AR

Systematic investigation of modified nanoparticles with additional functional groups that positively impact friction and wear behaviors will be discussed. These nanoparticles were specially designed for addition to oils/greases as additives to improve energy efficiency and durability. The temperature- and pressure-sensitive architecture of the nanoparticles enabled them to deliver a stable transfer tribofilm that reduced the extent of adhesive wear and solid-phase welding between sliding surfaces and provided better lubrication resulting in better reliability of mechanical integrity and lower energy consumption. The nanometric size allowed the entrapment of the particles at the asperity-to-asperity contacts and reducedasperity friction. The research efforts were focused on tribological testing of nanoparticles, improvement of their dispersion, and investigation of their behaviors in the presence of other additives in formulated oils/greases.

8:30 – 9 am
Experimental Studies on the Tribological Behaviour of Engine oil (SAE15W40) with the Addition of CuO Nanoparticles
R. Krishnan, M. Thottackad, P. Nair, National Institute of Technology Calicut, Calicut, India

Experimental studies on the influence of Copper oxide (CuO) nanoparticles utilised as an additive in lubricating oil (SAE15W40) under boundary lubrication conditions have been carried out using a pin-on-disc machine in accordance with ASTM D4052 standard. The variation of viscosity, coefficient of friction, wear and settling of nanoparticles has been studied as a function of particle concentration in the lubricant.

Results show that the frictional force and specific wear rate decrease with an increase in concentration of nanoparticles, comes to a minimum at a specific concentration and then increases, showing the presence of an optimum concentration. With the increase in concentration of nanoparticles the kinematic and dynamic viscosities, and the flash and fire points are found to increase. Thus, the use of CuO nanoparticles as additives to a moderate level, is a very efficient means of improving the tribological properties of lubricating oils.

9 – 9:30 am
Nanodiamond-based Nanolubricants
M. Ivanov, Ural Federal University, Yekaterinburg, Russian Federation, S. Pavlyshko, Institute of Engineering, Science Ural Branch RAS, Yekaterinburg, Russian Federation, I. Denis, Ural Federal University, Yekaterinburg, Russian Federation, I. Petrov, SKN, Snezinsk, Russian Federation, G. McGuire, O. Shenderova, International Technology Center, Raleigh, NC

Recently, certain nanomaterials in powder and colloidal forms have emerged as potential anti-friction and wear additives to a variety of base lubricants. Highly purified detonation nanodiamonds (DND) with small aggregate sizes are a relatively new nanomaterial additive [1, 2]. In the current work, we report results of the comparative analysis of the colloidal stability and tribological performance of DND-based additives as well as other commercial additives based on detonation soot, boron nitride and PTFE, nano-oxides (TiO2) and their combinations in mineral engine oil 15W40 (API CF/CC). Testing has been performed on these formulations using ring-on-ring (friction coefficient) and four ball tests (extreme pressure (EP) failure load and diameter of wear spot). Effects of different parameters of the formulations on their tribological properties will be discussed.


9:30 – 10 am
Experimental Analysis of Stable CuO Nanoparticle-Enhanced Lubricants
H. Ghaednia, R. Jackson, L. Fan, J. Khodadadi, Auburn University, Auburn, AL

The goal of this paper is to investigate the effect of different concentrations of nano-lubricants on the friction and wear of a disk-on-disk test setup. The uniquely developed nanoparticles used in this study are CuO and have been proven to be exceptionally stable. Existing literature also suggests that CuO particles may be able to enhance lubricant performance in the boundary lubrication regime. A disk-on-disk test setup used in this study can measure the friction coefficient and wear using torque and load sensors. The tested samples are submerged in a small reservoir of the nano-lubricant. The wear and possible mending of the surfaces is evaluated using average profilometer and weighing the samples before and after testing. Experiments have been carried out for lubricants with different concentration of additives in various rotational velocity and loads.

10 – 10:30 am • Break

10:30 – 11 am
Single Asperity Friction and Temperature Dependent Properties of Boundary Lubricant Additive Films

Automotive lubricants are designed to form low friction, wear resistant layers through interactions between additives and the steel surfaces during tribological contact. Atomic force microscopy (AFM), which simulates single asperity sliding contacts, was used to investigate local properties of additive films. Samples were produced in a high frequency reciprocating sphere-on-flat geometry using single additive and multi-additive lubricant blends. Films generated from these tests were characterized using AFM. To simulate macroscale test environments for the single asperity friction measurements, the probe and sample were immersed in a polyalphaolefin liquid. A heated stage was used to investigate local film properties at different temperatures. We will discuss the ways in which the nanoscale friction response can be related to macroscale friction behavior.
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See us in booths 30 & 31 at STLE 2011
11 – 11:30 am
Evolution of ZDDP-derived Reaction Layer Morphology With Rubbing Time
A. Naveira-Suarez, SKF Engineering and Research Centre, Nieuwegein, Netherlands, A. Tomala, Vienna University of Technology, Vienna, Austria, R. Pasaribu, SKF Engineering and Research Centre, Nieuwegein, Netherlands, R. Larsson, Lulea University of Technology, Lulea, Sweden, I. Gebeshuber, Universiti Kebangsaan Malaysia, Bangi, Malaysia

Functional additives, particularly extreme-pressure and antiwear additives, in formulated oil will compete to adsorb and function in tribological contacts. A low polarity commercial base oil, poly–olefin (PAO), blended with zinc dialkyl dithiophosphates has been studied. The tribological performance was evaluated using a ball-on-disc test rig under mixed rolling-sliding conditions in the boundary lubrication regime. An adapted in-situ interferometry technique was used to monitor the additive derived reaction layer formation. The thickness of the reaction layer evolves with rubbing until reaching a limiting thickness value of approximately 70nm. The evolution of the topography and mechanical properties of the ZDDP-derived reaction layer with rubbing time were studied using Atomic Force Microscopy. A constant roughening and hardening of the additive-derived layer with rubbing time is observed and related to the different tribological performance of the layer at different rubbing times.

11:30 am – Noon
Exploratory Research Work on Tribological Effects of Nanofluids
G. Molina, M. Rahman, V. Soleiu, C. Walker, M. Hulett, Georgia Southern University, Statesboro, GA

Nanofluids are fluids containing engineered colloidal suspensions of nanoparticles in ordinary base fluids, as water and organic liquids. Simulations of nanofluids dynamics predicts large enhancement in transport properties, especially in thermal ones, as compared to those of the base fluids. The authors have built and tested an erosion-test instrument for nanofluids, which allows control of a fluid jet impacting a material target for “accelerated testing” of cooling-system materials. Results of preliminary experiments are presented for suspensions of alumina and copper oxide nanoparticles in coolant fluids (i.e., weight concentrations of up to 2% in distilled water and its solutions of ethylene glycol), Erosion effects on material targets and changes of viscosity are assessed and discussed, and most relevant recent literature is reviewed.

8 – 8:30 am
Grid Generation in HL and EHL Using AMG
T. Lubrecht, M. Noutary, INSA Lyon, Villeurbanne, France, K. Venner, Twente University, Enschede, Netherlands

The solution of lubrication problems involves the solution of the Reynolds equation describing the fluid flow, integrated over the gap height. For certain cases the pressures are so high, that important elastic deformation occurs, and the fluid flow has to be coupled with an elastic deformation calculation. In those cases the lubricant viscosity varies as a function of the pressure as well. This paper uses Algebraic MultiGrid (AMG) to study the coarse grids generated, in order to optimise algorithm robustness and efficiency. A similar quest can be observed in the FEM solvers, which use non-structured grids in order to optimise the fine grid, and to limit the number of points used. The paper analyses two HL applications, the circular HL contact and the long elliptical contact. A third EHL application highlights the strong coupling in the high pressure zone.

8:30 – 9 am
A Simplified Mass-Conserving and Continuous Cavitation Model
N. Brunetiere, Institut Pprime, Futuroscope Chasseneuil cedex, France, J. Wang, Northwestern University, Evanston, IL

This paper presents a simplified continuous cavitation algorithm. The first cavitation model consisted in replacing negative pressure given by the incompressible Reynolds equation with a constant value generally equal to zero. However these models are not able to deal with film reformation. This was solved by the well known JFO or Elrod’s model with the use of a variable density in the cavitation area. The problems are that there are two distinct areas where the equations to be solved are different. More recent papers proposed to describe the fluid as a liquid contaminated with gas bubbles. Even if more realistic, these models are however complicated to implement. The model proposed in this work considers the fluid as a homogenous mixture of an incompressible liquid and a perfect gas. For a low gas concentration, the model behaves as the JFO model; and for a high concentration value, the results are similar to those obtained with a gas flow model.

9 – 9:30 am
Collision and Surface Interactions of Particles in Lubricated Interfaces
C. Barbosa, Q. Wang, Northwestern University, Evanston, IL

Sliding surfaces in machines are usually lubricated with oil to reduce friction and wear. Ideally, the oil is clean and free from impurities. In reality, oils are often contaminated with dust, debris, and wear particles. These loose particles may damage the interface surfaces, causing overall failure of lubricated applications such as gears, roller bearings, and pistons. The present study attempts to shed light on the behavior of contaminant particles in shear flow using fundamental physical modeling. The contamination model numerically solves the Navier-Stokes equations for fluid-solid flows, incorporating both particle collisions and particle contact with the interface walls. These transient particle interactions enter the governing Navier-Stokes equations through an additional force term. Resulting pressure and velocity fields are presented and validated against existing theoretical and experimental studies in the literature.
A numerical calculation of thermal EHL for line contacts has been developed. To improve the efficiency of MLMI in heavier load and larger length/diameter ratio analysis, the EHL pressure distributions of infinite line contacts at the similar working conditions and a piecewise function are used as the initial value. The repeated numerical experiments illustrate that it is helpful for the solutions convergent. The analysis results show that the maximal contact length/width ratio can reach to 169, while the contact pressure exceeds 2.0 GPa, in which the needle roller length/diameter is 6:1. The minimal entrainment velocity for convergent solutions is 0.3 m/s. It is also found that for the same diameter of needle roller, both the pressure at the roller ends and the relative contact length will be increased with the length/diameter ratio increasing when the load per unit length is same. The minimum oil film thickness in the roller ends will increase with the crowning value increasing.

10 – 10:30 am • Break

10:30 – 11 am
Ionic Liquids as Lubricants
P. Sutor, Paul Sutor R&D, Kansas City, MO

Ionic liquids are compounds of organic cations with organic or inorganic anions that are liquid below room temperature, but are held together by strong electrostatic forces. The suitability of ionic liquids for use as lubricants was first recognized in 2001. Initial studies of lubrication by ionic liquids demonstrated promising performance, especially friction lower than that of most lubricant base fluids. Also reported were load-carrying ability better than synthetic hydrocarbons, viscosity similar to synthetic lubricants, good lubrication of nonmetals as well as metals, good high-temperature stability, and very low volatility.

A review and assessment of the first ten years of work on ionic liquids as lubricants is presented.

11 – 11:30 am
Amplitude Reduction in EHL Circular Contacts Under Rolling Sliding Conditions
T. Lubrecht, INSA-Lyon, Villeurbanne, France

Surface roughness has an important influence on the performance of concentrated lubricated contacts. The standard way of accounting for the surface roughness is through the film thickness to roughness parameter: h/σ. However, under high load Elasto Hydrodynamically Lubricated (EHL) conditions, the surfaces and the roughness deform. Hence it is important to be able to predict this deformation. The roughness deformation has been studied using semi-analytical methods (Greenwood Hooke) or using numerical techniques (Venner Lubrecht). Furthermore, experimental techniques have been used to test the numerical predictions (kaneta, spikes, brno). A consensus exists for the deformation of sinusoidal waviness under pure rolling conditions. However, for rolling sliding conditions, the situation is more complicated and the semi-analytical models predict a deformation of the waviness for both high and low wavelengths. The current work analyses the waviness deformation under rolling sliding.

11:30 am – Noon
Effect of Density Flow Factor on Thermal Elastohydrodynamic Lubrication of Infinite Line Contact Rough Surfaces
H. Khan, P. Sinha, Indian Institute of Technology Kanpur, Kanpur, India

A numerical solution of a thermal elastohydrodynamic lubrication (TEHL) of infinite line contact rough surfaces is obtained. The effect of density flow factor on the bearing characteristics are studied based on an average flow model of rough surface lubrication with inter-asperity cavitation. The modified average Reynolds equation, elasticity equation and energy equations are solved simultaneously using a modified Houpbert and Hamrock fast approach. The inclusion of density flow factor influences the bearing characteristic for thermal rough EHL. The minimum film thickness increases by 20% approximately for longitudinally oriented surfaces when the inter-asperity cavitation is considered.

MATERIAL TRIBOLOGY II
Session 5D • Room 205

Session Chair: O. Eryilmaz, Argonne National Laboratory, Argonne, IL
Session Co-Chair: A. Erdemir, Argonne National Laboratory, Argonne, IL

8 – 8:30 am
Study of Wear Behaviour of Nylon 66 Blended with Graphite and MoS2 using Taguchi’s Technique
S. Dinesh, S. Jayaram, Malnad College of Engineering, Hassan, India

Wear and friction characteristics are experimentally studied for Nylon-66 blended with different percentages of Graphite & MoS2. Design of experiment has been carried out using Taguchi’s technique. Load, sliding velocity and sliding distances are varied. Technique indicates the betterment of mechanical properties with blending. Higher flexural modulus & impact strengths are obtained with 9% of Graphite. There is no remarkable improvement in tensile strength for higher percentages. Sliding speed and sliding distance are the influencing factors. For 6% & 12% Graphite blends, the coefficient of friction tends to decrease as time progresses. Thus, these blends are recommended for lower range of influential parameters for better tribological properties. The blending of Nylon with MoS2 made no remarkable impact on the coefficient of friction. The wear is less in the lower speed range. Up to 15% of graphite blends, the wear of the specimen is almost negligible.

