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Tuesday Overview

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

Beverage Breaks are scheduled at 10 am and 3 pm daily.

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

**Tuesday, May 8, 2012**

**Registration** (6:30 am – 5 pm)
Lobby Area Registration – Room 106

**Speakers Breakfast** (7 – 7:45 am) – 240-242

**Commercial Exhibits and Student Posters**
9:30 am – Noon – Exhibit Hall 1
(Noon – 2:00 pm – Closed for President’s Lunch)

**Technical Sessions** (8 am – Noon)
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- **3B** Tribotesting I – 224
- **3C** Lubrication Fundamentals III – 225
- **3D** Metalworking Fluids III – 226
- **3E** Environmentally Friendly Fluids III – 230
- **3F** Biotribology I – 231
- **3G** Engine & Drivetrain II – 232
- **3H** Commercial Marketing Forum III – 100
- **3I** Wind Tribology I – 101
- **3J** Synthetics & Hydraulics I – 102
- **3K** Seals III Facing Energy Related Challenges for Seals – 105

**President’s Luncheon/Business Meeting** ( Noon – 2 pm) – 221

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For more information, visit www.stle.org.
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NANOTRIBOLOGY III – NANOLUBRICATION I

Session 3A • Room 223

Session Chair: J. Choo, Petronas Research SDN BHD, Kajang, Malaysia
Session Vice Chair: M. Kalin, University of Ljubljana, Ljubljana, Slovenia

8 – 8:30 am
First-Principle Calculations of the Tribological Properties of Thin Inorganic Films on Metal Surfaces
W. Tysoe, UW-Milwaukee, Milwaukee, WI
Thin, inorganic boundary films are often deposited onto surfaces by tribocochemical reactions with lubricant additives or gas-phase lubricants. The properties of model boundary films are investigated using an ultrahigh vacuum tribometer. This strategy eliminates contamination and allows films of known composition and structure to be grown on well-characterized substrates. It is found that the presence of the inorganic films reduces friction and it is found that the friction coefficient reaches its minimum value when the surface is completely covered by a monolayer of the film. The shear properties at the sliding interface of the inorganic films are explored on different substrates and it is found that the shear strength depends on the pressure. First-principles quantum theory calculations are used to calculate the shear properties of the tribofilms and to provide insights into the molecular origins of the pressure-dependent shear strength.

8:30 – 9 am
Effects of Adsorbate Coverage and Capillary on Nano-Asperity Friction in Atmosphere Containing Organic Vapor
S. Kim, Pennsylvania State University, University Park, PA
The influence of alcohol adsorption on the nano-asperity friction of silicon oxide surfaces under equilibrium conditions was studied with atomic force microscopy (AFM). In the intermediate regime of the relative partial pressure (P/Psat) of alcohol, the friction versus applied load (F–L) curve deviates from the expected DMT behavior, while the F–L curve in dry and near saturation vapor conditions follows the DMT contact mechanics. The full analysis of the observed P/Psat dependence of the F–L data with theoretical models reveals clearly that the shear stress of the contact is governed by the coverage of the adsorbed alcohol on the surface while the friction near the critical snap-off is governed by the capillary meniscus formed at the nano-asperity contact.

9 – 9:30 am
Chemistry in Confined Geometries: Putting the Squeeze on Molecules
J. Batteas, Texas A&M University, College Station, TX
Here we have investigated how the organization of molecular layers on the sharply curved asperities found in MEMS devices impacts the resulting film integrity, and how mixed monolayer films of silane based SAMs and short chain alcohols can dramatically reduce friction in such devices. SAMs on nanoasperities have been found to uptake short chain alcohols which act to both protect the surfaces from water uptake, and to weakly trap and store alcohols within the SAM, which during shear, can be dislodged and act as a mobile lubricant during sliding contact. Using combinations of AFM, IR spectroscopy and MD simulations, the tribological properties of mixed monolayers consisting of a stationary alkylsilane SAMs combined with 3-phenyl-1-propanol on nanoscaled asperities have been explored. The interplay of high pressure, surface curvature and molecular forces, and their impact on friction in silicaasperity-asperity contacts will be discussed.

9:30 – 10 am
Bridging the Gap Between the Behavior of Single Nanoparticles at Nano-scale and Their Lubricating Properties Under Boundary Lubrication
I. Lahouij, F. Dassenoy, B. Vacher, J. Martin, Ecole Centrale de Lyon, Lyon, France
Fullerene-like nanoparticles of MoS2 and WS2 mixed as additives to base oil have already shown good friction and anti-wear properties under boundary lubrication conditions. The tribological performance of the fullerenes strongly depends on their response to mechanical stress into the contact area during friction test. The aim of this work is to establish a correlation between the behavior of single MoS2 and WS2 nanoparticles during mechanical solicitation at the nano-scale and their lubricating properties observed at macro-scale. The objective is to improve our understanding of the lubrication mechanisms of fullerenes. For this purpose, we used in situ HRTEM Nanoindentation experiments to observe in real time the behavior of individual fullerenes under pressure and ex situ characterization techniques like XPS and AES to analyze the tribofilm and HRTEM to observe wear nanoparticles after friction test.

10 – 10:30 am • Break

10:30 – 11 am
Lubrication of DLC and Steel Contacts with MoS2 Nanotubes Mixed to PAO Oil: From Boundary to Elastohydrodynamic Regime
M. Kalin, J. Kogovsek, University of Ljubljana, Ljubljana, Slovenia
Very few studies so far considered contacts other than steel in investigations of nanoparticle-assisted lubrication. We investigated the behaviour of multi-wall MoS2 nanotubes mixed to polyalphaolefin oil in steel/steel and DLC/DLC contacts. We used a ball-on-flat tribotester with a combination of sliding and rolling friction to measure the response of the system in all lubricating regimes. We obtained the Striebeck curves on the virgin surfaces and after the surfaces were well run-in. We also studied the effect of the surface roughness and came to several conclusions. In the EHD regime the nanoparticles showed no effect on the lubrication performance, whereas under the mixed and boundary conditions their influence was significant and depended on the state of the surfaces. In contrast to some other studies we noticed the tribofilm formation to be an important mechanism even on the DLC coatings. Nevertheless, the tribofilm was more influential on the steel surfaces.

11 – 11:30 am
Influence of Shearing Surface Topography on Frictional Properties of Nanoparticle-Based Lubrication Systems
M. Akbulut, Texas A&M, College Station, TX
Recent research has shown that nanoparticle-based lubrication systems (NBLS) demonstrated improved lubrication properties compared to traditional lubricants. Because of these promising results, NBLS have received increasing attention in various lubrication applications such as engines, turbines, and gears with a hope of achieving better tribological efficiency and durability. These applications involve a variety of surface properties and morphologies ranging from molecularly smooth to macroscopically rough surfaces. This presentation will summarize our recent systematic studies on how tribological properties of the NBLS depends upon the mechanical properties and characteristic length scales of vertical and lateral roughness of shearing surfaces. This work represents an important step in understanding the tribological properties of lubrication systems involving nanoparticles.
11:30 am – Noon

Tribological Properties of Nanofluids with Nano-diamond Particles

C. Novak, Oakland University, Rochester, MI, D. Kingman, University of Southern California, Los Angeles, CA, K. Stern, Temple University, Philadelphia, PA, Q. Zou, Oakland University, Rochester, MI

Friction accounts for a large amount of energy lost in mechanical systems and applications. Nanofluids, with particles less than 100 nm added to a base fluid, have been proven to be effective in reducing friction and wear. Diamond has superior mechanical, thermal, optical, electrical, and chemical properties. Therefore, nano-diamond holds a lot of promise to be used in nanofluids. The tribological properties of oil-based nanofluids with spherical nano-diamond particles with the size of 3-10 nm in diameter were investigated using a ball-on-disk friction test by varying nano-diamond concentration, sliding velocity, normal load, and disk roughness. The friction testing was performed using a UMT-2 Micro Tribometer. Wear analysis and chemical composition of disk surface were carried out using a WYKO 3D Surface Profiler and X-ray Photoelectron Spectroscopy. In general, the addition of nano-diamonds to oil leads to a reduction in the coefficient of friction but an increase in wear of the disk.

TRIBOTESTING I

Session 3B • Room 224

Session Chair: G. Krauss, University of Michigan, Ann Arbor, MI
Session Vice Chair: N. Gitis, Bruker, Campbell, CA

8 – 8:30 am

Contact Mechanics in the Nanoscratch Test for Magnetic Recording Disks

T. Karis, F. Rose, T. Suthar, Hitachi Global Storage Technologies, San Jose, CA

Nanoscratch and nanoindentation tests are being explored to study topography smoothing in the polishing of magnetic recording disks. Spheroconical diamond indenters with 10 or 20 um radius are employed to approximate the load and curvature of the polishing tape contact. The disk peak to valley roughness height is typically 2 nm. Indentations and scratches made in a series of decreasing maximum load are extrapolated to determine the remnant depth in the limit of zero load. The limiting remnant depth is approximately 1 nm, which implies plastic deformation of the surface topography. The surface topography measured before and after lightly loaded scratch or indentation is compared with the probability of plastic flow based on the surface slope and the magnetic layer and substrate modulus and hardness. The extreme cases of hard glass and soft aluminum magnesium alloy substrates are included to provide a wide range of contact pressure at comparable loads.