8:30 – 9 am
Reducing Friction in Plastics
M. Fox, Nylacast Ltd., Leicester, United Kingdom

Polymers divide into commodity/engineering/high temperature engineering plastics. The first include PE, PP, ABS, PS and PMMAs as cheap, readily transformed materials but limited to 100°C. The second includes polyamides and PET/PBT, 170°C. Other than PTFE, polymers have high friction coefficients, unsuitable for most applications. They need definition for the tribological pair, polymer/polymer pairs have higher values than polymer/steel and vary with PV. Reducing polymer friction introduces intermediate lubricating films between surfaces, e.g., a lower melting solid in a higher melting point matrices, as PTFE dispersed in PEEK as lubricant in a rigid polymer matrix. Or an oil or wax is used, dispersed into the monomer and then polymerised. ‘Low friction’ solid plastics have friction coefficients as low as 0.06. As friction values decrease, ‘stick/slip’ becomes proportionately more important and use of polymeric fluorinated liquids to counter this phenomenon will be discussed.
Solid lubricants, applied as coatings or as components in polymer composites, can be used for reducing friction and wear when conventional lubrication with oils and greases is not possible. Examples are cryogenic environments with temperatures out of the range for liquid lubricants, and vacuum where vaporisation, creep, and contamination are the main problems. Extreme examples of tribosystems in high vacuum at cryogenic temperature are supporting elements in the structure of large superconducting magnets which have to sustain high loads while allowing a certain amount of tangential movement without any stick-slip motion. In model tests in liquid helium and in vacuum at low temperatures a PVD-MoS2-coating has proven its suitability for these components. These and the results for other solid lubricant coatings and self-lubricating polymer composites, tested in cryogenic and/or vacuum environment, are presented.

Experimental High Temperature Solid Lubricants


Numerous applications exist where solid lubricants are required to perform at elevated temperatures. Pin-on-disk experiments for metal on ceramic contacts were performed at varying temperatures. A rotary pin-on-disk tribometer capable of controlled substrate temperatures up to 800°C was used for friction and wear experiments. Experimental solid lubricants were mated with a silicon nitride ball to determine the influence of the temperature on the tribological performance of the materials. Spectroscopic characterization techniques were employed to analyze the worn substrates, including Raman and EDS.

Understanding Environmental Effects of DLC and Preventing DLC Wear via Alcohol Vapor Lubrication

S. Kim, M. Marino, Pennsylvania State University, University Park, PA, A. Erdemir, O. Eryilmaz, Argonne National Laboratory, Argonne, IL

Two types of Diamond-like carbon (DLC) films were studied – highly-hydrogenated DLC (NFC-6) and mildly-hydrogenated DLC (NFC-10). In dry argon and hydrogen environments, the friction coefficient of NFC-6 is ultra-low (<0.02) while it is relatively high in oxygen and humid conditions. In contrast, the NFC-10 film shows high and unsteady friction behaviors in dry argon and hydrogen environments and low friction in oxygen and humid environments. In all these conditions, the run-in period behaviors are observed and some wear marks can be seen on the ball surface. The run-in period appears to be due to wear of oxidized surface layer which is readily formed upon air exposure. The equilibrium adsorption of alcohol vapor (such as n-pentanol) on DLC from the ambient can prevent wear of both NFC-6 and NFC-10 surfaces even though the friction coefficient is not ultra-low (~0.15). The mechanism for the run-in behavior and alcohol vapor lubrication are explained.

Friction Behavior of Hydrogenated Diamond-like Carbon Films in Dry Nitrogen and Air Environments at Elevated Temperatures

O. Eryilmaz, Q. Zeng, A. Erdemir, Argonne National Laboratory, Argonne, IL

We investigated friction and wear behavior of DLC films in dry nitrogen and air environments from room temperature up 600°C. The coatings were synthesized in r.f. gas discharge plasma. Combination of acetylene, methane, methane-hydrogen mixtures with different ratios were used during deposition. Since coated substrates were H13 steel, silicon bond layer is applied by using silane gas. Highly hydrogenated DLC films provided superlow friction (less than 0.01) at room temperature in dry N2 and slightly higher friction in air. All DLC coatings maintain their low friction behavior up to 200°C in both air and nitrogen. All DLC films showed high friction coefficient and wear (0.4 and higher) between 200- 500°C temperature range. However especially DLC film grown form pure methane provided less than 0.05 friction coefficient at 600°C. The wear life of the coating was also substantially increased. All test were performed using pin-on-disk system under 2-10 N loads and at 0.2-0.5 m/s sliding velocities.

Seals I

Session Chair: R. Salant, Georgia Institute of Technology, Atlanta, GA

Sealing Suitability of Hard-turned Shafts Operating with Rotary Lip Seals

S. Jung, W. Haas, Institute of Machine Components, Stuttgart, Germany

Leakage of rotary lip seals is prevented by a fluid flow from the air-side to the liquid-side of the seal, caused by microasperities on the lip surface. But the shaft surface is also of great importance for the reliable performance of a rotary lip seal. Usually, plunge ground shafts are used. But hard-turned shafts have proven their suitability as well. However, the effect of the macroscopic turning groove to the sealing system is still not entirely clear. In the present study, the sealing suitability and pumping effects of different hard-turned shafts are examined in short-term and long-term tests. Furthermore, the effect of different angles at the turning grooves, the resulting friction and the developing temperature are investigated. The results show a strong dependence between the orientation of the turning groove and the sealing performance. With this knowledge it is possible to get a better understanding of the effects of the shaft surface towards the sealing system.
Shaft Waviness Effect on Performance of Lay Down Radial Lip Seals: Part II
A. Berdichevsky, J. Jiang, FNGP, Plymouth, MI

In a previous study, the effect of shaft waviness on the performance of a radial shaft seal with 'lay-down' lip had been studied via FEA simulation. As a follow-up study, the present work was conducted to verify experimentally the criterion drawn from previous analysis. In this study, shafts were made with surface defects in the form of wavelets (circumferential grooves or protrusions) of various sizes. The seal pump rate was used as a test method in order to investigate shaft waviness effects on seal performance. In the test, seals were installed on the wavy shaft in the controlled position relative to the wavelet, and the pump rate was measured at each location under different shaft rotation speed. Three types of seals were tested, and the results were compared with the previous analysis.

Visco-Elastohydrodynamic Analysis of Rotary Lip Seals
B. Yang, Y. Liu, P. Sharma, F. Shi, General Motors Company, Pontiac, MI

Recent steady-state numerical analyses of rotary lip seals have revealed the basic principles about the operation of such seals, including the lubrication regime and the reverse pumping mechanism. However, in practical engineering applications, such seals always operate under dynamic conditions due to installation misalignment, shaft dynamic vibration and out of roundness. In the present study, a fully transient numerical model which takes into account the dynamic effects has been developed. The model consists of a fluid mechanics analysis of the lubricating film using implicit finite element based mass conserving EHD algorithm and a dynamic structural analysis of the seal considering the visco-elastic material properties. Results for a typical transmission lubrication regime and the reverse pumping mechanism. However, in ongoing research project at the University of Stuttgart. This paper covers the influence of the grease viscosity itself, the base oil viscosity, the thickener and the base oil type on temperature, friction-torque and wear of the seal edge and the counter surface. Tests were performed by using an experimental transmission, so that the sealing system interacts with its periphery, mainly rolling bearings and gears, by means of the lubricant. A difference of 25 K in seal edge temperature between different low-viscosity greases can be observed.

Rotary Lip Seal Pumping by a Ground Shaft with and without a Laser Structure
X. Jia, Tsinghua University, Beijing, China, R. Salant, Georgia Institute of Technology, Atlanta, GA, S. Jung, W. Haas, University of Stuttgart, Stuttgart, Germany

This study is part of an effort to develop and validate a computational model to predict the pumping rate produced by shafts that are manufactured by various techniques (with various surface finishes. The model includes a fluid mechanics analysis of the fluid film and a deformation analysis of the seal. In the present work pumping by plunge ground shafts with, and without, laser generated oblique grooves, is investigated. Plots of computed pumping rate versus shaft speed, for plain ground shafts and for ground shafts with various laser generated groove patterns, agree well with experimental measurements, providing validation of the model.

Lip Seals – Influence of the Lubricant
M. Narten, W. Haas, Institute of Machine Components, Stuttgart, Germany

Most of today’s research work and technological knowledge about lubricating grease is focused on the use in rolling bearings, plain bearings and slow rotating gears. Although the reliability of the sealing systems is crucial to every grease lubricated technical product, research about grease lubricated radial lip seals is still in its infancy. The influences of low-viscosity grease on radial lip seals is subject of an ongoing research project at the University of Stuttgart. This paper covers the influence of the grease viscosity itself, the base oil viscosity, the thickeners and the base oil type on temperature, friction-torque and wear of the seal edge and the counter surface. Tests were performed by using an experimental transmission, so that the sealing system interacts with its periphery, mainly rolling bearings and gears, by means of the lubricant. A difference of 25 K in seal edge temperature between different low-viscosity greases can be observed.

Future STLE Meeting Dates

2011 International Joint Tribology Conference
October 24-26, 2011
Marriott Los Angeles Downtown
Los Angeles, California

2012 STLE Annual Meeting & Exhibition
May 6-10, 2012
St. Louis, Missouri

2013 STLE Annual Meeting & Exhibition
May 5-9, 2013
Detroit, Michigan

2014 STLE Annual Meeting & Exhibition
May 18-22, 2014
Orlando, Florida
TRIBOTESTING I
Session 5F • Room 207

Wednesday, May 18 Technical Sessions

Session Chair: A. Segall, Pennsylvania State University, University Park, PA
Session Co-Chair: N. Gitis, Center for Tribology, Campbell, CA

8 – 8:30 am
A Screening Method for Deposit Forming Tendencies of Engine Lubricants
S. Kouame, S. Eser, A. Boehman, J. Perez, Penn State University, State College, PA

Deposit formation on pistons, valves, fuel pumps and injectors can degrade engine performance. Also, deposit formation during certification testing can lead a lubricant formulation to fail the test if excessive amounts of deposit form, or if small amounts of deposits form in areas that receive heavy weighting in the score, such as piston skirts, rings, etc. . It is important to gain a good understanding of deposit formation resulting from lubricant and metal surface interactions. In this paper, we propose a rapid screening method for lubricant performance testing. This was accomplished through a combination of post mortem analyses of the deposit using piston components from engine tests and laboratory studies of a combination of the Penn State Micro-oxidation and micro autoclave tests under controlled conditions, wherein metal coupons were exposed to commercial lubricants in reactor systems.

8:30 – 9 am
Experimental Study of Grease Lubrication Regimes Using Ball-On-Cylinder Bearing
W. Wong, H. Benabdallah, Royal Military College of Canada, Kingston, ON, Canada, D. James, University of Toronto, Toronto, ON, Canada

The performance of bearings depends on the lubrication regime. Striebeck curve illustrates these regimes by relating the friction to a dimensionless parameter expressing the operating conditions called Hersey number. The rheological properties of the lubricant are expressed by the viscosity in the computing of this parameter. The rheological properties of greases with consistency varying from NLGI grade 0 to 2 and base oil viscosity at 25°C from 46 to 1262 cP were assessed at shear rates ranging from 1 to 15000 1/s. Herschel-Bulkley model was chosen to describe the variation of grease viscosity versus shear rate. This information was used to determine the Hersey number. The friction tests were conducted on a ball-on-cylinder tester simulating point contact. Striebeck curves of these greases served to determine the lubrication regimes.

The proposed approach is suitable to determine lubrication regimes in case of grease.

9 – 9:30 am
Tribometry Studies on the Effects of Lubricant Contamination With Biofuels
G. Molina, V. Soloiu, S. Shanta, Georgia Southern University, Statesboro, GA

Research is presented on tribological effects of lubricant contamination with biofuels. Mixtures of SAE 15W40 mineral oil when contaminated by known percentages of biodiesel from canola oil, peanut oil, soybean oil and chicken fat biodiesel were tested in a pin-on-disc tribometer. This study used a model contact surface of AISI 1018 steel disk material and of 316 bearing-grade stainless steel for ball material, the assumption made that most of material loss would happen on the softer disk surface. Data of force of friction and contact temperatures were acquired, while wear was estimated by direct weight loss method. Changes in mixture viscosity for the very small mixture samples after tests were assessed by a ad-hoc method developed by the authors.

10 – 10:30 am • Break

10:30 – 11 am
Elastohydrodynamic Lubrication of Oscillating Roller Contacts
X. Chen, T. Hua, X. Shen, Shanghai University, Shanghai, China

Roller contacts are widely used in engineering components for heavy radial load. And most of rollers are normally profiled at their ends to overcome the edge effects caused by their finite length and by misalignment. The EHL oil film thickness and shape between a roller and a flat rectangular glass in pure rolling oscillated working conditions had been measured based on optical interferometry. The EHL behavior affected by the applied load, oscillating frequency and lubricant was investigated. The typical film shape varies of interference pictures on non-steady state motion, such as acceleration and deceleration, stop and start rapidly, was obtained. When the velocities of roller decreased to zero and then start in opposite directions, it was found the oil film can remain in a certain thickness for a short time because of the lubricant transient inertia effects, which is weakly velocity-dependent or load-dependent. These phenomena could reduce wear for oscillating roller contacts.

11 – 11:30 am
Experiment and Development of a Laboratory Test Rig for Traction Force of Shaft-sleeve Joint with Grease Lubrication Under Radial Load and Low Speed
Y. Boyuan, Henan University of Science and Technology, Luoyang, China, H. Diann Y, Caterpillar Inc., Mossville, IL, Z. Jian, Henan University of Science and Technology, Luoyang, China

Traction behavior of grease is essential to the reliability and durability of lubricated shaft-sleeve joint. In order to meet the demand of required traction data for shaft-sleeve joint design and analysis, a new test rig was developed to overcome the difficulties of measuring traction forces of grease lubricated shaft-sleeve joint due to the interference of its structure and radial load. The rig was designed with the capability of measuring traction with various running conditions of radial loads, speeds and temperatures. A description of the rig is presented. Testing results of a grease for engineering vehicles are discussed. And they are presented as the traction coefficient curves in relationship to relative speed, radial load and temperature separately. The testing results can
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provide basic traction data of grease-lubricated joints for heat transfer analysis, as well as efficiency prediction.

11:30 am – Noon
Friction Force Measurement in Reciprocating Tribometers

G. Plint, Phoenix Tribology Ltd, Newbury, United Kingdom

The transfer function of measuring systems for friction in tribological experiments is rarely analysed. This is of concern in reciprocating experiments, where claimed effects are not actual friction effects, but measurement artefacts or system resonance. For a measuring system with a fixed signal bandwidth, increasing the reciprocating frequency causes the apparent mean force to fall, giving the appearance of a reduction in friction with increasing frequency. As reciprocating frequency increases relative to the frequency response of the measuring system, the information content of the signal decreases. The transition from static to dynamic friction at the beginning of each stroke “plucks” the force measuring system. The magnitude of the resulting oscillations is a function of the magnitude of the plucking force and the rate of decay of the resulting vibration is a function of the resonant frequency of the measuring system and the variable damping coefficient of the frictional contact.

FLUID FILM BEARINGS V

Session 5G • Room 209

Session Chair: M. Filion, University of Poitiers, Futuroscope Chasseneuil, France
Session Co-Chair: A. Chandy, University of Akron, Akron, OH

8 – 8:30 am
Effects of the Feedline Restrictor Orientation of a Hybrid Bearing Hydrodynamic Behavior and Dynamic Coefficients

M. Braun, F. Horvat, University of Akron, Akron, OH

This paper comparatively presents a 2-D and 3-D numerical solution for the development of flow patterns and pressure profiles within a hydrodynamic journal bearing fitted with 4 circumferentially located hydrostatic jets. The dynamic characteristic of the journal bearing including whirl/whip situations as well as stiffness, damping and stability will be discussed as a function of the orientation angle of the restrictors. Cavitation effects will be accounted in a conservative mode using a mass fraction conservation equation coupled with the Navier-Stokes equations. In addition to the restrictors orientation angle, this parametric study will account for the effects of (i) feedline restrictor length, (ii) journal eccentricity and misalignment (iii) angular velocity and (iv) restrictor inlet supply pressure. The working fluid will be liquid oxygen. The steady, compressible solution is obtained using the commercially available software package ANSYS ICEM.

8:30 – 9 am
Finite Element Analysis of the Influence of Thermal Deformation on a Water-lubricated Hybrid Bearing’s Performance

Y. Zhang, W. Chen, Xi’an Jiaotong University, Xi’an, China

The influence of thermal deformation on a water lubricated hybrid bearing’s performance was investigated by using FEA software and solving related equations. A water lubricated hybrid bearing with multi-holes and deep/shallow recesses designed for high-speed machine tool spindle is proposed in the paper. The Ansys software was used to compute structural deformation due to temperature rise. A coupled solution of the Reynolds equation, the energy equation, the flow continuity equation and the temperature-viscosity equation was carried out to obtain the bearing’s performance parameters. The results show that bearing’s characteristics such as load capacity and stiffness are greatly changed after considering thermal deformation. An effective method to reduce thermal deformation also was discussed.

9 – 9:30 am
Influence of Wear and Method of Compensation on the Performance of 2-Lobe Multirecess Hybrid Journal Bearing System

S. Sharma, Indian Institute of Technology Roorkee, Roorkee, India, V. Phalle, Veeramata Jijabai Technological Institute, Matunga, Mumbai, India, S. Jain, Indian Institute of Technology, Roorkee, Roorkee, India

A comparative study concerning the performance of a multirecess 2-lobe hybrid worn journal bearing system compensated with different flow control devices, namely capillary, constant flow valve, orifice and membrane restrictors has been carried out theoretically. The wear caused on the bearing surface is modeled using Dufrane’s abrasive wear model. The Reynolds equation governing the flow of lubricant in the clearance space of a 2-lobe multirecess worn hybrid journal bearing system has been solved using FEM. The numerically simulated results obtained from the present study reveals that, the CFV compensated bearing is more suitable from the viewpoint of minimum fluid film thickness, fluid film stiffness and damping coefficient followed by membrane restrictor when bearing is operating under worn/unworn conditions. It is further observed that the proper selection of the type of restrictor, in conjunction with the value of offset factor( ), may provide improved bearing performance.

9:30 – 10 am
Performance of an Orifice Compensated Non-recessed Hole-entry Hybrid Journal Bearing Operating with Micropolar Lubricant

S. Sharma, Indian Institute of Technology Roorkee, Roorkee, India, N. Ram, Indira Gandhi Institute of Technology (GGS IP University), Delhi, India

In most of the industrial applications, the lubricants are mainly the polymer thickened oils or lubricants blended with additives. Usually these lubricants become heavily contaminated with suspended metal particles or dirt and hence they start exhibiting non-Newtonian behavior. The lubricant containing suspended additives behave as a fluid suspension and thus, the classical theory of Newtonian fluid is not able to predict their behavior. In the present study, the lubricating oil used to lubricate the hole-entry journal bearing has been modeled as micropolar fluid. The modified Reynolds equation for micropolar lubricant is solved using FEM and Newton Raphson Method. The numerically simulated results have been presented for a wide range of non-dimensional external load and micropolar parameters. The numerically simulated results suggest that in general the static and dynamic performance characteristics of a bearing get enhanced as the micropolar effect increases.

10 – 10:30 am • Break

10:30 – 11 am
A Study of a Constant Flow Valve Compensated Non-recessed Hole-entry Hybrid Journal Bearing Operating in Turbulent Regime

N. Ram, Indira Gandhi Institute of Technology (GGS IP University), Delhi, India, D. Sankla, S. Sharma, Indian Institute of Technology Roorkee, Roorkee, India

The continuous trend towards higher speed operation in turbomachinery and use of process fluids of low kinematic viscosity has received increasing attention due to its wide importance in bearing applications. High speed hybrid journal bearings lubricated with low viscosity fluids requires large levels of external pressurization to
provide required load support. These conditions give rise to large Reynolds numbers and thus cause the lubricant flow to be highly turbulent. Therefore, present work is aimed to study theoretically the performance of a constant flow valve compensated non-recessed hole-entry hybrid journal bearing operating in turbulent regime. The Reynolds equation based on Constantinou's lubrication theory has been solved by using finite element method. The numerically simulated results have been presented for a wide range of bearing operating and geometric parameters for the various Reynolds number.

11 – 11:30 am
Experimental Study on Dynamic Coefficients for Spindle System Supported by High-Speed Hybrid Bearings
S. Ma, S. Pei, H. Xu, Theory of Lubrication and Bearing Institute, Xi’an, China
In order to testify the reasonability of design method and the validity of calculation, a high-speed rotor-bearing test rig was built up supported by water lubricated hybrid bearing for its advantage of high-speed, high stiffness, high accuracy and low temperature rise, which could provide realizable experimental basis for bearing design in the future. In this paper, Additional masses attached to the rotor were taken to identify the dynamic coefficients of hybrid bearing system, and further experimental results shows the effect of supply pressure, rotating speed and other operating parameters on dynamic coefficients of bearing system. Experimental results demonstrated that, dynamic coefficients of rotor-bearing system increase with the incensement of supply pressure and spindle speed. The results provide guiding significance on improvement of structural parameters of rotor-bearing system design, and operation parameters optimization under different working conditions.

11:30 am – Noon
Thermal and Expansion Effects of a Shaft on Lubrication of a Water-lubricated Hybrid Bearing for High Speed Spindle
W. Chen, Y. Zhang, Xi’an Jiaotong University, Xi’an, China
A shaft expands due to heat generated in oil film of the bearing, which is often neglected because the expansion is very small compared to the clearance. But in the water-lubricated bearing designed for high speed spindle, the clearance is only 15 micrometers, so the expansion effects on the bearing’s performance should be considered. Thermal expansion of the shaft considering heat convection was analyzed by Finite Element Method. The results show that the shaft’s thermal expansion is related to shaft speed, shaft diameter and temperature rise of the oil film. The theoretical prediction of bearing’s performance would be changed by an amount depending on the clearance.

GEARS I
Session 5H • Room 210
Session Chair: A. Kahraman, The Ohio State University, Columbus, OH
Session Co-Chair: S. Li, The Ohio State University, Columbus, OH

8 – 8:30 am
Grease Lubrication – Pitting Load-carrying Capacity of Gears
J. Stempflinger, B. Hoehn, K. Michaelis, Gear Research Center (FZG), Munich, Germany, M. Hochmann, Marketing and Application Engineering, Munich, Germany
Open gear drives consisting of a case hardened pinion and a tempered girth gear are often applied in cement mills. For the girth gear lubrication often gear greases are used. The selection of the gear grease influences strongly the pitting load-carrying capacity.

For different flow greases NLGI 00 investigations were made in back-to-back test rigs determining pitting life time and pitting load-carrying capacity. Test gears in the pairing of a case carburized pinion and a tempered wheel were used. The test results show that gear greases NLGI 00 reach almost the same pitting life time as their base oil. Further the kinematic viscosity of the base oil shows a significant influence on pitting load-carrying capacity of gear greases NLGI 00. For the tested gear greases the calculation of the pitting load-carrying capacity according to DIN 3990 correlates well with the pitting load-carrying capacity of the test results.

8:30 – 9 am
Effect of Surface Roughness on Break-in and Micropitting of Heavy Machinery Final Drive Gears
H. Yoon, B. Feng, M. Ciolino, D. Blunier, P. Wang, D. Hua, Caterpillar, Inc., Peoria, IL
Break-in of gears is an important wear phenomenon that impacts the durability of gears, but still poorly understood and unpredictable. In this study, the effect of as-machined gear surface finish on break-in and micropitting behavior has been investigated using a full-scale final drive test rig. The plated-wheel ground gears with two different initial surface roughnesses (1.1 micron and 2.0 micron Ra) have been procured and tested. The progression of surface roughness change and the evolution of micropitting have been monitored with time by conducting interrupted tests and using the surface replicas taken from the tested gear flanks after each interrupted test. For both gears tested, the surface roughness values decreased as the number of test cycles increased and reached to the stabilized surface roughness, however, distinctive break-in and micropitting characteristics were observed.

9 – 9:30 am
New Test Method Proposal to Evaluate Pitting Behaviour of Lubricants
K. Topolovec Miklozić, G. Miklozić, Powertrit Ltd, Oxford, United Kingdom
Pitting is one of the key and most studied rolling contact fatigue modes. Despite significant amount of research however, it is still not fully understood how different operating conditions act together and control which mechanism is likely to prevail and cause pitting. Still today, a reliable bench pitting screening test method remains one of the greatest challenges for the industry. Newly established bench pitting and micropitting screener (MPR) offers great new possibilities to study of fatigue performance of fluids. In this work, MPR is used to look at the pitting performance of automotive transmission fluids. New proposed pitting screening test methodology enables evaluating of pitting performance of automotive transmission fluids with respect to their performance in a FZG C/9/90 test screener and even more
Session 5H

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<th>Time</th>
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<tr>
<td>10 – 10:30 am</td>
<td>Break</td>
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<tr>
<td>10:30 – 11 am</td>
<td>Gear Oil Innovations – Improving Axle Efficiency Without Compromising Durability</td>
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<td>J. Tomaro, M. Baker, G. Russo, The Lubrizol Corporation, Wickliffe, OH</td>
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<td>For lubricant manufacturers to design the right fluid for a vehicle manufacturer’s application, they must balance the need to reduce fuel consumption while offering equivalent or marked improvements in durability. For axle lubrication, this is easier said than done due to the severe operating conditions of the axles and the lubricant. Challenges like higher power densities and extreme axle temperatures make it difficult to insure the protection needed – let alone the desired fuel economy benefits – from the axle lubricant. Efficiency gains in axles may be realized by simply reducing the viscosity of the lubricant; however, these reduced viscosity fluids inherently can result in higher operating temperatures and durability loss due to reduced film thicknesses. This presentation highlights new innovations in Gear Oil Additive Technology. In particular, it focuses on the fundamental relationships between axle oil viscosity and the efficiency/durability balance.</td>
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<td>11 – 11:30 am</td>
<td>Tribodynamics of Hypoid Gear Pairs</td>
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<td>I. Karagiannis, S. Theodossiades, H. Rahnejat, Loughborough University, Loughborough, United Kingdom</td>
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<td>Dynamic response of hypoid gear pairs can be accompanied with untoward vibrations, for example in rear wheel drive vehicle differentials. These vibrations are often as the result of contact separation of meshing teeth pairs. The prevalent regime of lubrication in such conjunctions is elastohydrodynamic. Therefore, phenomena such as gear whine require solution of system dynamics and elastohydrodynamic meshing pairs. There are usually several gear teeth pairs in various stages of simultaneous mesh. Thus, a tribo-dynamics analysis is necessary, with tooth contact analysis and elastohydrodynamic lubrication (EHL). An analytical solution for EHL is used, based on the work of Ertel and Grubin with an also analytical solution of energy equation to include the effect of generated heat on lubricant viscosity. Furthermore, thin films cause non-Newtonian shear behaviour of the lubricant, thus lead to mixed thermoelasohydrodynamic conditions. The paper includes all these salient features.</td>
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<td>11:30 am – Noon</td>
<td>TEHL Analysis of Rough Surface Spur Gears with Non-Newtonian Lubricants Under Impact Loads</td>
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<td>M. Mongkolwongrojn, J. Panichakorn, King Mongkut’s Institute of Technology Ladkrabang, Bangkok, Thailand</td>
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<td>The time-dependent modified Reynolds equation, elasticity equation, and energy equation with initial conditions were formulated and solved numerically using a multi-grid multilevel with full approximation technique for an involute spur gear. In this analysis, the normal load and impact load are applied on either two pairs and one pair of gear teeth. The transition from two pairs to one pair and vice versa are modeled as a step variation of load. The effects of impact loads, surface roughness, non-Newtonian lubricant properties of the meshing gear in the region along the line of action are examined. The results show that spur gear with rough surface have significant affected on film thickness, film temperature and friction coefficient. The minimum film thickness is decreased rapidly with the decrease of lubricant power law index. For gear operated under impact load, the film temperature and friction coefficient are severely increased.</td>
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<tr>
<td>8 – 8:30 am</td>
<td>Superhydrophilic Surface on Cu Substrate to Enhance Lubricant Retention</td>
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<tr>
<td>J. Morehead, M. Zou, University of Arkansas, Fayetteville, AR</td>
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<td>The loss of lubricant from the surfaces of critical machine parts often lubrication, less and heat-related failures which can cause catastrophic damage to machinery. In this study, the effect of micro- and nano-texturing on lubricant retention was investigated. Micro-textures were produced by sandblasting Cu substrates; nano-textures were created by aluminum-induced crystallization of amorphous silicon. The topographies and the wettability of the textured surfaces were characterized by means of scanning electron microscopy and a video-based water contact angle machine, respectively. The lubricant retention of the textured surfaces was investigated using a dynamic method. It was found that superhydrophilic surfaces created by the combined micro- and nano-texturing technique can significantly improve the lubricant retention of Cu substrates.</td>
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<tr>
<td>8:30 – 9 am</td>
<td>Importance of Wetting and Surface Energy on Friction Behaviour</td>
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<tr>
<td>M. Kalin, M. Polajnar, University of Ljubljana, Ljubljana, Slovenia</td>
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<td>The surface properties are one of the crucial influences for tribological behaviour in almost every application. For boundary and mixed lubrication this is quite obvious. However, for (elasto)hydrodynamic lubrication, less and heat-related failures which can cause catastrophic relevance of fluid film parameters. However, fluid film and consequently friction also depend on surfaces and their physical and chemical interactions with lubricants. Recently, it is becoming obvious that solid-liquid interfaces play more important roles that it is typically considered – also under full film conditions. In this work, we present experimental and theoretical results of solid-liquid properties and their effects on friction for several engineering-relevant surfaces and liquids, such as various DLC coatings and base oils. We present significant differences in tribological behaviour depending on particular properties of these materials and suggest relevant mechanisms.</td>
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<tr>
<td>9 – 9:30 am</td>
<td>Experimental Impact of a Two-link System with Granular Matter</td>
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<tr>
<td>E. Banu, D. Marghitu, Auburn University, Auburn, AL</td>
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<td>In this paper, a two-link system impacting a granular media is studied with a focus on the influences of initial impact velocity on the stopping time into sand. The resistance forces are studied as a linear superposition of a dynamic frictional force (velocity dependent) and a static resistance force (depth dependent). The penetration depth of the two impact points is increasing with initial impact velocity as expected. The angle between the links is increasing with initial impact velocity during impact. However, the stopping time of the two-link system in sand is decreasing with initial impact velocity.</td>
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</table>
9:30 – 10 am
The Impact of Two Link Chain with a Flat Surface
Y. Xu, D. Marghitu, R. Jackson, Auburn University, Auburn, AL
In this study, a two link chain is impacting a massive flat surface. The equations of motion are obtained using Lagrange method. We calculated the impacts at both ends of the chain. A nonlinear contact force is considered for the impact. The effect of friction is taking into account at both ends of impacting chain. The impact is decomposed into elastic compression, elasto-plastic compression and restitution. The coefficient of restitution will be calculated for different geometrical and kinematic cases.