8:30 – 9 am

Improving Realtime Detection of Galling in Tribotests

G. Dalton, TribSys Inc., Sudbury, ON, Canada, M. Timusk, Laurentian University, Sudbury, ON, Canada

Tribotests are invaluable tools for lubricant development since many parameters can be screened with only the best candidates going to production trials. Friction force or coefficient of friction (COF) is often used as an indicator of lubricant performance with sudden increases in COF indicating galling failure. There are cases where friction does not rise suddenly but stays the same or even decreases with the onset of adhesive wear. In other cases friction rises suddenly without any signs of adhesive wear. Under these conditions the identification of the point of failure can be a subjective process. Clearly a better indicator of lubricant failure would be beneficial for the lubricant development process. In this investigation the Twist Compression Test (TCT) was instrumented with a variety of sensors and tests were interrupted to correlate surface condition with the friction data. Results show that adhesive wear can be identified in real time by sensor data features.

9 – 9:30 am

Limitation of PV Tests in Plain Bearing Material Evaluation

R. Adams, Q. Zou, Oakland University, Rochester, MI

For decades tribologists have considered the PV limit as the wear property of plane bearing materials. PV limit is defined as the maximum product of pressure and velocity at which a plane bearing material can operate. Since PV is the power per unit contact area, this seems to make sense that wear property of the material might be the limit of power that the material can process. When PV is multiplied by the coefficient of friction, the resultant is the heat generated at the contact surface. The heat then dissipates through the contacting bearing material to its mounting substrate. In this study, wear behavior of plain bearing materials were experimentally investigated. It is found that PV limit is related to the heat dissipation ability of the test equipment. Giving sufficient heat dissipation capacity to the test equipment, no PV limit would exist. Materials may operate at PVs hundreds of their published and tested limits.

9:30 – 10 am

Design of In-Situ Thermal Microtribometer

A. Bennett, K. Rowe, B. Krick, W. Sawyer, University of Florida, Gainesville, FL, D. Morris, O. Gerardin, Michelien, Greenville, SC

Frictional heating is present in every instance of contact between two surfaces. It is often responsible for much of the energy loss between two surfaces sliding against each other. Heating of a contact may also affect friction coefficient, contact area, surface hardening, softening, and wear rate. An in-situ tribometer was designed and built in order to accurately measure and analyze the temperature at contact and its effect on tribological properties. Both transient heating and steady state temperature rises have been measured using an infrared camera viewing a contact buried in a counterface of either calcium fluoride or germanium optical windows. Sliding speeds of 50mm/s to greater than 3m/s can be held while normal force loads of up to 5N with µN accuracy have been applied in experiments to measure temperature rise in polymers, elastomers, and composites between 5% and 50% of the bulk temperature at ambient.

10 – 10:30 am • Break
Session 3C • Room 225

10:30 – 11 am
Interfacial Wear Temperatures with a Receding Boundary with Implications for Tribotesting
A. Segall, Penn State University, University Park, PA
Frictional temperatures are of interest during tribotesting and materials evaluations. Unfortunately, it is very difficult to directly interrogate interacting surfaces, especially when the wear surface recedes. While remote measurements of temperature are obtainable, they only hint of the frictional temperatures unless just below the surface and vulnerable to wear. To overcome these difficulties, a least-squares enforcement of remote temperature data was used with a Direct solution (cylindrical specimen) with a receding surface to determine interfacial temperatures over time. Comparisons between the Direct and Inverse analytical solutions, as well as resulting interfacial predictions showed excellent agreement and verified the ability of the method to determine temperatures based on remote data. Stray transfer from the lateral surface of the pin, dimensions, and recession velocity clearly influenced the interfacial temperatures and has important ramifications for tribotesting.

11 – 11:30 am
Full-scale Sleeve Bearing Testing for Heavy Machinery Drivetrain Systems
B. Feng, H. Yoon, M. Ciolino, B. Beardsley, Caterpillar Inc., Moshville, IL
The working mechanism and the correlation between the design parameters and the sleeve bearing performance in the lower powertrain systems of heavy machinery are not well understood. Low speed and high pressure regime is the main challenge for such application. The standard bench-top testing configurations are not accurate in simulating real life machine operation conditions. The full-scale drivetrain testing is very expensive and time consuming. To close that gap, a test facility utilizing real-size sleeve bearings in heavy machinery drivetrain systems has been built for screening sleeve bearing designs. A series of test procedures were developed on this platform to identify scuffing limits at different pressure and speed levels. Tests were performed with a floating sleeve bearing configuration under lubricated conditions. In this presentation, full-scale sleeve bearing testing capability and scuffing PV testing procedures will be discussed.

11:30 am – Noon
Four-ball Friction Testing of Oils Using a Flow-through Test Cup for Better Repeatability and Less Run-in Time
J. Domeier, Ann Arbor Testing & Development, Inc., Ann Arbor, MI
With every four-ball test, we have a run-in period that can last ten minutes or it can go for hours, depending on the formulation. Usually we are interested in the friction value after the run-in period. When using a four-ball flow-through test cup, we can change oil on-the-fly without stopping the test machine. We can do a run-in with oil A, measure its friction, and then change to oil B and measure its friction without stopping the machine. When testing the next oil, we are testing it under already run-in conditions so we not only save time but are also comparing these oils on basically identical surfaces. Additives containing zinc, molybdenum, antimony, and amine phosphate compounds were tested using this four-ball flow-through cup system.

LUBRICATION FUNDAMENTALS III

8 – 8:30 am
A Laboratory Simulation of Composition and Structure of Diesel Soot by Treatment of Carbon Black and its Tribological Assessment
M. Patel, P. Aswath, University of Texas at Arlington, Arlington, TX
Carbon black has been used as soot surrogate to simulate the soot induced wear mechanism. Carbon black is analogous to diesel soot in terms of the turbostratic structure, but significant differences have been observed between carbon black and diesel soot in terms of its morphology, agglomeration, elemental compositions, particle sizes etc. In the present study carbon black was subjected to different treatments in an attempt to alter its chemistry and structure to simulate conditions similar to diesel soot. To evaluate, if the treatments have successfully simulated the chemistry and structure of diesel soot, various post characterization techniques such as transmission electron microscopy, Raman spectroscopy and XANES spectroscopy were employed. Tribological behavior of these treated carbon blacks was studied using four ball wear tester. Scanning electron microscope and optical microscope were used to study the mode of wear.

8:30 – 9 am
Influence of Soot Particle Size on Wear
D. Brass, M. Devine, K. Sinha, J. Bansal, Infineum USA, Linden, NJ
Today’s emission compliant heavy duty diesel engines generate a great deal of soot during the combustion process. Some of this soot ends up in the engine oil; indeed modern HDD lubricants can accumulate as much as 5-6% soot during their life cycle in the engine. Unfortunately, soot is known to promote wear at the contacting surfaces in the engine. Consequently, understanding the nature of soot and its role in engine wear is a major area of research in the lubricant industry. This paper will report on a detailed study of soot from several different engine types. In addition, since many researchers tend to use artificially produced soot or carbon black as a surrogate for engine soot in their studies, this paper will also compare and contrast the relevant properties of soot from real engines with a wide range of carbon blacks. Finally, the relationship between soot properties and wear in certain tribology tests will also be discussed.

9 – 9:30 am
Comparison of Chemistry, Structure and Morphology of Diesel Soot Extracted from Crankcase Oil of Commercially Operated Truck and Dynamometer Engine Tests
P. Aswath, M. Patel, University of Texas at Arlington, Arlington, TX
Environmental regulations to reduce the emissions using exhaust gas recirculation have resulted in higher soot level in the crankcase oil of diesel engines. Impact of soot present in the crankcase oil on the critical diesel engine components is well known. In this study soot was extracted from the crankcase oil of commercially operated diesel engine during drain interval and hence represent field conditions. Soot samples were also extracted from crankcase oil from Mack T-8A, Mack T-11, Cummins ISM, Cummins ISM, GM RFWT. The composition, structure and morphology of crankcase soot were characterized using X-Ray Absorption Near Edge Spectroscopy (XANES), Synchrotron Radiation X-ray Diffraction (SR-XRD), and High-Resolution Transmission Electron Microscopy (HRTEM). Efforts have been made to correlate the composition, structure and morphology of soot on soot induced wear.
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### 9:30 – 10 am  
**Composition, Structure and Morphology of Soot Extracted From a Mack T-12 Dynamometer Engine Test**  
*M. Patel, P. Aswath, University of Texas at Arlington, Arlington, TX*

Study was conducted to understand the effect of crankcase environment as well as combustion chamber environment on the composition, structure and morphology of soot. Soot samples were extracted from Mack T-12 dynamometer engine test. Soot sample was extracted from crankcase oil that represents effect of sump environment on the soot composition, structure and morphology. Soot samples were scraped off from piston block walls and hence represent the effect of severe conditions of combustion chamber on the composition, structure and morphology of soot. The soot was characterized using XANES, and HRTEM. This study was further extended to understand the effect of soot composition and structure on the tribofilm formation of piston ring. XANES was used to study the tribofilm formation on the piston ring and SEM was employed to characterize the wear track morphology of piston ring.

### 10 – 10:30 am • Break

### 10:30 – 11:00 am  
**Effect of Surface Velocity Directions on EHD Film Shape**  
*I. Krupka, M. Hartl, M. Omasta, Brno University of Technology, Brno, Czech Republic*

Thin-film colorimetric interferometry has been used to evaluate film thickness distribution in smooth glass-steel contacts to provide basic data on the effects of the slide-roll ratio and the direction of sliding velocity with respect to entrainment velocity. It has been observed that as the sliding velocity perpendicular to the entrainment velocity increases, the overall film thickness is reduced, and asymmetry of the film profile with respect to the direction of the entrainment velocity increases. Asymmetry of the film profile with respect to the direction of the entrainment velocity increases as the entrainment speed or the overall film thickness. When the speed of the glass disk is larger than that of the steel ball, a dimple is formed even if there is a difference in the directions between the entrainment and sliding velocities. A part of the dimple is exhausted from the EHL conjunction as the angle between the entrainment and sliding velocities approaches to 90 degrees.

### 11 – 11:30 am  
**Effects of Loading Process and Contact Shape on Point Impact Elastohydrodynamics**  
*M. Kaneta, Brno University of Technology, Brno, Czech Republic, F. Guo, J. Wang, Qingdao Technological University, Qingdao, China, I. Krupka, M. Hartl, Brno University of Technology, Brno, Czech Republic*

Elastohydrodynamic lubrication (EHL) theory is well developed and has brought about a large improvement in working performance and durability of numerous machine elements. The contact surfaces of machine elements receive two types of relative motion: tangential and normal. A majority of EHL researches have been focused on the tangential motion represented by rolling and/or sliding motion. However, in order to understand EHL characteristics more in detail, it is important to make clear the lubrication characteristics under pure squeeze motion. The purpose of this study is to understand the fundamental time-dependent behavior of the film thickness and pressure distributions under impact loading. It is elucidated what type of loading process is appropriate when the contact surfaces are subjected to impact load. Furthermore, the effect of ellipticity of elliptical contacts on the film thickness and pressure distributions is discussed.

### 11:30 am – Noon  
**Normalized Ashurst-Hoover Scaling and a Comprehensive Viscosity Correlation for Compressed Liquids**  
*S. Bair, Georgia Tech, Atlanta, GA, A. Laesecke, National Institute of Standards and Technology, Boulder, CO*

The recent move toward physics-based elastohydrodynamics (EHD) promises to yield advances in understanding of the mechanisms of friction and film generation not possible before. However, the accurate correlation of the low-shear viscosity with temperature and pressure is an essential requirement. The Ashurst-Hoover thermodynamic scaling, which has been useful for thermal EHD simulation, is normalized here in a manner which maps the viscosity of three widely different liquids onto a master Stickel plot. The master curve can be represented by a combination of two exponential power law terms. These may be seen as expressions of different molecular interaction mechanisms similar to the two free-volume models of Batschinski and Doolittle, respectively. The new correlation promises to yield more reasonable extrapolations to extreme conditions of temperature and pressure and it removes the singularity that has prevented wide acceptance of free-volume models in numerical simulations.

### METALWORKING FLUIDS III  
**Session 3D • Room 226**

**Session Chair:** R. Butler, Chemtool, Inc, Rockton, IL  
**Session Vice Chair:** G. Foltz, CIMCOOL Industrial Products LLC, Cincinnati, OH

### 8 – 8:30 am  
**Tapping Torque Study of Metalworking Fluid Systems**  
*G. Krauss, S. Skerlos, P. Roy, S. Supkar, The University of Michigan, Ann Arbor, MI*

Metalworking Fluid delivery techniques such as minimum quantity lubrication (MQL) and super-critical carbon dioxide (scCO2) have been shown to reduce the use of MWFs and to reduce the environmental impact of the machining process. Part of this improvement is the result of reducing additives required for fluid stabilization, anti-corrosion, and prevention of biological growth, and other issues which are not required for MQL or scCO2 systems. In a metal forming process such as tapping, the incorporation of an extreme pressure additive to a MWF is commonly used to reduce the forming torque required. This study investigates the performance of conventional aqueous fluids, MQL, vapor-phase scCO2, and liquid-phase scCO2 metalworking fluid delivery systems with and without EP additives in a tapping operation. The influence of MWF delivery system on the activation of an EP additive as well as tapping speed influence on the system performance will be considered.

### 8:30 – 9 am  
**Application of Universal Mechanic Tester in Tribology Tests of Metalworking/Metalforming Products**  
*Y. Zhao, Chemetall US, New Providence, NJ*

The lubrication mechanism of metalworking fluids and metalforming lubricants usually follows boundary lubrication. Lubrication film formed on metal surfaces is correlated to lubricity. An instrument called Universal Mechanics Tester has been adopted in tribology tests of coolants and lubricants. The tester can get tribology data such as COF, friction forces and torque numbers from ball-on-disk, reciprocating cutting, tapping torque, Falex, Four Ball and twist compression etc. During any tribology tests the lubricant film properties of coolants and lubricants can be simultaneously monitored by electric contact.
resistance (ECR) censor and acoustic emission (AE) censor, respectively. This presentation will focus on showing some COF, ECR and AE data from Ball-on-Disk tests of various coolants and lubricants. From these results, we can not only compare lubricities, but also get information about changes of lubricant films, which are related to the lubrication of these products.

9 – 9:30 am
An Assessment of Chlorinated Paraffin Replacements Using the Twist Compression Test
G. Dalton, TribSys Inc., Sudbury, ON, Canada, T. McClure, TribSys LLC, Valparaiso, IN
Metalworking applications prone to galling have relied on lubricants with the EP additive, chlorinated paraffin, to prevent excessive tool wear and damage, and rejected parts. Perceived environmental and health concerns continue to lead to increased regulatory burden and restrictions on chlorinated paraffins. Lubricant companies struggle to find suitable replacements for many severe operations. The Twist Compression Test (TCT) has proven to be one of the most effective laboratory tests for evaluating a lubricant’s ability to reduce galling. The test allows lubricant developers to compare formulations prior to costly and time consuming production trials. In this study the TCT is used to evaluate additives recently developed as chlorinated paraffin replacements. This paper describes strategies for evaluating chlorinated paraffin substitutes using TCT. Test results are presented for a variety of additives and provide insight for their suitability as chlorinated paraffin substitutes.

9:30 – 10 am
Gemini Surfactants: Unique Emulsifiers for Metalworking Applications
T. Oleksiak, F. Kroto, C. Kolp, M. McGuiness, B. Wessler, Lubrizol Corporation, Wickliffe, OH
Gemini surfactants have utility for metalworking operations. These surfactants are prepared by connecting two alkenyl succinic anhydrides via a bridging group. The bridging group has two sites of reaction for the anhydride groups. The resulting structures, which are anionic in nature, are salted with amines to act as oil-in-water emulsifiers. Performance of this chemistry as an emulsifier is dependent on the molecular weight of the alkenyl succinic anhydride, the bridging group, as well as the salting amine. Emulsification properties were found to be improved synergistically by blending with synthetic sodium sulfate.

10 – 10:30 am • Break

10:30 – 11 am
New High Performance Lubricity Additive for Use in the Machining of Aluminium and Steel
J. Eastwood, L. Phillips, Croda, Snaith, United Kingdom
Neat oil metalworking fluids are formulated by blending performance enhancing additives into a petroleum derived base oil, a vegetable oil or a synthetic ester. The inclusion of boundary lubricant additives in neat metalworking fluids is essential to ensure adequate lubrication between the workpiece and the tool, thereby optimizing cutting efficiency and maximizing tool life. Conventional boundary lubricants contain sulphur, phosphorus or chlorine. Esters are also used to provide some degree of boundary lubrication in neat metalworking fluids. This paper will introduce a new boundary lubricant additive. The product is based on C, H and O and is free from chemically reactive elements such as S, P and Cl, yet demonstrates outstanding friction control properties and cutting performance potential. Laboratory bench tests (Mini-traction, Reichert, Falex and Micro-tapping) will be used to demonstrate the performance of this novel product in both mineral oil and ester based neat oils.

11 – 11:30 am
The Use of Novel AAA’s (AAA alkylalkanolamines), Novel ASA/AAA (ASA Alkenyl Succinic Anhydride) Compounds and Novel AAA Based Carboxamides as Emulsifiers in Emulsion Metalworking Fluids
M. Gernon, K. Buyse, Taminco, Gent, Belgium
This talk will describe the preparation of a number of amide/ester/ammonium ASA/AAA adducts along with novel AAA based amides and structurally unique AAA’s. The reaction of alkenyl succinic anhydrides (ASA’s) with N-alkylalkanolamines (AAA’s) provides mixed amide/ester/ammonium carboxylates with good emulsifying properties. Analogous completely ammonium compounds can be prepared by pre-hydrolysis of the ASA followed by neutralization with AAA. AAA alkylanolamides can be prepared by the reaction of secondary AAA’s with carboxylic acids and/or esters. Structurally unique AAA’s can be prepared by adaptation of standard methods. A comparison of the emulsifying, corrosion inhibiting, staining and biostabilizing properties of these novel additives/emulsifiers will be presented. Formulation guidelines and economic considerations will be summarized, and the overall applicability of these materials to metalworking fluids will be presented.