10 – 10:30 am · Break

10:30 – 11 am
Significant Rough Surface Constituents for Consistent Contact and Lubrication Analysis
S. Zhao, Wuhan University of Science and Technology, Wuhan, China, N. Brunetiere, Institut Pprime, Universite de Poitiers, Futuroscope Chasseneuil Cedex, France, Q. Wang, Northwestern University, Evanston, IL
Analyzing the contact and lubrication performance of rough surfaces is important to understand the severity of their interaction. However, engineering surfaces are complicated and involve multiscale constituents. Where or not all surface details should be included in the analyses deserves attention. A fine discretization with a large grid number can dramatically increase the computational burden. The authors investigate the relationship between the pressures of contact and lubrication of rough surfaces and the surface structural information. Flat surfaces are artificially generated, the contact of rough surfaces is analyzed with the continuous-convolution and fast Fourier transform algorithm, lubrication is studied with a cavitation modeling approach. Comparison of the numerical results from surfaces of the same frequency spectrum but different constituents leads to the determination of appropriate discretization wavelengths for effective numerical analyses of tribological parameters.

11 – 11:30 am
Prediction of Real Rough Surface Deformation in Pure Rolling EHL Contact: Comparison with Experiment
I. Krupka, M. Hartl, P. Sperka, Brno University of Technology, Brno, Czech Republic
In current highly loaded machine components the roughness features bring the risk of surface failures. Therefore, the effects of surface roughness on lubrication film thickness and pressure distribution is an important subject with significant practical impact. To make a rational choice during the design process rapid examining of several different combinations of loading and surface profiles must be assessed. At present this cannot be done and designs tend to be based on empirical rules.

Recently some researchers have considered harmonic features of various wavelength and amplitudes to explain the behaviour of real roughness. In this study this approach is used to predict the behaviour of real rough surface roughness within EHL contacts and obtained results are compared with the experimental data. It has been found that in such a way it is possible to obtain realistic in-contact deformation of surface roughness that can be used during the design of highly loaded machine components.

ENVIROMENTALLY FRIENDLY FLUIDS I
EFF APPLICATIONS
Session 5J · Room 212

Session Chair: M. Miller, Terresolve Technologies, Ltd., Eastlake, OH
Session Co-Chair: B. Sharma, University of Illinois, Champaign, IL

8 – 8:30 am
Hydraulic Fluids from an Environmental View
G. Gaule, B. Mueller-Zermini, Hermann Bantleon GmbH, Ulm, Germany
Standards on environmental requirements often do not keep step with new findings. This can slow down the introduction of new products and findings in the field of environmental protection. Industrial enterprises must act according to economic aspects and at the same time they must comply with the legal regulations and with environmental laws.

Environment-specific requirements on products are mostly deduced from the known regulations and standards. In the past it was often assumed to meet the requirements of the environment as far as possible. However, the problems arising between environment – biology – chemistry – lubricants are more complicated than initially assumed. The increasing number of new findings concerning environmental compatibility, new limits and REACH force us to place more individual responsibility on the lubricant companies and to develop lubricants which do not only comply with regulations and standards, but also meet further environmental requirements.

8:30 – 9 am
Design Considerations for an Environmentally Friendly Hydraulic Fluid
J. Burke, R. Adams, A. Cross, Houghton International, Valley Forge, PA
Hydraulic fluids are used in many industrial, agricultural, mining and off-shore applications. Some of these areas demand that hydraulic fluid that has minimal or low impact on the surrounding environment in the event of a leak or a catastrophic release. Terms such as environmentally friendly, green chemistry and biodegradable are used interchangeably to identify certain fluid characteristics. None of these terms addresses actual performance considerations for fluid performance or environmentally specific parameters. This paper discusses the basic performance tests that a hydraulic fluid should pass. This paper will also discuss how certain performance standards and chemistries conflict with the vision towards environmentally friendly fluids.

9 – 9:30 am
Development and Performance of a New Heavy Duty Biodegradable Grease for General Purpose Lubrication
D. Goshorn, S. Burkett, BioBlend Renewable Resources, LLC, Joliet, IL
A new class of biodegradable grease which meets the criteria for readily biodegradable lubricants has been developed for heavy duty and general purpose lubrication in several applications. This paper will review the development and the multiple uses of this new product.
9:30 – 10 am
Changing to Enviro-Friendly Grease in Rail and Wheel Flange Lubrication
J. de Koker, University of Johannesburg, Johannesburg, South Africa
Trackside lubrication is used in many railways to lubricate the rail-wheel interface where the wheel flanges of passing trains bear against the side of the rail crown around curves. (1) The reasons why enviro-friendly grease should be used are discussed and graphically displayed. The suitability and desirability of the use of these greases, as well as the economic and technical suitability are discussed.

10 – 10:30 am • Break

10:30 – 11 am
Environmental Lubricants in Industry
M. Miller, Terresolve Technologies, Mentor, OH
This presentation is a no nonsense approach to environmentally safe lubricants. It will help you chose the right environmentally safe fluid for your application. It will review the definitions of environmentally preferable products and strengths and limitations of each type. It will also review the various definitions of "biodegradable" and the maintenance practices required to prolong the life of the fluid and the equipment. Included will be environmental fluid compatibility with stern tubes, hydraulics, pumps, sealing materials, hoses, and other important components. Water infiltration, high pressure, wide temperature range usage as well as ways to manage these challenges will also be discussed.

11 – 11:30 am
Comparative Study of Formability of 304 L Steel Sheets with Green Lubricants-theory and Experiments
Y. Shashidhara, S. Jayaram, Malnad College of Engineering, HASSAN, India
Deep drawing experiments are conducted on 304L steel sheets under the raw and modified Pongamia pinnata and Jatropha carcas as forming lubricants. A press of 250 ton capacity is used. The drawn cups are laser scanned and the wall thickness profiles & draw-in-lengths are measured. A FE model of the cups are developed using ABAQUS/ Explicit to find the friction between the die and punch for various lubricants. Results show that, cups drawn under epoxidised Jatropha oil have uniform wall thickness profile compared to Pongam and mineral oils. Around 23% higher thickness values are noticed under epoxidised Jatropha oil compared to mineral oil. However, uneven distribution of material is observed under methyl esters of Pongam and Jatropha oils. Better metal flow is found under vegetable oils mode in terms of draw-in-length. The simulation results predict low friction coefficients encountered under Jatropha compared to mineral oil.

11:30 am – Noon
Novel Bio-Based Esters for use as an Effective Replacement for Phthalates as a Seal-Swell Agent
A. Kurchan, Croda, New Castle, DE
Formulating oils with longer drain intervals and improved fuel efficiency demands low viscosity and volatility, and oxidation stability. PAO and upcoming Fischer-Tropsch process derived basestocks allow formulators and lubricant manufacturers to meet new requirements. Non-polar basestocks can cause seal shrinkage and loss of seal elasticity. Esters are very effective seal swell agents with no harmful effects on additive package stability and lubricant performance. For many years phthalate esters were materials of choice for use as seal swell agents. Multiple toxicity and environmental studies have raised serious concerns regarding eco-toxicity of phthalates. A new family of environmentally friendly esters with seal swelling efficiencies rivaling phthalates has been developed. This paper will discuss the relative efficiency of these bio-based esters compared to various seal swelling esters in static elastomer compatibility testing.

NON-FERROUS METALS I:
BIOBASED LUBRICANTS OPTIONS FOR INDUSTRY
Session 5K • Room 213

Session Chair: G. Biresaw, USDA, Peoria, IL
Session Vice Chair: P. Deneuville, Alcan, Voreppe, France

8 – 8:30 am
Biodased Products: Key Federal and State Policy and Regulatory Issues
S. Pfifferling, United Soybean Board, St. Louis, MO
The presentation will provide an overview of key federal and state policy issues related to the purchase and use of biobased products. Included will be discussions of federal and state purchasing preference requirements for biobased products; the federal labeling program for biobased products; emerging federal policies on supply chain greenhouse gas reporting; and emerging federal and state activities related to “green chemistry.”

8:30 – 9 am
Development and Evaluation of Nonferrous Stain Inhibitors
Aluminum and magnesium metals are prone to develop dark surface corrosion (stain) when exposed to alkaline metalworking fluids in machining operations. Surface active phosphorus and other chemistries are used to passivate these surfaces and prevent stain. These products are often phosphonate and phosphate chemistries. Alkyl phosphate structure was found to impact the ability of the phosphate to prevent stain. This is related not only to the ability of the phosphate to interact with the nonferrous surface but also the solubility of the additive in the metalworking formulation. The magnesium machining process is further complicated by hydrogen evolving when the magnesium reacts with high alkalinity water. The prevention of hydrogen evolution was also investigated. Performance was measured relative to industry phosphate and phosphonate controls.

9 – 9:30 am
The Development and use of Biobased Lubricants for Hot Rolling Aluminum
R. Reich, Alcoa, Pittsburgh, PA
Due to environmental concerns and the high cost of petroleum, we have developed a series of water-based lubricants that use vegetable oil rather than petroleum oil for hot rolling aluminum. These lubricants have been developed with the cooperation and help from the USDA (NCAUR) and the UI@Chicago. They have been implemented in several plants throughout the world. Their development, testing, implementation and Life Cycle Analysis will be discussed in this presentation.
9:30 – 10 am
Film-forming Properties of Vegetable Oil-synthetic Oil Blends in Elastohydrodynamic Conditions
G. Bantchev, G. Biresaw, USDA, Peoria, IL
There is a need for more environmentally-friendly and renewable lubricants that can be met by formulating lubricating blends with bio-based components. One of the most important properties of lubricants is its ability to form films between moving parts, such as those encountered in gears and bearings. In the presentation we will report the study of the viscosity and elastohydrodynamic (EHD) film thickness properties of binary blends of vegetable oils with synthetic oil. The viscosities of the blends were correlated with the predictions of existing theoretical models. The elastohydrodynamic film thicknesses were used to calculate the pressure-viscosity coefficients of the blends. The results for the pressure-viscosity coefficients are compared with the literature data for similar oils. The film thickness of the blends displayed complex dependence on the composition of the blends and could not be fully described with the existing simple models.

10 – 10:30 am • Break

10:30 – 11 am
Estolides – Ready for Commercialization
S. Cermak, National Center for Agricultural Utilization Research, USDA/ARS, Peoria, IL, J. Bredsguard, B. John, K. Isbell, LubriGreen BioSynthetics, Irvine, CA, A. Durham, T. Isbell, National Center for Agricultural Utilization Research, USDA/ARS, Peoria, IL
Estolides have shown great promise as a bio-based lubricant and are ready for commercialization. Estolides are nontoxic and biodegradable. Testing has shown estolides have increased oxidative stability over vegetable oil based lubricants and have a relatively low pour point allowing them to be used in a wide range of applications. Estolides are formed when the carboxylic acid functionality of one fatty acid links to the site of unsaturation of another fatty acid to form an ester. Estolides were derived from a number of raw material sources and evaluated. In addition, a one-pot process was performed in which the ester functionality of an estolide ester was varied. The estolide esters were converted to their corresponding hydroxy fatty acid and the degree of polymerization and iodine values were determined by GC analysis. Physical properties (pour and cloud points, viscosities, viscosity index, and color) of these estolide esters will be compared to commercial products.