ENVIRONMENTALLY FRIENDLY FLUIDS III
Session 3E • Room 230

Session Chair: B. Sharma, UIUC- University of Illinois, Champaign, IL
Session Vice Chair: D. Garbark, Battelle Memorial Institute, Columbus, OH

8 – 8:30 am
Study on Viscosity Modifiers for Biodegradable Ester Based Lubricants
D. Vargo, D. Devore, Functional Products Inc., Macedonia, OH, S. Wang, University of Akron, Akron, OH
Environmental mishaps that have occurred worldwide have resulted in an ever increasing interest in eco-friendly, readily biodegradable and non-toxic fluids as alternatives to petroleum-based products in the lubricant industry. The ester structure gives synthetic esters and natural ester oils biodegradable properties. However, the ester structure introduces significant molecular polarity into the ester base oil. The compatibility between several polymers and synthetic ester and vegetable oils were studied. Mutual compatibility requires similarities in structure of the polymer and the base oil such as the presence of double bonds and/or the presence of ester functionality. Polymers that contain ester functionality such as alkyl-diester (AD) copolymers and polymers that contain double bonds such as polybutadiene (PB) have been found to be the most soluble in a variety of synthetic ester and vegetable base oils.
**Tuesday, May 8**

**Technical Sessions**

**Session 3E**

**8:30 – 9 am**

**Property-Blending Relationships and Tribological Properties of Elektron™ Vegetable Oils**

B. Zhmud, M. Roegiers, Elektron s.a., Brussels, Belgium

Elektron™ oils are produced from vegetable feedstocks by using the Elektron process. Elektron oils exhibit a unique combination of properties: high viscosity (visc.40 = 2300 cSt; visc.100 = 260 to 300 cSt), high polarity (A.P. = 35 to 90 C), and very high viscosity index (VI. 260 to 300); and are used as lubricity and fatty oiliness additives, solvency improvers, VI improvers, sludge control agents and tackiness additives for stick-slip and chatter reduction.

The present study focuses on viscosity-blending relationships, solubility, oxidation stability and tribological performance of Elektron oils. It is shown that Elektron oils (1) have good seal compatibility in combination with various mineral base oils; (2) stabilize mineral bases against oxidation/sludge and have a strong VI boosting effect, specially appreciated in combination with napthenic products and API Group I base stocks; (3) are efficient friction modifiers acting synergistically with conventional EP additives.

**9 – 9:30 am**

**Palm-based Polyol Esters for Industrial Lubricant Applications**

D. Garbark, Battelle Memorial Institute, Columbus, OH, N. Samsodin, W. Shamsudin, S. Shahrudin, F. Yasin, Petronas, Bangi, Malaysia, H. Benecke, Battelle Memorial Institute, Columbus, OH

An effective synthesis pathway using palm-based fatty acids has been developed to produce a unique class of environmentally friendly polyol esters for use as high performance lubricant base fluids. The resulting base fluids exhibit an exceptionally good low temperature fluidity having pour points in the region of less than -40°C. The base fluids also show good thermal characteristic with flash points of above 250°C and viscosity index of above 150. Most importantly, the method used eliminates the existence of double bonds in the backbone structure of the base fluids thus making them more oxidatively stable during their service life. An inherent advantage of this synthetic method is the flexibility which allows for production of a wide range of viscosities meeting the viscosity requirements of the various lubricant applications such as engine oil, hydraulic fluid, refrigeration oil, compressor oil, gear oil, turbine oil, etc.

**9:30 – 10 am**

**Improvement of the Low Temperature Properties of Vegetable Oils using Glycerol Tris-2-Ethylhexanolate as Diluents**

S. Shah, The M. S. University of Baroda, Vadodara, India, B. Moser, Agricultural Research Service (ARS), United States Dept. of Agriculture (USDA), Peoria, IL, B. Sharma, Pennsylvania State University, University Park, PA

As the large-scale commercial manufacturing of biodiesel has led to a surplus of glycerol as co-product, so the novel use of this co-products are being hunted [1,2]. In present study, twenty-three vegetable oils (VO) were evaluated using glycerol tris-2-ethylhexanolate (GTEH) as a diluent to get better the low temperature properties. Palm oil (PO) and Epoxidized soybean oil (ESBO) have shown maximum improvements in pour points (PP) upon addition of GTEH as diluent. Maximum improvements in PP of 16 and 9°C were observed in ESBO and PO, with 50 and 25 vol % GTEH, respectively. The five VO camellina oil (CO), ESBO, PO, mid-oleic sunflower oil (MOSFO) and SFO with maximum improvement in PP were assessed further at lesser concentrations of GTEH. The distinction in PP response to GTEH is attributed to variations in the fatty acid compositions of the vegetable oils. This study reveals the feasibility of using GTEH as diluents with vegetable oils to improve their low temperature properties.

**10 – 10:30 am • Break**

**10:30 – 11 am**

**Jatropha Oil based Epoxy and Acyloxy Octadecanoic acid Alkyl Esters as Potential Lubricant Base Stocks KV Padmaja*, A Sammaiah and RBN Prasad Centre for Lipid Research, Indian Institute of Chemical Technology, Hyderabad, 500 007**

K. Padmaja, A. Sammaiah, R. Prasad, Indian Institute of Chemical Technology, Hyderabad, India

Jatropha curcas, a tropical oilseed bearing tree has attracted considerable attention as a potential source for biodiesel industry. In the present work jatropha oil was explored for its use as a feedstock for biolubricants. Jatropha oil and its fatty acid alkyl esters were epoxidised and its alkyl esters were further hydroxylated and acylated to obtain acyloxy derivatives such as 9,10-di acyloxy and 9,10,12,13- tetracycloxy octadecanoic acid alkyl ester-rich fatty acid alkyl esters. The products were characterized by spectral studies and were evaluated for lubricant properties: viscosity (7.6-14.6 cSt at 40°C, viscosity index,114-139), pour point (0-120 C), flash point (>200°C), copper strip corrosion (1a), oxidation stability (RBOOT value 5-20 min) and weld load value (> 140 Kg). These products offer great potential as lubricant basestocks for hydraulic, metal working and other industrial fluids.

**11 – 11:30 am**

**Environmental Friendly/Biodegradable Base Fluids**

S. Kaul, P. Nagendra, CSIR-Indian Institute of Petroleum, Dehradun, India

The development of a universal biodegradable base stock that could replace the conventional mineral oil base stock in the new generation of lubricants is a big challenge. To obtain a base fluid with high degree of biodegradability one has to select judiciously an appropriate processing scheme for this specific purpose. Synthetics and vegetable oil esters offer the best choice in formulating environmental friendly base fluids.

The present study addresses two basic approaches: One covers synthesis of a large number of Polyls and vegetable oil esters. The second deals with the tribological evaluation of potential candidates either as base stocks or as formulations for industrial applications. It has been observed that some of the vegetable oil derivatives can also be used as bio additives for some distinct formulations. The biodegradability and eco-toxicity results will also be addressed in detail.

**11:30 am – Noon**

**Screening of Natural Oils as Basestock for Lubricant Applications**

B. Sharma, UIUC, Champaign, IL, S. Shah, K. Doll, USDA/NCAUR/ARS, Peoria, IL, S. Erhan, Eastern Regional Research Center, USDA/ARS, Wyndmoor, PA

Natural oils offer significant advantages in terms of resource renewability, biodegradability, and comparable performance properties to petroleum-based products. Their amphiphilic character makes them an excellent candidate as lubricants. The wide use of vegetable oils is restricted due to low thermo-oxidative stability and poor cold flow behavior. This paper presents screening of various natural oils including genetically modified oils as basestock for lubricant formulations. These oils were evaluated for oxidative stability using PDSC, OSI, and PetroOR1; low temperature flow properties; friction and wear behavior; and viscosity. These parameters were correlated to their fatty acid composition. Among these natural oils, the best ones are high-oleic vegetable oils which when formulated with chemical additives, provide lubricants exhibiting improved low temperature properties, superior oxidative stability and wear properties.
BIOTRIBOLOGY I
Session 3F • Room 231

Session Chair: C. Schwartz, Texas A&M University, College Station, TX
Session Vice Chair: D. Burris, University of Delaware, Newark, DE

8:30 – 9 am
The Role of Macro-scale Surface Geometry in the Coefficient of Friction of Fingertips and Elastomers Against Textured Surfaces
C. Schwartz, M. Darden, Texas A&M University, College Station, TX

Tactile interaction with surfaces is important in product selection. Previous work has shown that friction coefficient influences tactility. Classic friction models that use adhesion and deformation work well for nominally flat surfaces, but not for macro-scale textures. It has been shown that many textured surfaces exhibit a lower coefficient of friction than smooth surfaces due to decreased contact area and that friction can be dependent on directionality. This suggests that an additional macro-scale deformation mechanism must also be considered. We investigated the frictional behavior of fingertips and elastomers sliding across various polypropylene textures. We also employed a nylon resin photopolymer to generate textures of controlled geometry in order to determine individual texture parameter contributions friction coefficient. Results show that material penetration into the texture and sliding direction with respect to texture geometry play a significant role in friction.

9 – 9:30 am
Debris Size Investigation of Polyethylene Wear
C. Schwartz, K. Plumlee, Texas A&M University, College Station, TX

Ultra-high molecular weight polyethylene has been the sole polymer bearing material in artificial joints, but these devices have limited lifespan. Crosslinking and composite fillers have been used in an effort to extend device lifetimes. Many of these methods involve unfavorable property tradeoffs. To better understand the factors affecting debris size, three different forms of polyethylene (linear low density, high density, and UHMWPE) were tested on a multi-axis tribometer. The resultant wear surfaces and wear debris were analyzed. Specific material properties, such as modulus, elongation-at-break, and viscoelastic properties were then correlated to wear rates and debris size. Markers on the wear surface, as well as debris size, shape, and fractal dimension provide insights into wear mechanisms present. These results suggest that the accumulation of plastic deformation at the wear surface is a dominant wear mechanism and plays a critical role in determining debris size.

9:30 – 10 am
Hydrodynamic Suspension of Rotary Blood Pumps with Blood Lubrication
R. Wampler, R&A Design, Loomis, CA

Mechanical circulatory assist devices (MCAD’s) using rotary pumps adapted to the pumping of blood is a rapidly emerging treatment for patients with severe congestive heart failure. Since only 2,000 donor hearts/year are available for cardiac transplantation (CT), MCAD’s could be used to treat 50,000 patients/year who could, otherwise, be treated with CT. Permanent implantation of MCAD’s requires durability exceeding 5 years and demands radical solutions to the problems of torque transmission and suspension of hydraulic rotors. Hydrodynamic bearings, using blood as the lubricant, have been employed in proven clinical designs. Adaptation of blood as a lubricant poses special challenges; including a very narrow operating temperature range and low shear levels to avoid thermal and mechanical injury to the blood. The special design considerations and analysis for adapting blood for use as a hydrodynamic lubricant are discussed and a summary of clinical results will be presented.

10 – 10:30 am • Break
10:30 – 11 am
Microscale Damage and Erosive Wear in Tooth Enamel
C. Korach, Stony Brook University, Stony Brook, NY, M. Wolff, New York University College of Dentistry, New York, NY

Enamel, the hardest substance in the human body, takes the form of a protective crown on teeth, and is a human’s only exposed hard tissue. Though enamel is a robust biological composite with a high hardness and rigidity, it is susceptible to significant localized wear in the form of cervical lesions located at the margin between the gum and crown. The etiology of the lesions is attributed to high mechanical stresses in the cervical region and the abrasion of the surface combined with erosives. The unique hierarchical microstructure of enamel plays an important role in the wear process and is studied here by instrumented microscraping and atomic force microscopy to observe the effects of erosive application on surface damage formation.

11 – 11:30 am
In-situ Studies of Cartilage Microtribology as a Novel Route to Study OA
D. Burris, E. Bonnevie, V. Baro, L. Wang, University of Delaware, Newark, DE

Osteoarthritis (OA), a degenerative joint disease associated with the degradation of articular cartilage, is the leading cause of chronic disability in the United States. OA is difficult to detect (especially in the early treatable stages), difficult to treat and poorly understood. Joint lubrication is known to be highly sensitive to the unique biphasic structure of the cartilage matrix and its fluid pressurization response to loading. It is hypothesized that local damage from early grades of OA may interfere with the natural lubrication mechanism of the material. The goal of this study is to evaluate microtribometry as a route to study OA initiation and propagation from an early stage. In this paper, we discuss the microtribological response of cartilage and its response to controlled and characterized grades of surface degradation.

ENGINE & DRIVETRAIN II
Session 3G • Room 232

Session Chair: S. Watson, Imperial Oil Ltd., Sarnia, ON, Canada
Session Vice Chair: V. Wong, Massachusetts Institute of Technology, Cambridge, MA

8 – 8:30 am
Differentiating Mono-, Bis- and Tris-Dispersant Performance in Automotive Lubricants:
Reactivities with Primary and Secondary ZDDP’s
M. Fox, University of Leeds, Leeds, United Kingdom

Differentiating the reactivities of closely related additives formulated in automotive lubricants is difficult. One approach uses an intensive engine test, a reduced volume sump VW Tdi @ 3k & 4k rpm. Hourly samples are analyzed for physical and chemical properties. The data base is then analyzed by multivariate analysis. Samples at 4000rpm are more degraded and differentiated than at 3000rpm, the bis-dispersant is the most stable. Of two bis-dispersants, the shorter chain length PIB is more resistant to degradation in the presence of the primary ZDDP. The shorter PIB bis-succinimide showed greater reactivity with the secondary ZDDP.

PLS-DA multivariates analysis applied to a data base from the intensive engine testing of closely related additives is shown to be very effective at discriminating between formulations. An application to the forensic testing of illegally produced substitutes is demonstrated.

Technical Sessions
8:30 – 9 am
The Role of Polymeric Viscosity Modifiers in Managing the Misting Properties of Automotive Lubricants
C. Dyson, M. Priest, P. Lee, University of Leeds, Leeds, United Kingdom
Several studies have identified lubricant droplets in the gas flow through the piston assembly and crankcase of an automotive engine. These suggested that this phenomenon could significantly affect lubricant transport through the piston assembly and thus impact upon engine oil consumption, emissions and lubricant degradation. However, quantification of the nature of this lubricant mist flow is lacking in the literature. It is thought that these droplets are formed, primarily, in the piston assembly, particularly at the ring gaps. This research investigated how the tendency of lubricants to form droplets varies with different additives and formulations. A bespoke laboratory rig was used to produce representative mist flows and characterise them. Polymeric viscosity modifiers with different molecular weight and molecular architecture were used to vary the rheology and molecular dynamics of the lubricant blends. The effect of these parameters on lubricant misting tendency was quantified.

9 – 9:30 am
Enhancing Friction Durability in Wet Clutch Systems Using Oxidatively Stable Esters
A. Kurchan, Croda, New Castle, DE
Continuous innovation in the design of new transmissions has led to the development of new lubricant technology for transmission fluids. With a doubling of the market share expected in the next 5 years, research into wet clutch lubrication has increased accordingly. With the industry heading towards a ‘fill for life’ DCT system, lubricant developers need to consider the long term performance of the transmission fluid. The inclusion of boundary lubricant additives to control friction is essential. Higher temperatures in the transmission require more thermally stable components to be used in the formulation of these lubricants. This paper will focus on top treating a fully formulated dual clutch transmission fluid with various esters, and will demonstrate the effect these products can have on the friction durability of a wet clutch transmission fluid. A novel laboratory bench test will be used to show how an ester dose rate of 5-15% can significantly increase the lifetime of the fluid.

9:30 – 10 am
Oil-Miscible and Non-Corrosive Ionic Liquids as Candidate Lubricant Additives
Ionic liquids (ILs) have been receiving considerable attention from the lubricants industry as potential friction and wear-reducing additives, but their solubility in oils is an issue. Unlike most ionic liquids that are insoluble in non-polar hydrocarbon oils, this study reports new ILs that are fully miscible with both mineral oil-based and synthetic lubricants. The measured viscosities of the oil-IL blends agree well with the Refutas formula for solutions containing multiple components. High thermal stability, non-corrosiveness, and excellent wettability were observed for these ILs. Effective anti-scuffing and anti-wear functionality have been demonstrated in tribological bench tests when adding 1-5 wt.% of ILs into base oils, suggesting good potential for using the new oil-miscible ILs as lubricant additives. Further more, a synergistic effect on wear protection was observed with the existing additive package when the ILs were added into a fully-formulated engine oil.

10:30 – 11 am
Coking Deposit Formation of the Mixture of Marine Diesel Engine Oil and Fuel Oil
F. Yokoyama, IHI Corporation, Yokohama, Japan
In marine diesel engines, the cleanliness of the piston is one of the important requirements in the long-term reliability. The smooth movement of the piston ring and the flow of oil are disturbed when remarkable deposits formed, and there is a possibility of causing abnormal wear and seizure failure. Therefore, proper engine oils which have good results in experimental method such as panel coking test are usually applied to engines. However, the coking deposit formation can be affected by mixing in of fuel oil. Even if excellent engine oil was adapted, the deposit formation is actually inevitable. In this study, the effect of mixture on the coking deposit formation was investigated. As a result, it was found that inflammable fuel oil promotes the deposit formation although flammable fuel oil hardly promotes the deposit formation. And the deposit formation is affected also to the mixture ratio of fuel oil.

Future STLE Meeting Dates
2012 International Joint Tribology Conference
October 8-10, 2012
Denver, Colorado
68th STLE Annual Meeting & Exhibition
May 5-9, 2013
Detroit, Michigan
69th STLE Annual Meeting & Exhibition
May 18-22, 2014
Orlando, Florida
70th STLE Annual Meeting & Exhibition
May 16-21, 2015
Dallas, Texas
71st STLE Annual Meeting & Exhibition
May 14-19, 2016
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See us in booth 317 at STLE 2012
Tuesday, May 8 Technical Sessions

COMMERCIAL MARKETING FORUM III
Session 3H • Room 100
(See page 137 for full abstracts)

8 – 8:30 am
SurfaTec Laser Solutions
Nano-Slick™ – Game Changing Green Lubrication Coating
Serge Tesker, Ph.D., President of SurfaTec Laser Solutions
8:30 – 9 am
Open

9 – 9:30 am
Sea-Land Chemical
Navigating a World of Opportunities with Sea-Land Chemical
Joseph Clayton

9:30 – 10 am
Additives International
Growing Up Fast in Additives for Metalworking and Lubricants
Gregory Jorjorian, President, Additives International;
E Jon Schnellbacher, Technical Director, Additives International

10 – 10:30 am • Break

10:30 – 11:00 am
Dover Chemical Co.
Chlorinated Paraffin Free Additives
John Nussbaumer

11 – 11:30 am
The Lubrizol Corporation
Low Foam Metalworking Fluid Emulsifier Systems: An Expanded Product Range and Future Directions
Jennifer Ineman

11:30 am – Noon
Open

WIND TRIBOLOGY I
Session 3I • Room 101

Session Chair: S. Sheng, National Renewable Energy Laboratory,
Golden, CO
Session Vice Chair: M. McKenzie, American Roller Bearing Co.,
Greer, SC

8 – 8:30 am
Sampling and Analyzing Grease From Wind Turbine Components
R. Wurzbach, L. Williams, E. Bupp, MRG Labs, York, PA
As the fleet of wind turbines continues to grow, and the goals for greater percentages of power generation using renewable sources increase, the reliability of wind turbine components becomes more important. Focus on lubrication issues has primarily been focused on the oil lubricated gearboxes, however, ten or more critical grease lubricated components in a wind turbine also can impact reliability. New tools have been developed for improved sampling techniques and grease analysis tests have been added to address concerns of sample trending as well as accommodating small sample sizes. New tests are emerging, including die extrusion and rheology, to efficiently prepare samples for analysis, including a new ASTM standard practice on grease sampling. This paper will discuss how these new technologies can produce improvements in reliability and reductions in lubrication costs through monitoring of grease condition and trending of wear levels, with samples as small as 1 gram.