11 – 11:30 am
Characteristics of Novel Renewable Base Fluid Derived from Castor Oil
G. Khemchandani, The Dow Chemical Company, Freeport, TX, D. Vinci, M. Greaves, Dow Benelux B.V., Terneuzen, Netherlands
Traditionally mineral oils have dominated the market for lubricating hydraulic equipment due to their good lubricating performance and reasonable fluid costs. However, recently environmental performance has become an important feature in Europe, and in North America, which has resulted in the appearance of environmental accreditations like the European ECO-label (2005/360/EC). A new renewable base oil has been developed to offer formulators an alternative option to vegetable oils and synthetic esters for formulating industrial lubricants and especially those which may require Eco-label accreditation. The new base oil offers a high viscosity index, hydrolytic stability and is compatible with hydrocarbon oils. The oxidation stability of the new base fluid containing an anti-oxidant inhibitor package demonstrated superior performance to commercially available canola and ester oil formulations.

8:30 – 9 am
Color Analysis of Membrane Patches using a Transmitted Light
T. Honda, H. Aoyama, Y. Iwai, University of Fukui, Fukui, Japan, A. Sasaki, Maintek Consultant, Yokohama, Japan
Degradation of lubricating oil is roughly classified into two types, one is caused by solid particles and the other is caused by oil oxidation products. Diagnosis methods for solid particles in lubricating oils have many standards and researches. However, there are few diagnosis methods for the oil oxidation products. The authors have used a RGB system to study the color of contaminants on the membrane patches after filtration of the oxidized oils. In the present paper, the new diagnosis method of the degradation level of used oils by the transmitted light and color characterization of membrane patches were discussed. As a result, we found that the transmitted light through the membrane patch can distinguish the slight difference of color due to the degradation level of oils.

9 – 9:30 am
A Field Investigation of the Behavior of Gas Turbine Oil Oxidation Products
A. Sasaki, Maintek Consultant, Yokohama, Japan, C. Galli, RIGHINI Industrial Division s.r.l., Torino, Italy
The oil temperature of modern gas turbine is relatively high. Recently what is called “varnish”, which is formed by oil oxidation, is one of the hottest problems to gas turbine oils. Such oil oxidation products are of molecular sizes and difficult to check by particle count, even when they become insoluble in oil. Recently electrostatic oil cleaners, which can remove any kind of oil insoluble contaminants regardless of particle size, have been used for gas turbine oil maintenance. The authors investigated contamination of working gas turbine oils with electrostatic oil cleaners and found that oils were clean when they were checked immediately after taking oil samples but that varnish formation became apparent two days after Varnish formation was checked by a RGB colorimetric analyzer. The findings will be useful for maintenance of gas turbine oils.

9:30 – 10 am
In Turbine Oils, Minor Ingredients can have the Biggest Impact
A. Fentress, Lubrication Engineers, Inc., Wichita, KS
This paper is going to show how minor ingredients; additives, can have the biggest affect on the oil health. Monitoring the health of in-service oil through a condition monitoring program and its test package makeup is the primary source of key identifiers when maintaining a healthy oil system. In turbine oil condition monitoring, there are quite a few testing procedures that are considered industry standards and
some that are new or optional. A group of these tests were chosen to monitor the affects of different types of additives with different functions when related to base oils and aging. Some of the tests used were: Viscosity, RULER, and Varnish Potential. Using the data produced and additive type, a lot of eye opening results can be seen and new conclusions about additives can be made.

10 – 10:30 am • Break

10:30 – 11 am
Developing a Low Varnish Turbine Oil
J. Hannon, ExxonMobil Corp, Fairfax, VA
Gas turbines in power generation and plant operations have been plagued by varnish related unit trips or no starts for years. This presentation focuses on a process to develop turbine oil to address varnish which is the major problem faced by many users of gas turbines the power generation industry. Discussion will range from researching and understanding the issue to developing a proprietary test and rig field testing.

The resulting low varnish turbine oil that was developed will offer gas turbine users greatly improved turbine reliability.

11 – 11:30 am
Optimized Oil Conditioning for Steam Turbines
As world demand for dependable power grows, turbine reliability becomes increasingly important. The presence of moisture in turbine oil, combined with catalysts like copper or iron and heat from operation can lead to oil degradation and turbine wear through a number of mechanisms: varnish and sludge formation, oil oxidation, loss of lubricity, etc. The long-term impacts include bearing wear and failure, hydrogen embrittlement, control valve failures, and additive degradation. The end result is an increase in O&M costs and the potential for costly lost production situations.

In this paper, we will use case histories from several plants to illustrate the specific challenges each faced at maintaining fluid quality and their unique sources and severity of contaminant ingress. Additionally, we will discuss the technologies employed to remediate the fluid, as well as solutions to remove contaminants as they enter the process; and then, finally, minimize the potential for ingestion.

WIND ENERGY I
Session 6A • Room 202

Session Chair: A. Greco, Argonne National Laboratory, Argonne, IL
Session Co-Chair: W. Needelman, Donaldson Co., Minneapolis, MN

1:30 – 2 pm
Investigation of Image-based Particle Shape and Size Analysis Techniques for Wind Turbine Gearbox Lubricants
S. Sheng, National Renewable Energy Laboratory, Golden, CO
W. Herguth, Herguth Laboratories, Inc., Vallejo, CA, T. Drake, Aspex Corporation, Delmont, PA
One dominant wind turbine gearbox condition monitoring technique is lubricant test and analysis. The present practice adopted by the industry appears to be real time in-line or on-line particle counts, combined with periodic off-line oil sample analysis. It is potentially beneficial for the owner/operators to have some onsite equipment, which can provide immediate machine condition information. Image-based particle shape and size analysis systems can do the job by providing not only particle counts, but also particle shape and size information. This presentation will describe three different types of image-based particle shape and size analysis techniques. Their operational principles and some analysis results obtained using wind turbine gearbox lubricants will be discussed. Their performance will be evaluated by using off-line oil sample analysis results as the benchmark.

2 – 2:30 pm
Wind Turbine Gearbox Oil Water Testing and Analysis
J. Leather, S. Halajian, J. Haspert, Castrol Industrial, Naperville, IL
Currently in the wind industry there is wide variance in oil analysis testing results for water in the predominant Wind Turbine Gear Oils. This is causing unnecessary oil changes and related high maintenance costs. This paper will examine the current methods used to measure water in gear oil. This will include the Karl Fisher Indirect Method, ASTM D 6304C and Crackle Test. We will offer solutions to provide repeatable and reproducible data that can be used by all labs and energy companies.

2:30 – 3 pm
Particle Counting, Sizing and Characterization in Wind Turbine Gearbox Lubricants Utilizing Scanning Electron Microscopy (SEM) with Automated Electron Beam and Automated Feature Analysis (AFA) Software
W. Herguth, Herguth Laboratories, Inc., Vallejo, CA
Oil analysis an important part of wind turbine gearbox condition monitoring programs. A critical aspect to the long term performance of these gearboxes is cleanliness from particulate contamination. Typically, laboratories have used automatic particle counters to determine the number and size of particles in these systems. Once number and size of the contamination was determined, there has been the question of; what are they? The logical next step was to look at the metals analysis or extract them onto a filter membrane and view them under magnification. The problem with these two approaches is; the metals analysis is often unreliable in identify larger particles and; under optical magnification it is not possible to tell for sure the makeup of the particles. This study illustrates the performance and innovative approach to resolving the aforementioned limitations on sizing and identifying particles using “Automated Feature Analysis” (AFA) software.

3 – 3:30 pm • Break
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3:30 – 4 pm
Field Experiences Using Advanced Oil Contamination Control to Increase Gearbox Life and Reliability
W. Needelman, M. Barris, Donaldson Company, Inc., Minneapolis, MN
An important strategy for improving wind turbine gearbox reliability is minimizing oil contamination. Clean and dry gear oil conservatively increases bearing, gear, and lubricant life by 2 to 5 times. Modern methods for maintaining rigorously clean and dry oil in wind turbine gearboxes include reservoir headspace management and new oil filtration designs. Quantitative relationships between contamination and component life are reviewed. An extensive set of field data is then presented for turbines operating with multiple gear oil chemistries in a wide range of environments. It is shown that gearboxes can be maintained 5-10 times cleaner (~2 to 3 ISO Codes), with similar improvements in oil dryness. Replacement intervals for advanced filter elements and related consumables were also extended beyond 12 months. In conclusion, it is shown how wind turbine gearbox life, reliability, and uptime can be significantly improved through cost-effective contamination control practices.

4 – 4:30 pm
Improving the Lubrication and Filtration of Large Wind Turbine Gearbox Components by Superfinishing
R. Benson, G. Sroka, REM Research Group, Brenham, TX
Demand for cleaner sources of energy production grows along with the global demand of energy. Renewable energy, namely wind energy, is rapidly becoming a larger portion of the energy industry. The iconic wind turbine is leading this 21st century growth. However, gears are suffering from several modes of gear failure including micropitting after only a few years of the 20-year estimated lifetime. Superfinishing works by planarizing the surface of the metal. The result is isotropic mating surfaces devoid of the metal peak asperities that interact, break away from the surface and contribute to micropitting. Hence, the lubricant can be substantially free of the additives designed to protect ground, lapped or honed gears surfaces from wear. Moreover, a finer in-line filter may be utilized to remove damaging metal debris. Results show that superfinished surfaces operate at reduced temperatures and resist micropitting even under extreme loading conditions that occur in wind turbine gearboxes.

4:30 – 5 pm
Condition Monitoring Methods and Analysis
E. Ryan, K. Dinwiddie, AMSOIL INC, Superior, WI
Wind turbine oils utilized in the past were darker, opaque oils that were heavily additized, which resulted in inaccurate oil analysis. However, with new wind turbine gear oil technologies available today, modern on-line analysis promises greater precision and predictive capabilities, garnering the ability to collect valuable data to maximize operational hours and mitigate issues before failure. The AMSOIL paper Condition Monitoring Methods and Analysis outlines the major improvements of new wind turbine oil technologies and how they significantly improve the efficiency and precision of on-line wind turbine oil-monitoring system analysis. Oil analysis and field trial data of highly specialized wind turbine gear box oils will be presented, demonstrating the increased accuracy of condition-monitoring analytics when utilizing these highly-specialized oils.

5 – 6 pm
Wind Energy Business Meeting

LUBRICATION FUNDAMENTALS VI
Session 6C • Room 204

Session Chair: X. Chen, Shanghai University, Shanghai, China
Session Co-Chair: P. Sutor, Paul Sutor R&D, Kansas City, MO
Session Co-Chair: C. Barbosa, Northwestern University, Evanston, IL

1:30 – 2 pm
Surface Characterization with Functional Parameters
A. Spencer, I. Dobryden, N. Almqvist, A. Almqvist, R. Larsson, Luleå University of Technology, Luleå, Sweden
Typically engineering surfaces are characterized with traditional roughness parameters that perform some type of height averaging over the surface. Although these parameters describe the topography of the surface none of them necessarily describe the ability of the surface to carry out its function in a tribological contact. In this study an ICE cylinder liner has been investigated. The traditional Rk parameters (based on the Abbott curve) have been calculated as well as functional ‘flow factors’ which modify the Reynolds equation to incorporate the effects of surface topography. To calculate flow factors the homogenization technique has been implemented and a full 3D contact mechanics model has been incorporated so that surface functionality in mixed lubrication can be studied. Furthermore, the cylinder liner surface has been measured with both white light interferometry and an AFM so that the effect of measuring technique on roughness and functional parameters can be investigated.

2 – 2:30 pm
A Deterministic Multiscale Method Modelling Surface Texturing Effects in Hydrodynamic Lubrication Regime
S. Pei, S. Ma, Y. Zhang, H. Xu, Theory of Lubrication and Bearing Institute, Xi’an, China
A deterministic multiscale method, finite element cell method (FECM), is presented dedicated to surface texturing hydrodynamic lubrication problem. This method uses micro-macro approach that is based on a domain decomposition into cells and interfaces, which involves the resolution of independent micro problems in each cell and transfers macro information only through the interfaces. Several partial texture models with different texture numbers were considered. Excellent agreement of pressure distribution and load capacity has been found by the comparisons among finite element method (FEM), computational fluid dynamics (CFD) and FECM results on simple texture model. Moreover, it only took FECM about 14 min to solve more than 30 thousand textures model on personal computer. Furthermore, both computing time and the storage space required for FECM were significantly reduced and the computable scale is remarkably expanded, compared with the conventional FEM.

2:30 – 3 pm
A Theoretical Investigation of Surface Texturing Effect on the Strieberck Curve
S. Pei, S. Ma, N. Shen, H. Xu, Theory of Lubrication and Bearing Institute, Xi’an, China
A mixed lubrication model, based on the load-sharing concept which assumes that the total transmitted load is carried by the asperities as well as the fluid film, is presented by which Strieberck curve can be calculated. The finite element method was employed to discretise the averaged Reynolds model[1,2] and an interpolation algorithm was employed to solve the elasto-plastic asperity contact model[3] in order to compute the contact pressure. The Newton-Raphson method was used to compute Strieberck curves at different loads. The presented method is applied to a typical partial textured slider with different
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*Patent Pending*

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**Super Azole Mix**

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The *Copper Bullet* is a unique combination of azoles (Super Azole Mix) which provides enhanced protection in aqueous and hydrocarbon systems.

### Copper Bullet Products

<table>
<thead>
<tr>
<th>Product</th>
<th>System</th>
<th>Replaces</th>
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<tbody>
<tr>
<td>Wintrol® SAM-H90</td>
<td>Aqueous</td>
<td>Solid Tolyltriazole/Benzotriazole</td>
</tr>
<tr>
<td>Wintrol® 38Na</td>
<td>Aqueous</td>
<td>Sodium Tolyltriazole</td>
</tr>
<tr>
<td>Wintrol® SAM 40(OS)</td>
<td>Hydrocarbon</td>
<td>(39); N,N-bis(2-ethylhexyl)-tolyltriazole-1-methylamine</td>
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**Hydrocarbon**

The test tube contained a conventional mineral oil, an EP additive containing 6% active sulfur and corrosion inhibitors at 250 ppm active. The test tube was held in a oil bath at 100 °C for 6 hours. Please contact Wincom for further test information.

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**Aqueous**

![Inhibitor Film Resistance to Na'ClO for Copper Corrosion at 2ppm Active Inhibitor in Solution (25°C) (LPR)](chart)

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For more information on the above test results, please contact Wincom.

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enables contact visualization and film thickness and friction experimentally simulated using an EHD tribometer that simultaneously of fatty acids that can be fully characterized. Their lubricating ability is micellar, hexagonal and lamellar phases as a function of the percentage herein, the phase behaviour of the system presents a succession of tribological behaviour, this work focuses on simplified lubricants investigate the correlation between physico-chemical properties and to their good cooling and lubrication capabilities. In order to water based lubricants are widely used in metal forming processes due to polymerisation in the casting process. Incremental wear releases lubricated cast nylon gears are discussed in terms of temperature limits of use, gear contact point Hertzian stress analyses, drive torque limits, lubricant to the interface. Guidelines for the design of intrinsically- produced by judicious choice of automatic transmission fluid additives and it has recently been shown that such additives control friction by forming appropriately-structured boundary films. However a wet clutch contains two surfaces, one steel and one friction material and it is not always clear on which surface the additives form boundary films. In this paper, the adsorption of additives and consequent friction characteristics in a wet clutch contact are investigated systematically by modifying the friction material and steel surfaces. The results provide further insight into the mechanism of the friction generated in a wet clutch.

4 – 4:30 pm
Design for Intrinsically Lubricated Nylon Gears
M. Fox, University of Leeds, Leeds, United Kingdom, H. Bradfield, L. Grice, Nylcast Ltd, Leicester, United Kingdom
Intrinsically lubricated cast nylon can be used as engineering gear materials. The material has different properties from metals and informed design is critical.

Intrinsically lubricated nylon have low friction coefficients against steel, ~0.10 or less, with higher values against each other. The lubricant is either a Gp 1+ oil or a wax hydrocarbon held within very small particles of uniform size and distribution within the nylon mass, formed before to polymerisation in the casting process. Incremental wear releases lubricant to the interface. Guidelines for the design of intrinsically-lubricated cast nylon gears are discussed in terms of temperature limits of use, gear contact point Hertzian stress analyses, drive torque limits, maximum operating speeds and output ratios and also operating life. Applications of such gears in systems such as automotive electric power steering systems and construction plant are analysed.

4:30 – 5 pm
Lubrication Mechanisms of Aqueous Fatty Acids/Diamine Lamellar Systems
H. Fay, O. Mondain-Monval, V. Ponsinet, Centre de Recherche Paul Pascal, University of Bordeaux, UPR 8641, Bordeaux, France, J. Cayer-Barrioz, D. Mazuyer, Laboratoire de Tribologie et Dynamique des Systèmes, Ecole Centrale de Lyon, UMR 5513, Ecully, France, S. Meeker, P. Le-Corne, S. Deroo, Rhodia, Centre de Recherche et Technologies d’Aubervilliers, Aubervilliers, France
Water based lubricants are widely used in metal forming processes due to their good cooling and lubrication capabilities. In order to investigate the correlation between physico-chemical properties and the tribological behaviour, this work focuses on simplified lubricants composed of ethylenediamine and fatty acids, dispersed in water. Herein, the phase behaviour of the system presents a succession of micellar, hexagonal and lamellar phases as a function of the percentage of fatty acids that can be fully characterized. Their lubricating ability is experimentally simulated using an EHD tribometer that simultaneously enables contact visualization and film thickness and friction measurements in controlled kinematic conditions. It is observed that the lubricant structure controls the occurrence of a boundary film on the surfaces while entrainment speed, contact pressure and lubricant supply clearly influence its formation kinetics. The friction behaviour is also investigated.

5 – 5:30 pm
Ultrasound Reflection Technique for Measuring Film Thickness in the I-EHL Regime
D. Gasni, Andalas University, Padang, Indonesia, K. Wan Ibrahim, R. Dwyer-Joyce, University of Sheffield, Sheffield, United Kingdom
This paper describes the application of ultrasound reflection techniques to investigate oil film thickness in I-EHL regime. The reflection of an ultrasonic pulse from the interface was recorded from a range of bulk lubricated and dry conditions. The reflection coefficient approaches a minimum value, when the perfect contact has been formed. So, this method can be used to determine the speed of sound of the rubber sphere, if the speed of sound of Perspex is known. Absolute film thickness results, and also profiles of film thickness in the sliding direction were recorded for a range of load and sliding speed cases. Even though the spatial resolution of the method is relatively low, the profiles show a constriction in exit region. Cavitation could be seen in outlet region at the higher speeds. Measured oil film thickness trends were found to be significantly lower than those predictions by I-EHL theoretical solution, but consistent with other published experimental data.

MATERIALS AND NANOTRIBOLOGY JOINT SESSION: IN-SITU TECHNIQUES, MODELING AND MULTI-SCALE PHENOMENA
Session 6D · Room 205

Session Chair: R. Carpick, University of Pennsylvania, Philadelphia, PA
Session Co-Chair: T. Haque, ExxonMobil Research and Engineering Company, Annandale, NJ

1:30 – 2 pm
In-Situ Microtribology of Soft Materials
J. Vail, W. Sawyer, University of Florida, Gainesville, FL
Elastomeric materials are commonly used in a variety of engineering applications, including biomedical and automotive parts. The design of a novel tribometer allows in situ measurement of the microtribology of soft materials. During an experiment, real time optical images are obtained, providing insight into the contact of the pin on the substrate. In particular, changes in the contact area during testing and under varying conditions are observed. A variety of elastomers will be studied to garner a better understanding of the performance of these materials. The friction coefficient, contact area and break load force of each material will be reported.

2 – 2:30 pm
In-Situ Characterization of Nanoscale Wear of Sharp Silicon Asperities
T. Jacobs, R. Carpick, University of Pennsylvania, Philadelphia, PA
Nanoscale wear is a primary limitation of devices such as micro-/nano-electrical mechanical systems, and a better understanding of the physics of wear would allow the development of rational strategies for controlling it. In prior work, we have demonstrated the ability to characterize single-asperity wear with a high degree of precision by performing in-situ wear tests inside of a transmission electron microscope. In the present study, silicon probes of different initial radii have been tested by sliding against a-flat diamond punch. The shape evolution and volume loss due to wear allow insights to be gained about the kinetics of atomic-scale wear [1]. Additionally, periodic

2:30 – 3 pm
Tribochemical Surface Monitoring of Tantalum in an In-Situ Electrochemical Atomic Force Microscope
D. Huitink, F. Gao, K. Wang, H. Liang, Texas A&M University, College Station, TX
An AFM based technique for observing in situ tribochemical nano-scale surface transformations was demonstrated on polycrystalline tantalum. This technique allows for determination of surface wear concurrently with surface property changes during rubbing processes as well as combined rubbing and electrochemical reactions. Oxidation experiments were carried out in aqueous KCl. The evolution of the Abbott-Firestone curve throughout the electrochemical-mechanical stimulus was characterized for determining the surface property variation during measurement. Corollary electrochemical and XPS were conducted to verify the surface reactions on multiple scales. The understanding of surface reactions under chemical-mechanical stimuli is important for divulging the nature of contacting materials in corrosive environments; and furthermore, the ability to measure these interfacial transformations in various material systems makes this understanding available to tribologists and lubrication engineers.

3 – 3:30 pm • Break

3:30 – 4 pm
Development of an Instrument for Studies of Charged Triboemission Transport in Gas Atmospheres
G. Molina, Georgia Southern University, Statesboro, GA, C. Kajdas, Warsaw University of Technology, Plock, Poland, A. Kulczycki, Air Force Institute of Technology, Warsaw, Poland
The authors carried out extensive research on the triboemission of electrons, charged particles and photons from sliding contacts under high vacuum. But the dynamics of charged emission and their transport in controlled gas atmospheres is still to be investigated. Research is presented on the design, development and testing of an instrument to detect charged emissions in controlled atmospheres and gas flows. This work also includes a review of most relevant literature in the topic, and advantages and disadvantages of the technique are discussed, particularly to characterize charged and correlated photon emission. The authors plan to use this instrument for further investigation of possible mechanisms of low-energy plasma formation, and to study feasibility of employing such triboemissions for monitoring surface phenomena, or as precursor signals for material failure.

4 – 4:30 pm
Atomic Stick-slip Friction Studied by Optically-matched Experiments and Simulations
Q. Li, R. Carpick, University of Pennsylvania, Philadelphia, PA, Y. Dong, A. Martini, Purdue University, West Lafayette, IN
The atomic stick-slip behavior of a platinum tip sliding over a gold (111) surface is studied both experimentally and through optimally-matched accelerated molecular dynamics (MD) simulations. In experiments, clear stick-slip friction is measured using an atomic force microscope in an inert, dry environment. We observe a logarithmic dependence of the energy dissipation on velocity, which can be well described by the Tomlinson-Prandtl model with thermal activation. The measured barrier height and potential shape are consistent with those obtained from MD simulations yet the attempt frequency is vastly different. We attribute the disparity to the drastic difference in the vibrational characteristics of the two systems. In experiments, we also observe significant modulation of friction on a reconstructed gold surface. By comparison with MD simulations, we will discuss how the buried interface affects stick-slip and energy dissipation during sliding on the reconstructed surface.

4:30 – 5 pm
Atomic Stick-slip Friction Studied by Optimally-matched Simulations and Experiments
Y. Dong, A. Martini, Purdue University, West Lafayette, IN, Q. Li, R. Carpick, University of Pennsylvania, Philadelphia, PA
Atomic-scale stick-slip friction of platinum on gold (111) surface is quantitatively studied both experimentally and through optically-matched accelerated molecular dynamics (MD). The Parallel Replica Dynamic Method (ParRep) is used to accelerate the simulation so scan velocities can be decreased to scales approaching those used in atomic force microscope experiments. A logarithm dependence of friction on scanning velocity is observed both in experiment and simulation, and its underlying mechanism will be discussed. Moreover, in order to make a direct comparison between simulation and experiment, many other factors are matched as closely as possible, such as misalignment, size effect of the tip, cantilever compliance, normal load and so on.

5 – 5:30 pm
Study of Friction on Graphene Using Simulation
A. Udupa, A. Martini, Purdue University, West Lafayette, IN
Using molecular dynamics simulation, we have studied the frictional characteristics of atomically thin graphene sheets. A model capable of capturing non-bonded interactions as well as the forming and breaking of covalent bonds has been used. The phenomenon of superlubricity was observed under certain conditions while stick-slip motion was observed in most other cases. The maximum friction was found to increase as the number of graphene layers decreased, as has been observed before experimentally. Various theories suggested to explain these behaviors have been evaluated based on visualization of the simulation as well as numerical evidence. The model has been used to further predict the dependence of friction on other properties including contact size and material.

5:30 – 6 pm
Nanotribology Business Meeting
SEALS II
Session 6E  •  Room 206
Session Chair: T. Lai, John Crane, Morton Grove, IL

1:30 – 2 pm
Mixed EHD Analysis of Lip Seals Based on Measured Seal Surfaces
Y. Liu, B. Yang, General Motors, Pontiac, MI, P. Sharma, General Motors India Technical Center, Bangalore, India, F. Shi, General Motors, Pontiac, MI
Surface roughness plays an important role in a successful rotary lip seal. Currently computer modeling based on mixed elasohydrodynamic (EHD) lubrication is able to predict the surface deformation, contact area as well as the reverse flow rate, etc. However, most simulations were based on assumed or computer generated surface roughness. We present the simulation results with measured real rough lip surfaces. The measured surface is extracted into two parts: a macro geometry and a micro roughness. The macro geometry is used to determine the contact load from a contact analysis due to interference fit. The micro roughness is directly incorporated into a static mixed EHD solver to simulate the mixed lubrication behavior of the seal. Results for a typical transition seal reveals the roughness effect on the performance of the seal, especially reverse flow rate and frictional loss.

2 – 2:30 pm
1 kW Less Friction Due to Textured Sliding Faces
L. Hoel, University of Stuttgart, Stuttgart, Germany, C. Pflueger, SB LiMotive, Stuttgart, Germany, W. Haas, University of Stuttgart, Stuttgart, Germany, A. Laage, M. Heine, Konzelmann GmbH, Loechgau, Germany
Lot of transmissions have a hydraulic actuator on a rotating shaft. In order to supply these actuators, hydraulic oil must be transferred from the housing into the rotating shaft. It is demonstrated that with a structured sliding face of the sealing contact it is possible to achieve fully hydrodynamic lubrication. The results are a much lower friction – 1kW less power loss per seal – and lower wear. The shape/dimensions of the structures were developed by fluid film calculation in the sealing gap. The first prototypes for the proof of concept of structured seals were produced by a time consummating and therefore costly laser texturing. Konzelmann as a specialist in high performance plastic parts took over the know how of suitable structures and developed a manufacturing method to realize such structures on sealing faces by injection molding. So the benefit of power saving structures could be integrated in a large-lot manufacturing process.

2:30 – 3 pm
Mechanism of Combined Coning and Waviness Mechanical Face Seal for Nuclear Reactor Coolant Pump – Theoretical and Experimental Research
X. Wang, Y. Liu, J. Li, W. Huang, Y. Wang, The State Key Laboratory of Tribology, Beijing, China
Combined coning and waviness mechanical face seal, characterized by circumferential waviness superimposed on coning seal face, works as a noncontact seal on hydrodynamic and hydrostatic effect. An FEA research into sealing film based on the shaft seal of a nuclear reactor coolant pump under laminar flow assumption is presented. The mechanism of combined coning and waviness mechanical face seal is achieved. The theoretical results show that hydrodynamic effect and hydrostatic effect do not work simultaneously: the former plays a lead role under normal working condition and the latter contributes to the lifting force only when cavitations occur. A test rig is built, and model tests in different operating conditions are conducted. Consistent with the experimental results, the theoretical conclusions are testified. Due to the hydrodynamic effect, the seal keep noncontact under a certain of abnormal working condition. Thus the reliability is ensured and the operating life is prolonged.