8:30 – 9 am
Importance of Solid Lubricant Selection as Ingredient for Wind Turbine Greases
M. Jungk, R. Vanecek, Dow Corning GmbH, Wiesbaden, Germany
Most lubrication points of a wind turbine that are not lubricated by oil require greases and/or pastes that contain special solid lubricant packages. Pitch/Yaw Bearings need to resist to high loads and are affected by vibrations. Bearings/Gears operate in the Boundary/Mixed friction regime. Threaded Connections need to be lubricated with a constant coefficient of friction to allow the required pre-tensioning force and make best use of applied torque. Shrink Discs connect the main shaft with the gear box and are frictional connections, thus ultimate low coefficient in boundary friction is required at assembly as well as disassembly. Brakes are used to quickly prevent over speeding and to lock the shaft during maintenance operation. Reduction of friction between the back plate and jacks on each side of the caliper is required to allow safe operation.
This presentation will explore bench test results that were used to develop special solid lubricant packages for the a.m. applications.

9 – 9:30 am
Novel Boron-based Nano-lubricants for Mitigating Wear and Micropitting Failures in Gearboxes
A. Erdemir, A. Greco, K. Mistry, Argonne National Laboratory,
Argonne, IL
In this paper, we introduce an innovative ultra-nano-boron lubrication technology that can help mitigate wear and micropitting problems under the severe rolling/sliding conditions of gears and bearings in wind turbine drivetrains. When mixed with gear oils up to 1 wt.%, these novel nano-boron additives were able to eliminate micropitting on the rollers of a dedicated micropitting test rig, and at the same time greatly reduce wear of rolling/sliding surfaces. Without the additives, the micropitting and wear damage were rather extensive as confirmed microscopically and through vibration measurements using an accelerometer. Lower friction afforded by these novel additives was another positive attribute which may further improve efficiency and reduce heat build-up on highly stressed contact spots of gears. Overall, these nano-boron additives present a possible alternative to traditional EP chemistries that may have certain detrimental environmental and performance characteristics.

9:30 – 10 am
Nanoparticle-Based Lubricants to Improve Wear Resistance, Reliability, and Lubrication Efficiency of Wind Turbine Gearboxes
D. Demydov, A. Suresh, NanoMech, Inc., Springdale, AR, A. Malshe, University of Arkansas., Fayetteville, AR
Detailed investigations of advanced nanolubricants that favorably impact robust boundary tribofilm formation to reduce wear and friction in wind turbine parts such as gearboxes were conducted. These additives are designed as surface-stabilized nanomaterials that are dispersed in a formulated oils/grease for maximum effectiveness. They have been prepared for use in performance testing that closely simulates the conditions faced by lubricants and greases in wind
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turbines. Specimen of the most widely used materials in wind turbine gearboxes has been prepared for evaluation in several tribological tests to assess the performance of developed nanolubricants. These tests were used to demonstrate consistent performance meeting the demanding requirements for lubrication of wind turbine gearboxes.

10 – 10:30 am • Break

10:30 am – Noon
Panel Discussion: US Dept of Energy National Laboratory Research into Improvements in Reliability and Performance of Wind Turbine Drivetrains
Myron McKenzie, Panel Chair
The US wind energy industry has experienced steady growth over the last decade, in 2010 reaching over 40 GW installed capacity and accounting for over 25% of all new electricity generation additions. With the average size of a single wind turbine generator being just under 2 MW compared to a coal powered plant, 200-500 MW, the number generator units is significantly greater ofr generating electricity from wind energy. Other factors, including the unsteady operation and remote location of wind turbines, contribute to the high cost of operations and maintenance, and component replacement, especially for the drivetrains. With the goal to make wind energy cost competitive with fossil fueled electricity generation, the U.S. Department of Energy (DOE) has made significant investments in R&I to improve the reliability and performance of wind turbine drivetrains. This panel discussion will include representatives from DOE national laboratories active in wind turbine drivetrain R&I.

SYNTHETICS & HYDRAULICS I
Session 3J • Room 102

8 – 8:30 am
Ionic Liquids as Engineering Fluids
J. Mezger, B. Gaspar, BASF SE, Ludwigshafen, Germany
Ionic Liquids (ILs) are a new class of purely ionic substances that melt below 100°C. Some of them are even liquid at room temperature and below. The access to a broad range of imidazolium based ILs having tailor made physical properties is realized by a flexible multi plant process at BASF. ILs show remarkable physical properties that can be exploited in many high-tech engineering and functional fluids such as non-flammable hydraulic liquids, high-performing lubricants or liquid piston in gas compression. Using the examples of the industrial developments such as ionic compressor or waste heat recovery process it will be shown in the talk that ILs are valid alternatives to existing engineering fluids. Moreover, the broad range of possible chemical modifications allows us to design specific ionic liquids with the desired physico-chemical properties.

8:30 – 9 am
Tribological Properties and Solubility of Phosphonium Ionic Liquids as Lubricant Additives in Synthetic Base Oils
J. Dyck, M. Moser, A. Robertson, Cytec Industries Inc., Niagara Falls, ON, Canada, J. Clyburne, Saint Mary's University, Halifax, NS, Canada
Phosphonium ionic liquids are unique tribologically active materials that exhibit remarkable thermal stability and feature a high viscosity index. These non-volatile materials having low flammability reduce wear, exhibit high loading capacity and form effective boundary films for extreme pressure applications. The highly tunable nature of phosphonium ionic liquids provides an exceptionally diverse range of physical properties including viscosity, miscibility with base oils as well as compatibility with additives and materials. The ionic nature of the phosphonium salts also imparts electrical conductivity to the lubricant formulation. We will report bulk physical properties of the novel phosphonium ionic liquids as well as solubility data in synthetic base oils. Comparative 4-ball wear and coefficient of friction data will also be presented for synthetic formulations of phosphonium ionic liquids against those for standard EP additives.

9 – 9:30 am
Friction and Wear Reduction by Halogen-free Ionic Liquids
V. Totolin, AC2T research GmbH, Wiener Neustadt, Austria, I. Minami, Iwate University, Iwate, Japan, C. Gabler, N. Dörr, AC2T research GmbH, Wiener Neustadt, Austria
The tribological properties of halogen-free Lewis type complexes were evaluated by ball-on-disc tribotests using an oscillating steel-steel contact under boundary conditions. The special chemical compositions selected allowed the replacement of hetero-elements usually found in ionic liquids such as fluorine and sulphur. The tribological properties of these complexes were inferior to those of 1 butyl 3 methylimidazolium bis(trifluoromethanesulfonyl)amide (BMIM TFSA). The latter was chosen as a reference lubricant due to its familiarity in the field of ionic liquid tribology. The addition of a phosphorus-containing ionic liquid considerably improved the tribological properties of the Lewis type complexes. The friction and wear caused by these mixtures were even lower than those by neat BMIM TFSA and BMIM TFSA added to Lewis type complexes. XPS confirmed the formation of a phosphate based tribofilm that improved significantly the friction and wear properties of Lewis type complexes.

9:30 – 10 am
Contamination Control of Hydraulic Oils by Colorimetric Patch Analysis
A. Sasaki, Maintek Consultant, Yokohama, Japan, T. Honda, Y. Iwai, University of Fukui, Fukui, Japan, C. Yong, Focus Machinery Pte. Ltd, Singapore, Singapore
Modern hydraulic systems are controlled by servo valves, which are sensitive to oil contamination. Contamination control of hydraulic oils has been conducted by particle count method, as established standards like NAS 1638 and ISO 4406 are available. To maintain stable operations of such hydraulic systems, fine filtration has been used to oil contamination control of hydraulic oils. Then the formation of oil oxidation has been highlighted by spark discharging of static electricity during filtration. As having polarity, oil oxidation products will be adsorbed on the metal surfaces of hydraulic valves, and last chance filters and/or pencil-type filters of servo valves and cause mal-function of servo valves. As oil oxidation products are of molecular size, it is difficult to detect formation of oil oxidation products by particle count. Colorimetric patch analysis, which was developed by University of Fukui, can detect formation of oil oxidation products at an early stage.

10 – 10:30 am • Break
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See this new technology at STLE booth 403/405 or visit www.perkinelmer.com/oilexpress
10:30 – 11 am
Energy Efficient Natural Gas Engine Lubrication

Engine designs, operating conditions, customer’s needs and environmental factors place high demands on lubricants for natural gas engines. Operators are trying to reduce energy costs while improving productivity and sustainability. In many cases, a well designed lubricant can provide benefits that contribute to sustainability such as extended oil life, reduced oil disposal, energy efficiency and extended equipment life.