3 – 3:30 pm  •  Break

3:30 – 4 pm
Factors Affecting Performance of Mechanical Seals in CANDU Reactor Shutdown Cooling Pumps
G. Staniewski, K. Ellison, R. Ben-Shlomo, Ontario Power Generation, Pickering, ON, Canada
The shutdown cooling pumps (SDC) are primarily used during CANDU reactor cooldown operation to remove heat from the nuclear reactors and transfer it to the high pressure service water open system. This paper will present typical failures of the seal components including ring cracking, formation of erosion groves, pitting, scoring, dynamic O-ring extrusion and excessive deposits on the seal faces. The effect of Heat Transport heavy water chemistry initiating crevice corrosion, SDC pump operating modes, inadequate seal cooling during reactor shutdown operation and pump condition will be discussed as the main factors affecting seal performance. Finally, the effect of implemented operational changes on the seal performance will also be presented.

4 – 4:30 pm
A Mixed Thermoelastohydrodynamic Lubrication Analysis of Mechanical Face Seal by a Multiscale Approach
A. Nyemeck, N. Brunetièreme, B. Tournier, University of Poitiers, Poitiers, France
This paper presents an improvement of a previous multiscale approach used to model the mixed lubrication in a mechanical face seal. The physical mechanisms considered by the improved model are surface roughness effects on the fluid film lubrication, thermal deformations and heat transfer in the seal ring due to the viscous and dry frictions. The developed numerical model incorporates the pressure distribution by taking account of cavitation and asperities contact. The heat transfer and deformations are computed from the heat dissipated at the seal interface by a finite element technique. The multi-scale model significantly reduces computation time whilst maintaining the accuracy of the results. Results obtained through a parametric study show that there exist different operating zones where the lubricating film thickness is controlled by the roughness height or so by the thermal effect.

4:30 – 5 pm
Optimization of Face Groove Parameters Based on an Integrated Performance Parameter for Dry Gas Seals
W. Huang, Y. Wang, Z. Gao, S. Suo, Tsinghua University, Beijing, China
In this paper, a dimensionless Integrated Seal Performance (ISP) parameter is proposed to estimate the performance of dry gas seals from a comprehensive view. The ISP parameter is composed by film thickness, film stiffness, and leakage rate in the force-balance state. Numerical simulations are performed to obtain the ISP parameters of three typical face groove types: classical spiral groove, modified spiral groove and V-shape groove. The influence of groove geometric parameters on the ISP is investigated. Using the ISP parameter as the objective, the groove geometric parameters of the three types of grooves are optimized with a global optimization algorithm. It is found that among the three groove types, the modified spiral groove has the best ISP and V-shape groove is worse than the other two in ISP. The ISP parameter provides a criterion to select groove type and an objective to design the groove parameters.

5 – 5:30 pm
Seals Business Meeting
TRIBOTESTING II
Session 6F • Room 207

Session Chair: G. Krauss, University of Michigan, Ann Arbor, MI
Session Co-Chair: A. Segall, Pennsylvania State University, University Park, PA

1:30 – 2 pm
Nanoscratch Test for Magnetic Recording Disks
T. Karis, F. Rose, Hitachi Global Storage Technologies, San Jose, CA
Magnetic recording disk tribology continues to be challenged by the demand for thinner disk lubricant and overcoats. Precise measurements of nanoscale friction and wear enable design of reliable interfaces to meet the new requirements. We describe the development of a nanoscratch test for this purpose. Scratch tests were performed on magnetic recording disks using a series of spheroconical diamond indenters with tip radii from 1 to 10 μm, and corresponding maximum load from 0.5 to 100 mN. Over this range, the residual indentation changed from mostly plastic flow of the underlying magnetic layers to a little plastic flow with overcoat wear. The residual indentations are characterized by peak force quantitative nanomechanics (PF-QNM), a mode of atomic force microscopy which simultaneously measures deformation, adhesion, and modulus image data along with surface height. This extra information provides unique insight into the tribophysics of the scratch mechanism.

2 – 2:30 pm
Tribological Behavior of Different Thin-film Coatings
N. Demas, A. Navratil, O. Ajayi, Argonne National Laboratory, Argonne, IL, I. Shareef, Bradley University, Peoria, IL, G. Fenske, Argonne National Laboratory, Argonne, IL
Hard coatings are commonly used in a variety of applications. In this work, the tribological performance of five commercially available thin-film coatings was evaluated under reciprocating test conditions. TiAIN, CrN, TiN, TiCN and a-C:H:Me were deposited on case carburized and hardened 4118 steel substrates that were tempered at three different temperatures. Tests against 52100 steel balls were performed at room temperature under both dry and lubricated conditions using PAO10 basestock lubricant. The coatings were characterized using optical microscopy and profilometry, their nanomechanical properties were measured and their performance was rated in terms of friction and wear. The a-C:H:Me coating showed the least wear under both dry and lubricated conditions, while the TiCN exhibited the most severe wear. The damage on the ball was also assessed. The lowest ball wear was observed against the a-C:H:Me coating while the highest ball wear was observed against TiAIN.

2:30 – 3 pm
Evaluation of Sliding, Reciprocating, and Fretting Wear of Self-lubricating Coating Created by High Velocity Particle Consolidation
A. Segall, I. Smid, The Pennsylvania State University, University Park, PA, T. Eden, Applied Research Lab, University park, PA, L. Stark, The Pennsylvania State University, University Park, PA
A new method of coating deposition known as the High Velocity Particle Consolidation (HVPC) or Cold-Spray was developed to avoid the problems associated with traditional thermal spray methods such as HVOF and Plasma. In fact, HVPC is a promising lower-temperature spray method that rapidly and efficiently creates a coating through a process related to friction welding by exposing a substrate to a high-velocity jet of solid-phase particles. The unique and very practical feature of HVPC is that the solid-phase particles are accelerated by a supersonic jet of gas at temperatures well below the melting temperature of most materials including solid lubricants. Currently, Ni with boron nitride systems are currently under study and optimization with promising results in terms of reduced wear and friction. While the results are promising thus far, evaluating HVPC coatings do present a number of interesting tribotesting challenges given their unique properties and anticipated wear regimes.

3 – 3:30 pm • Break

3:30 – 4 pm
Study of Friction in Military Braking Systems
E. Jun, Director General Major Projects Delivery, Ottawa, ON, Canada, H. Benabdallah, K. Khayati, Royal Military College of Canada, Kingston, ON, Canada
The Canadian Army introduced additional armour and protection on its Light Armoured Vehicle III (LAV III) fleet in an effort to enhance survivability. The unintended consequence of this modification was the increase in braking distance due to heavier load. The purpose of this study was to determine if changes in coefficient of friction within the components of the LAV III braking system has an impact on the increase in the braking distance. An experimental procedure was setup at the Royal Military College of Canada (RMC) to replicate the dynamic loading of the LAV III braking system. Sample specimens representing the LAV III brake lining and drum were used to measure the coefficient of friction. Analysis of the experimental result proved that the dynamic normal loading nature of the LAV III braking system decreased the kinetic coefficient of friction under certain conditions.

4 – 4:30 pm
Causes and Implications of Data Variability in Basic and Applied Tribotesting
P. Blau, Oak Ridge National Laboratory, Oak Ridge, TN
Tribotests are conducted for a variety of reasons, ranging from basic research in tribophysics to the selection of materials, lubricants, and coatings for specific applications. The effective utilization of tribotest data depends on understanding the limitations of the test methods themselves. Sources of variability include deviation from standard protocols, inconsistent specimen preparation and cleaning, the skill of the operator, the design of the apparatus, and variability in the specimen materials or lubricants. When conducting and planning tribotests, the number of replicate experiments required depends on the type of wear, the regime of lubrication, and the uniformity of the materials of interest. Perspectives gained from the development of ASTM tribotesting standards will be used to discuss test-to-test data variability, as well as the relationship between bench-scale test data and the performance of the same materials and lubricants in engineering components.
4:30 – 5 pm
Micro-scratch Testing for Adhesion Study of Diamond-Coated Tools
K. Chou, P. Lu, The University of Alabama, Tuscaloosa, AL; X. Xiao, M. Lukitsch, General Motors R/D Center, Warren, MI

Despite of significant advances in diamond deposition technologies that can produce superior tribological properties, coating-substrate adhesion remains the major challenge to substantially extend tool life, and understanding the interface characteristics are of primary interests to coated-tool makers and users. In this study, a micro-scratch tester was applied to evaluate the adhesion of diamond coated carbide tools. Forces, acoustic emission (AE) signals, and depth of the scratch were acquired. Scratch marks and delamination areas were examined by white-light interferometry. The results indicate that the onset of delamination can be clearly captured from the force and AE signals. Though scratch testing may indicate critical loads for delaminations, the interface characteristics cannot be directly applied to evaluate interface behaviors under tribological loading. A finite element model was developed to simulate the scratch process with the interface modeled by a cohesive zone.

5 – 5:30 pm
TriboTesting Business Meeting

GEARS II
Session 6H • Room 210

Session Chair: A. Kahraman, The Ohio State University, Columbus, OH
Session Co-Chair: S. Li, The Ohio State University, Columbus, OH

1:30 – 2 pm
Lubrication of Industrial Gears with Synthetic Gear Oils
W. Bartz, Technische Akademie Esslingen, Ostfildern, Germany

The energy consumption of gears depends on their efficiencies which itself are strongly influenced by the power losses by friction between meshing gear flanks. This friction depends mostly on the sliding speed on the flanks, which itself is governed by the friction reducing properties of the gear oils. At given speeds and sizes of the gears worm and hypoid gears are characterized by higher sliding speed compared to spur and bevel gears. Therefore the efficiency influence of lubricants is more pronounced for worm and hypoid gears than for the other gear types. It can be shown that certain synthetic base fluid based gear oils exhibit the following effects: less pronounced viscosity decrease with increasing temperature, higher oxidation stability, less friction losses under mixed film conditions, flow behavior, higher oxidation stability resulting in longer oil change periods, 1.3% higher efficiency resulting in fuel consumption reduction of up to 0.5%.

2 – 2:30 pm
Influence of Aerated Lubricants on Gear Churning Loss – An Engineering Model
G. Leprince, C. Changenet, Université de Lyon – ECAM de Lyon, Lyon, France; F. Ville, P. Velex, Université de Lyon – INSA de Lyon, Villeurbanne, France; C. Dufau, PSA, La Garenne-Colombes, France; F. Jarnias, TOTAL, Solaize, France

It is assumed that churning losses can be described by using only the density and the of the lubricant. A number of transient measurements were carried out on a specific gear test rig over a range of oil temperatures. It appears that, for high temperatures and/or high rotational speeds, the drag torque can suddenly increase with an increasing Reynolds number. Extensive on-line lubricant aeration measurements were conducted showing that this particular behavior can be related to churning losses when the fraction of air in the lubricant reaches a certain threshold. In order to quantify the influence of oil sump aeration on churning losses, a simplified original model, based on surface tension and lubricant aeration is proposed. This study shows clearly that density and viscosity are not sufficient to estimate churning losses under some specific operating conditions and emphasizes the need to account for other physical properties of the lubricant.

2:30 – 3 pm
Experimental Research on Reasonable Lubricant Quantity for Transmission Gears Used in High-speed Train
L. Ying, Z. Xiangjun, W. Xiaohong, Z. Yiming, M. Yonggang, The State Key Laboratory of Tribology, Beijing, China

Anti-agglutination performance of four kinds of lubricating oil for transmission gears used in high-speed train (350km/h) were tested by an improved FZG standard gear tester in order to decrease the failure probability and the cost of gear maintenance. Load of agglutination, temperature on gear surface during rotation and transmission efficiency were measured under different lubricant volume levels. The results showed that the influence of lubricant quantity on the anti-agglutination performance is distinct. The excellent oil quantity can be found by testing and going with analysis according to ISO criterion. Also, the reasonable lubricant quantity is given for certain working condition.

3 – 3:30 pm • Break

3:30 – 4 pm
Gears Business Meeting

SURFACE ENGINEERING II
Session 6I • Room 211

Session Chair: N. Demas, Argonne National Laboratory, Argonne, IL
Session Co-Chair: D. Schall, Oakland University, Rochester, MI

1:30 – 2 pm
Tribological Evaluation of Surface Texturing used in Air Conditioning and Refrigeration Compressor Surfaces
A. Polycarpou, S. Mishra, University of Illinois, Champaign, IL

Environmental regulations are necessitating the replacement of hydrofluorocarbon with alternative natural refrigerants for air conditioning and refrigeration compressors. Miscibility issues between the lubricant and refrigerant could lead adverse effects on the efficiency of the system. Thus, advanced material systems like surface coatings are being explored to develop oil-less compressors. Surface texturing is a promising method to improve tribological performance and has been successfully applied in other engineering applications but not compressors. Under boundary/mixed lubrication conditions, they act as micro-reservoirs of lubricant. Under dry sliding conditions, they can trap wear debris. The aim of this work is to conduct a feasibility study on the use of surface texturing to improve the tribological performance under unlubricated and mixed/boundary lubricated conditions in the presence of environmentally friendly refrigerants.
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Helping Customers Innovate, Improve & Grow
2 – 2:30 pm Diamond-coated Tools with Different Etching Treatments – Delamination Characteristics and Machining Performance
Chemical etching to remove surface cobalt is a common practice for CVD diamond coating on carbide tools. Though low-cost, the control of material removal process is lack of precision and uniformity. Thus, variations in tool performance may be significant. In this study, both conventional etching (CE) and electrolytic etching (EE) methods were tested. After etching, diamond films were produced by a high-power microwave plasma-assisted CVD process. Machining of metal matrix composite bars was used to evaluate differently etched tools. During machining testing, the cutting inserts were periodically inspected by optical microscopy to measure flank wear-land. The preliminary results show that (1) the coated EE tools have smaller delamination area under indentation loads, (2) The coated EE tools have smoother surfaces, and (3) the EE tools have less flank wear and a longer tool life compared to CE tools, though with the same wear patterns.

2:30 – 3 pm Developments in Frictional Property by Micro-scale Dimples
A. Amanov, J. Kim, Y. Pyun, G. Choi, Sun Moon University, Asan-si, Republic of Korea, S. Lee, J. Im, ILJIN GLOBAL, Seoul, Republic of Korea
The evaluation of surface texturing on tribological characteristics is often performed by pin-on-disc measurement. The present study deals with the frictional behavior of the untreated and UNSM-treated specimen surfaces. Various micro-scale dimpled surfaces were made by Ultrasonic nanocrystal surface modification (UNSM) treatment and its frictional results were compared to the untreated surface. Frictional studies of SAE 52100 bearing steel against silicon nitride ceramic (Si3N4) were performed using a pin-on-disc configuration under various normal load and sliding speeds in dry-, grease-, and oil-lubricated conditions. Results indicated that the coefficient of sliding friction under all conditions was lower by about 30% comparing to the untreated surface. The influence of the micro-scale dimples on friction behavior was determined and its mechanisms were explained. The main concept and effects of UNSM treatment are also explained.