This paper will discuss next generation natural gas engine oil development utilizing leading edge technology that has demonstrated extended oil life, excellent piston deposit control and increased engine efficiency. This will include extensive engine durability test programs which evaluated the oil life, piston cleanliness, lube oil consumption and wear performance of gas engine oils in shop tests and field demonstrations. Next generation natural gas engine oils could significantly enhance the sustainability of natural gas fueled engines.

11 – 11:30 am
J. Souchik, Evonik Oil Additives, Horsham, PA, T. Bartels, T. Schimmel, Evonik Industries, Darmstadt, Germany, R. Iyer, Evonik Oil Additives, Horsham, PA, O. Eyrisch, Evonik Industries, Darmstadt, Germany, S. Tillery, Evonik Oil Additives, Horsham, PA

A new field trial was conducted with a medium sized, 24-ton excavator with an experienced operator. The study had three goals: a) Develop a standardized test method reflecting the typical work cycles for an excavator; b) Compare the fuel consumption and productivity of an excavator operating with a monograde hydraulic fluid, a high VI fluid with lower shear stability made using conventional free radical polymerization process and one with high VI, high shear stability made using a controlled radical polymerization process, and c) Verify findings from earlier field trials. Unlike cars or trucks, energy efficiency tests for off-highway equipment are not well-established in the industry. We devoted considerable effort to the trial design to develop a testing framework that was broad enough to include typical movements such as active digging, loading, planning and driving for a 24 ton excavator. The paper will present promising results and learning from this field trial.

11:30 am – Noon
Aspects of PAGs for Heavy Duty Equipment
Y. Marques, M. Greaves, The Dow Chemical Company – Dow Brasil Sudeste, Sao Paulo, Brazil

Large heavy duty machinery has experienced operational evolutions that demand performance improvements in lubrication systems, requiring the finest properties of fluids with the aim of optimizing equipment efficiency and minimizing wear. Polyalcohol glycols have several attractive tribology characteristics that can offer good equipment reliability including excellent friction control, anti-wear and deposit control features. Aspects of their performance will be discussed including how different polymer architectures can lead to different performance. Case studies of the successful use of these products in sugar cane processing will be discussed.

10:30 – 11 am
An Integrated Surface Technology for Seal Applications
S. Hsu, George Washington University, Washington DC

Surfaces are made to be isotropic and uniform. Mating of surfaces under lubricated conditions is influenced by roughness, lubricant, and tribochemistry. We have developed an integrated surface technology consists of surface texture, DLC film, and in some cases, bonded chemical films to facilitate the entry of stable and robust hydrodynamic lubrication regime. The talk will also discuss the use of soft masks for large area texture fabrication.

9 – 10 am
Application of Energy Saving Sealing Systems Technologies
H. Azibert, FSA, Wayne, PA

Improved technology sealing systems available today can completely eliminate the need for energy-wasting systems that result in cooling/dilution of the process and the need for downstream separation/evaporation, re-heating, and/or effluent treatment. Case studies will be presented to illustrate the points.

10 – 10:30 am • Break

10:30 – 11 am
Improved Performance of Carbides through Surface Conversion
M. Slivinski, Carbide Derivative Technologies, Inc., Tuscon, AZ

A novel conversion process for the running surface of carbides has shown dramatic performance improvements in challenging services such as flashing fluids and dry running. The process converts the carbon already sintered-into the carbide into a matrix of various carbon nanospecies. The resulting net shape, size, roughness surface is extremely low in running friction. In addition to the nanocrystalline diamond which is created in this process, graphite is also produced, providing self-lubrication. This feature provides long duration dry running capability, with extremely low surface degradation. The treatment is not a coating, and shares the same microstructure with the virgin carbide, thus eliminates delamination risk. Results of dry running, water and flashing fluid testing will be presented, along with pin-on-disc results.

11 – 11:30 am
How Face Features and Design can be used to Reduce Seal Power Consumption in Liquid Mechanical Face Seals While Maintaining Leakage Control
A. Lebeck, Mechanical Seal Technology Inc., Albuquerque, NM

Various means to design lower power face seals are being pursued. In this paper, the fundamentals of this problem are examined. What is necessary to maintain low leakage? How can a fluid film be shaped to reduce friction and yet control leakage? How does fluid film cavitation act to reduce friction and control leakage and how can it be controlled? In sealing particularly oils how does the temperature variability of viscosity enter? There are a complex set of interactions among these essential variables that are carefully examined here, and some guidelines are proposed.
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The practicality of non-contacting face seals for sealing liquids was discussed. The stability of nanofluids was analyzed by dispersion procedures and methods on the stability of oil-based nanofluids. Moreover, the effect of different conductivity is meaningful in application only if it can remain stable for a sufficient duration of time. In the paper, the effect of different dispersion procedures and methods on the stability of oil-based nanofluids was discussed. The stability of nanofluids was analyzed by measuring the particle size and the zeta potential of the solutions.

### NANOTRIBOLOGY IV – NANOLUBRICATION II

**Session 4A • Room 223**

**Session Chair:** K. Sinha, Infineum, Linden, NJ  
**Session Vice Chair:** D. Demydov, NanoMech, Springdale, AR

**2 – 3 pm**  
**Invited Presentation Nanoparticles: A Potential Additives for Sustainable Lubrication**  
**Fabrice Dassenoy, Ecole Centrale De Lyon, France**

**3 – 3:30 pm • Break**

**3:30 – 4 pm**  
**Nanolubricants Additives with Low Phosphorous Content for Oils and Greases**  
**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 behavior was performed. A low phosphorous content approach was considered for nanoparticles and their tribological performance was evaluated. These nanoparticles were specially designed for addition to oils and greases as additives for extreme pressure and high temperature applications where the phosphorous presence is undesirable by specific applications and environmental regulations. Their tribological performance showed synergistic effect when combined with others additives in formulated oils. The research efforts were focused on tribological testing of these nanoparticles, improvement of their dispersion, and investigation of their behaviors in the presence of other additives in formulated oils and greases.

**4 – 4:30 pm**  
**Effect of Dispersion Procedures and Methods on the Stability of Oil-Based Nanofluids**  
**S. Thrush, Q. Zou, J. Schall, G. Barber, Oakland University, Rochester, MI**

Nanolubricants have enhanced thermal conductivity and tribological properties in comparison with base fluids. However, the potential of a nanofluid to reduce friction and wear while increasing thermal conductivity is meaningful in application only if it can remain stable for a sufficient duration of time. In this paper, the effect of different dispersion procedures and methods on the stability of oil-based nanofluids was discussed. The stability of nanofluids was analyzed by measuring the particle size and the zeta potential of the solutions.

Aluminum oxide nanoparticles were dispersed in light mineral oil using two different methods, i.e. a 150 watt ultrasonic bath and a 400 watt ultrasonic homogenizer. Different types and amounts of surfactant were used to optimize the zeta potential of the particles and to reduce the rate of particle collision and agglomeration. Various procedures in which the nanofluids are prepared were examined to see the effect on the stability.

**5 – 5:30 pm**  
**Nanotribology Business Meeting**

### TRIBOTESTING II

**Session 4B • Room 224**

**Session Chair:** A. Segall, Penn State, University Park, PA  
**Session Vice Chair:** G. Krauss, University of Michigan, Ann Arbor, MI

**2 – 2:30 pm**  
**Tribological Evaluation under Heavy Loading of 3 Bushing Materials and 2 Greases**  
**S. Shaffer, T. Merriman, Battelle Memorial Institute, Columbus, OH, D. Grgas, The Boeing Company, Long Beach, CA**

CuBe AMS 4533B has long been used for heavily loaded, grease lubricated air frame bushings. However, environmental and health concerns are driving the replacement of this alloy in certain applications. This paper discusses the results of tribological characterization tests conducted on two alloys being considered as potential replacement materials for the CuBe alloy. Using newly developed, heavy load capability test rigs, wear tests and pressure-velocity (PV) limit tests were conducted on a CuBe alloy, a spinodal bronze alloy, and a high strength stainless steel alloy under identical test conditions. Two greases, a polyalphaolefin (PAO) synthetic base oil with clay thickener, and a petroleum based grease containing MoS2, were tested with each of the three alloys.

While the results identified a replacement material/grease combination, possibly of more general interest was the light shed on the applicability of the PV concept for metals under severe sliding/loading conditions.
2:30 – 3 pm
Keeping Your Balance: Adding Stability to Your Formulations
E. Schnellbacher, Additives International LLC, Flint, MI
From time to time, every manufacturer faces raw material shortages, price increases, or supply problems which force formulation changes. Evaluating new raw materials or process changes has always been a challenge requiring effort and expense. Is the traditional single-variable replacement approach always the best? This study looks at how and when to use computers, mathematical comparisons, spreadsheets and statistics to help build models for formulating. As an example, metalworking fluids like soluble oils, synthetics, and semi-synthetics have specific measurable characteristics related to their performance and stability. Characteristics like hydrophilic-lipophylic balance (HLB), acid/alkalinity, emulsion stability, clarity, foam, or others can be used to create models for evaluating and possibly building better formulas. This paper will look at using methods to build and test formulations in the laboratory; and whether these methods can make better, stronger and faster changes.