3 – 3:30 pm • Break

3:30 – 4 pm Multiphase Nano-Structured Coating for Cutting Tool Application
J. Nainaparampil, A. Rai, R. Bhattacharya, UES Inc., Dayton, OH
TiAlN is the widely used material base for cutting tools. The crucial drawback of TiAlN compared to TiN is the excessive stress acquired during the deposition. To enhance the operational performance and durability of TiAlN small amount of oxidation resistant Cr, a metal with relatively high modulus and toughness can be added. In this work we report the deposition and optimization of TiAlN added with various amounts of Cr. A hybrid process of direct and filtered cathodic arc is used to select the appropriate material phase concentrations. Optimum compressive stress acquired by coatings deposited with appropriate amount of Cr and optimum deposition parameters allowed us to deposit thicker coatings with excellent adhesion. The tribological properties of these coatings are characterized along with cutting performance under both lubricated and dry conditions. XRD, SEM and AFM are used to analyze the chemical phases, microstructure and surface morphology of selected coatings.

4 – 4:30 pm Different Effects of Micro-Grooves on the Lubricated Sliding Surfaces
X. Wang, H. Yu, S. Yuan, Nanjing Univ. of Aeronautics & Astronautics, Nanjing, China
The pattern of micro-grooves is the most successful surface texture used for industrial applications. Experiments were carried out to study the effect of groove orientation on friction performance. Groove patterns with the width of 100 m, area ratio of 10%, depth of 7 m and 19 m were fabricated on the surface of cast iron by lithography and electrolytic etching technique. The orientation effect of micro-grooves on friction was evaluated by reciprocating test between a conformal contact with contact area of 20mm×20mm at different normal loads and speed conditions. The experimental data indicate that the grooves perpendicular or parallel to the sliding direction has a strong impact on the friction performance of sliding surfaces, and the merits of perpendicular or parallel orientation will swap under different contact conditions. These results were then discussed from the aspect of hydrodynamic effect, lubricant supply effect, and contact stress effect.

4:30 – 5 pm Effects of Surface Texturing on Friction and Wear Reduction Between Silicon Nitride and Steel Materials
A. Amanov, G. Choi, J. Kim, Y. Pyun, Sun Moon University, Ansan-si, Republic of Korea
In this paper, Ultrasonic nanocrystal surface modification (UNSM) treatment which generates thousands of micro-scale dimples has been applied to the disk specimens at different parameters with the aim of producing various micro-scale dimpled structures. The pin-on-disk tribotests using a ball-on-disk geometry were conducted with a silicon nitride ceramic (Si3N4) ball on SUS304 and SUS630 stainless steel disks. The main purpose of this study is to evaluate the friction coefficient and wear results of the polished and UNSM-treated specimens and to understand the effect of different micro-scale structure on tribological characteristics in dry-, grease-, and oil-lubricated conditions. Overall micro-scale dimpled disk specimens showed better tribological properties in terms of reduced friction coefficient and wear results compared to the polished surface.

5 – 6 pm Surface Engineering Business Meeting

ENVIRONMENTALLY FRIENDLY FLUIDS II
Panel Discussion-biodegradability, Environmentally Friendly Certification for Biobased Lubricants in the US and Europe and USDA Bio-acceptability
Session Chair: J. Perez, Pennsylvania State University, University Park, PA
Session Co-Chair: S. Erhan, USDA/ARS/NCAUR, Peoria, IL
1:30 – 3 pm Panel Discussion
Panelists:
J. Perez, Pennsylvania State University, University Park, PA
W.J. Bartz, Technische Akademie Esslingen, Ostfildern, Germany
S. Erhan, USDA-ARS-NCAUR, Peoria, IL
M. Miller, Terresolve Technologies, Eastlake, OH
3 – 3:30 pm • Break
Panel Discussion (continued)

5 – 5:30 pm
Environmentally Friendly Fluids Business Meeting

Non-Ferrous Metals II
Surfaces and Chemicals
Session 6K • Room 213

Session Chair: J. Cepec, The Allegheny Petroleum Products Co., Wilmerding, PA
Session Vice Chair: P. Deneuville, Alcan CRV, Voreppe, France

1:30 – 2 pm
Aluminum Sustainability – A World of Opportunity
S. Larkin, The Aluminum Association, Arlington, VA
Aluminum has long been recognized as an eminently recyclable material. In 2008 the Aluminum Association launched a Sustainability Initiative comprised of research and communication. The paper will outline significant results since the initiative launch.

2 – 2:30 pm
Herringbone Status in Aluminum Cold Rolling
P. Deneuville, Alcan CRV, Voreppe, France
The herringbone pattern on cold rolled sheets is the well-known chevron pattern alternating bright and dull markings. The most admitted origin is a local failure of the lubricant film in the roll bite. Very few papers have addressed the problem, and the real mechanism is not fully identified. According to the film thickness influencing parameters, some rough trends to get rid of it may be found.

This paper reminds the phenomenon, and the features that are generally admitted. From the mechanisms described in literature, we list all the actuators that are available on a mill. Parallel, cold rolling experiments on a laboratory pilot mill were led to provoke herringbone defects with different alloys. The rolling conditions generating those defects are analyzed and some rough trends are given. With this procedure this is possible to evaluate some actuators and to discuss those given by the literature.

2:30 – 3 pm
Analysis of Volatile Organic Content in Non Ferrous Metal Forming Fluids by Thermo-gravimetric Analysis
J. Burke, R. Blithe, Houghton International, Valley Forge, PA
California South Coast Air Quality Management District (SCAQMD) passed Amended Rule 1144 on July 9, 2010 regulating the volatile organic compound (VOC) content of metalworking fluids. Amended Rule 1144 specifies test method ASTM E1868-10 for VOC determination analysis. This ASTM method uses Thermo-Gravimetric Analysis (TGA) as the key instrument for weight loss determination of metalworking fluid samples. This ASTM method was approved in July 2010 with minimal data having been generated specific to non-ferrous metalworking fluids used in rolling, stamping, wire drawing and die casting applications. Therefore compliance to this revised Rule 1144 is not certain when these fluids are used. This paper will compare VOC aspects of various non-ferrous forming products utilizing mineral oil, vegetable oil, and synthetic ester technologies.

3 – 3:30 pm • Break

3:30 – 4 pm
Effect of Chemical Modification on Tribological Properties
G. Biessaw, G. Bantchev, J. Hoffmann, S. Cermak, USDA-ARS-NCAUR, Peoria, IL
Bioabsed ingredients possess a number of properties that makes them very desirable for applications in lubricant formulations. They also have a number of inherent weaknesses that make them less desirable in lubricant applications. Various approaches are under development or being applied to improve the inherent weaknesses of bioabsed raw materials. One of these methods involves chemical modification. In this presentation, recent efforts at chemical modification of biobased raw materials for improving certain properties will be discussed. In addition, efforts at establishing correlations between the structures of chemically modified biobased oils and their tribological properties will be presented.

4 – 4:30 pm
ESTERS: Various Methods to Identify and Quantify These Additives
P. Mortreuil, Centre de Recherches de Voreppe, Voreppe, France
Esters are the product of reaction of an acid (or a poly-acid) heated with an alcohol (or a poly-alcohol). Because they have lubricating properties in the middle of base oil and fatty alcohols they are added to oils, for hot rolling (in emulsion) or cold rolling oils (neat oil). Various esters have been early used as lubricants: they are made out of vegetal, animal, and nowadays industrial unlimited origins. The author will compare various methods to quantify esters in lubricating oils: limited infrared quantification, direct liquid chromatography, RP-HPLC. The author will compare various methods to identify unknown esters, sometimes found where they should not be: What can be identified from infrared spectrum, inside the lubricant or on aluminum sheet, what can be expected from gas chromatography and mass spectrometry. Some tricks to identify the organic acids and (much more difficult) the alcohols composing the esters will be shown.

4:30 – 5 pm
The Effect of a Water Soluble Renewable Resources Based Polymeric Lubricant Additive on the Lubricity, Misting and Foaming Potential of Metalworking Fluids that are Especially Designed for Aluminum
S. Erhan, S. Morton, S. Anderson, G. Bentley, Afton Chemical, Bedford Park, IL
Our previous studies have shown that complex, naturally derived water-soluble lubricant additives, with unique polymeric structures, have a strong attraction to metal surfaces, especially aluminum, provide good surface wetting, and excellent boundary lubrication. In addition because renewable based additives are generally larger in size and more polar with a strong attraction to each other, they give low foaming and low misting properties to metalworking fluids.

This paper is designed to show the effect of the changing molecular weight, polarity and structure of such a product on the emulsification properties, coupling properties, foaming, misting and lubricity properties of synthetic and semi-synthetic metalworking fluids.

5 – 5:30 pm
Determination of Dicarboxilic Acids in Rolling Emulsions
O. Seiferth, J. Hoffmann, B. Hansen, G. Kudermann, Hydro Aluminium Deutschland, Neuss, Germany
Oil-in-water emulsions may cause steel corrosion. Therefore, different types of corrosion inhibitors are applied. Corrosion inhibitors were selected and useful concentrations were investigated by laboratory
This paper presents the corrosion behavior of different emulsions and presents the efficiency of a corrosion inhibitor based on a mixture of dicarboxilic acids. Different testing methods for the inspection of dicarboxilic acids in service emulsions are described.

5:30 – 6 pm
Non Ferrous Business Meeting

POWER GENERATION II
Session 6L • Room 214

Session Chair: James Hannon, ExxonMobil Corp., Fairfax, VA

1:30 – 2 pm
ASTM Standard Practice & Guide Updates Impacting Power Generation

A. Wardlow, Exxon Mobil Research & Engineering, Paulsboro, NJ

Two key ASTM Standards impacting power generation are in the processes of being updated. These updates will greatly improve end user oil and system maintenance practices. This presentation will highlight these changes and offer background. These ASTM Standard Practices are as follows: ASTM D 4378 – Standard Practice for In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines; ASTM D 6439 – Standard Guide for Cleaning, Flushing, and Purification of Steam, Gas, and Hydroelectric Turbine Lubrication Systems; Updates to ASTM D 4378 offer improvements turbine oil analysis and inspection guidelines where unique tables have been established for new oil, field inspections, steam turbine oil, gas turbine oil and combined gas and steam turbine oil. Updates to ASTM D 6439 add a section dedicated to surface active flushing, a.k.a. varnish flushing. Procedure details support the effective removal of varnish in turbine lubrication systems.

2 – 2:30 pm
Counting and Sizing Sub Micron Particles in Oil Provide the Basis for Novel Correlations with Other Test Results

G. Munson, D. McCormick, Fluid Assets, LLC, Madison, CT

New technology which can count and size sub micron particles in oil provides surprising data for future correlation functions with other test parameters and results. Contamination from small Ghost particles has long been suspected of contributing to foaming and air release properties of lubricating and hydraulic fluids. These first test results seem to point the way to new data which will be able to predict incipient conditions earlier than other tests. Surprisingly these tests have a lower limit of detection near 10 nanometers in size and less than one part per billion in concentration.

2:30 – 3 pm
Sub-Micron Particles Contribute Greatly as Charge Carriers and Charge Generators in Lubricating Oil Systems, Creating More Particles: A New Technology May Prevent this from Occurring

G. Munson, D. McCormick, Fluid Assets, LLC, Madison, CT

Lubrication oil refining and formulation have changed dramatically in the past twenty years, to provide near zero sulfur products with higher thermal capacity and long term oxidation stability, according to laboratory tests. The counting and sizing of particulate in the range of 20 to 1000 nanometers simultaneously while measuring electrostatic charge at several locations in a flowing lubrication system provide a new insight into the charging mechanisms, and the results of that charging. The charging in the system creates a mechanism for creating new sub micron particles as an unintended consequence. The system under these conditions becomes regenerative with small particles carrying electrostatic charges creating more very small particles, creating more charges. A new technology holds promise of providing a solution for some of these issues by preventing the generation of new particles eliminating the regenerative cycle.

3 – 3:30 pm • Break

3:30 – 4 pm
Modern, Ester-based Hydraulic Fluids for Power Generation

N. Broekhof, Quaker Chemical, Uithoorn, Netherlands, P. Skoog, Quaker Chemical, Conshohocken, PA, R. Knecht, Quaker Chemical, Uithoorn, Netherlands

In recent years, hydraulic fluids based on modern, synthetic polyol esters have gained considerable attention in Power Generation as an alternative for EHC fluids based on mineral oil or on phosphate esters. The typical characteristics of polyol ester-based hydraulic fluids – such as viscosity index, oxidation stability, seal-and metal compatibility, fire resistance and lifetime – will be presented. Further, a comparison will be made between mineral oil-, polyol ester – and phosphate ester-based hydraulic fluids with respect to fire resistance, environmental impact, maintenance requirements, and fluid costs.

4 – 4:30 pm
Steam Turbine Lubricant Development: A Case Study Approach

W. Hewson, Ontario Power Generation, Pickering, ON, Canada, G. Staniewski, University of Western Ontario, Samia, ON, Canada

A case study of steam turbine lubricant performance at Ontario Power Generation resulted in new lubricant technology with greatly extended oxidation life. RPVOT life was decreasing 50% within the first few months of lubricant service, rapidly approaching the lower acceptable limit of 70 minutes. New technology avoided this rapid loss of RPVOT life and was rigorously tested in service for an extended period. Frequent monitoring for 8 years showed the new lubricant maintaining an RPVOT life between 500 and 600 minutes, slightly less than the unused lubricant life of 600 minutes. The previous short RPVOT life was attributed to the hydrolysis of important additives and subsequent evaporative loss of the low molecular weight hydrolysis product fragments.

4:30 – 5 pm
Power Generation Business Meeting