3 – 3:30 pm • Break

3:30 – 4 pm
Tribology Measurement Device Based on a Rheometer: Principle and Applications
F. Wolf, J. Laeuger, P. Heyer, Anton Paar Germany GmbH, Ostfildern, Germany
The study of phenomena at low velocities such as the transition from static friction to dynamic friction or the measurement of stick-slip effects as well as the film formation characteristics at increasing velocities are of great interest in tribology. A measuring device for these specific applications requires high resolution with respect to torque, speed, deflection angle and normal force. A rheometer fulfills all these demanding requirements. Therefore a new accessory for this instrument was designed allowing the use of the outstanding performance of a rheometer motor for model scale tribological measurements. The accessories are based on a self-aligning mechanism and feature ball-on-plate measuring systems and a rolling element bearing test-setup. The contribution will show the design and general measurement principles of the device and measuring accessories. It will further give application examples showing the potential in industrial as well as academic research and development.

4 – 4:30 pm
Precision Measurement Techniques for Generated Axial Force (GAF) at Tripod Constant Velocity Joint
Generated axial force (GAF) due to internal friction of driveshaft joint is one of the causes generating the shudder of vehicle. It also causes vibration problem on steering wheels of vehicles during idling. In this study, automated test machine is developed to precisely measure the GAF caused by internal friction in constant velocity (CV) joints. As the developed machine can control the temperature of joint, loading torque, angle of rotation and joint angles, actual vehicle driving condition can be applied. In order to validate the developed CV joint tester, GAF is compared by using different types of grease in tripod joints. Also GAF is measured for both on new and used CV joints to be compared and analyzed. The test result shows the repeatability and consistency of the test machine in terms of the different test conditions. By using the CV joint tester, friction performance of the joint can be evaluated by proposing the best CV joints as well as greases generating lowest GAF.

4:30 – 5 pm
Development and Dynamic Characterization of a Novel Tribometer
S. Wang, Harbin Institute of Technology, Weihai, China
In order to investigate the mechanism of high-frequency braking noise and to evaluate the dynamic tribological properties of sliding contacts, a dynamic tribometer to operate at high frequency (over 2 kHz) is developed, based on the finite element modal analysis method. This tribometer is a development of a standard type of tribological tester, the pin-on-disc machine. It is novel to traditional tribometers because a PZT drive is used to superimpose small sinusoidal fluctuations of sliding speed on a given steady sliding speed. The frequency and amplitude of these fluctuations can be varied and accurately controlled, and the dynamic response of the pin can be measured in amplitude and phase. The new tribometer is validated by transfer function measurement, experimental modal testing, computer simulation, and dynamic friction measurement with various contact materials and steady sliding speeds.

5 – 5:30 pm
Tribotesting Business Meeting

LUBRICATION FUNDAMENTALS IV
Session 4C • Room 225

Session Chair: B. Papke, Shell Projects and Technology, Houston, TX
Session Vice Chair: J. Qu, Oak Ridge National Laboratory, Oak Ridge, TN

2 – 2:30 pm
Lubricant Antiwear Performance as a Function of Aging in the ASTM Sequence IIIG Engine Test
C. Chen, B. Papke, P. Parthasarathy, Shell Global Solutions, Houston, TX
Wear performance of three new and used reference lubricants from the ASTM Seq. IIIG engine test were evaluated in an Optimol SRV-4. A “de-greening” effect was observed; wear rates for lubricants after 10 minutes “idling” were lower than those of the new oil. A continued low wear rate was observed until 80 hrs of Seq. IIIG engine aging, well beyond the depletion of the antiwear film-forming abilities as measured in the MTM, indicating that antiwear film formation in the MTM does not correlate with wear protection measured in the SRV-4. Wear protection begins to deteriorate markedly after 80 hours engine aging. Wear performance of the new and used lubricants was further analyzed using surface analytical techniques (EDX, Raman, FTIR) to characterize the antiwear films as a function of lubricant aging.

2:30 – 3 pm
Development of a Laboratory Test to Simulate Piston Deposit Formation in the ASTM Sequence IIIG Engine Test
B. Papke, C. Charles, Shell Global Solutions, Houston, TX
A laboratory deposit test has been developed which correlates with weighted piston deposit (WPD) merit weighting and ring land deposits (RLD) in the ASTM Sequence IIIG engine test. The test utilizes (A) Bulk lubricant oxidation, simulated by passing a dry air/NO2 gas mixture through a porous gas frit into the hot oil lubricant mixture, (B) Realistic lubricant oxidation, simulated by pre-blending the test lubricant with a used reference lubricant, (C) A deposit-generating step, simulated by thin film lubricant oxidation on a heated aluminum alloy surface where the thin lubricant film is exposed to hot simulated engine exhaust gases, and (D) A merit rating step, where the deposit-covered metal surface is visually rated using the Seq IIIG piston rating scheme. Correlations with Seq. IIIG WDP and RLD were established, and the composition of the simulated piston deposits were compared with piston deposits obtained from Seq. IIIG pistons.
Tuesday, May 8  Technical Sessions

Session 4C

3 – 3:30 pm  •  Break

3:30 – 4 pm

Elucidation of Degradation Mechanisms of Lubricant Components by Mass Spectrometry

N. Doerr, A. Kassler, L. Pisarova, AC2T research GmbH, Wiener Neustadt, Austria

Mass spectroscopy (MS) finds intense use in the field of biology (proteomics). In lubrication science, the added value which can be gained from the qualitative and quantitative knowledge of the chemical structures of degradation products in lubricants will be demonstrated.

Selected additives, among others antioxidants, were assessed for their ability to deliver thermo-oxidative stability by small-scale artificial alteration. The degradation mechanisms on the molecular level were examined by highly accurate measurements of the ion masses produced from the degraded components with the Orbitrap MS. The structures of the degradation compounds were confirmed by fragmentation experiments.

The results show that only the use of this high-end analytical technique allows the reliable detection of degradation products such as disulfide formation and thermally induced methylation.

4 – 4:30 pm

Application of Ionic Liquids for Anti-Wear Applications

P. Aswath, University of Texas at Arlington, Arlington, TX, N. Doerr, AC2T Research GmbH, Wiener Neustadt, Austria, X. Chen, University of Texas at Arlington, Arlington, TX, C. Gabler, V. Totolin, AC2T Research GmbH, Wiener Neustadt, Austria

Ionic liquids are a new generation of salts that find various applications such as solvents, electrically conductive fluids, battery applications and more recently as additives for anti-wear applications. In this study two ionic liquids were examined in blends of oils containing these ionic liquids either by themselves or with other antitrust additives such as ZDDP and ashless fluorothiophosphates. Tribometrical experiments were performed using a SRV tester. Tribofilms generated at the end of the tribological test were examined using XPS and XANES spectroscopy.

4:30 – 5 pm

Nanostructure and Composition of Tribo-Boundary Films Formed in Ionic Liquid Lubrication


Many studies have demonstrated superior lubricating performance for ionic liquids (ILs), and it is widely believed that a protective tribo-boundary film is formed on the contact area. However, the literature has been limited to 2D topography examination and chemical analysis. This study demonstrates a multi-technique 3D approach to characterize the IL induced boundary films to provide direct measurement of the film thickness, visualization of the nanostructure, and analysis of the composition change. The boundary films observed on different alloys are substantially distinct from both physical and chemical perspectives. The measured mean film thicknesses for cast iron, steel, and aluminum worn surfaces are 300, 60, and 200 nm, respectively. The boundary films on ferrous alloys are dominated by amorphous phase mixing with well-dispersed very fine (a few nm) nanocrystals, while the film on aluminum contains metallic particles in a relatively large size range from a few to tens of nm.

5 – 5:30 pm

Lubrication Fundamentals Business Meeting

METALWORKING FLUIDS IV

Session 4D  •  Room 226

Session Chair: E. White, CIMCOOL Industrial Products LLC, Cincinnati, OH
Session Vice Chair: G. Foltz, CIMCOOL Industrial Products LLC, Cincinnati, OH

2 – 2:30 pm

MWF Preservation - Alternatives to Formaldehyde-Releasers

P. Wachtler, Lanxess Deutschland GmbH, Leverkusen, Germany

Metalworking fluids, due to their high water content, provide an ideal environment for the growth of micro-organisms. To get control on this, the use of preservatives is indispensable. For decades, biocides based on Formaldehyde-releasers have played a major role in this application. However, as a consequence of ever growing regulatory requirements, the use of these established preservatives recently has come under pressure. In order to maintain the process quality in metalworking, alternatives to keep the micro-organisms under control are urgently needed. In this presentation, possible substitutes of FA-releasers are discussed. Special emphasis is put on phenolic biocides like o-Phenylphenol(OPP) or p-Chloro-m-cresol(PCMC), which are globally available and well suited with all relevant biocide approvals (BPD,EPA). In terms of formulation flexibility, the existing range of phenolic biocides enables treatment of concentrates as well as the post-treatment of ready-to-use emulsions.

2:30 – 3 pm

Quantifying Adenosine Triphosphate (ATP) in Water-miscible Metalworking Fluids – ASTM E 2694 Interlaboratory Study to Determine Test Method’s Precision


In January 2011, ten companies participated in an interlaboratory study (ILS) of ASTM E 2694 Method for Measurement of Adenosine Triphosphate in Water-Miscible Metalworking Fluids. The purpose of the ILS was to determine the repeatability (single analyst) and reproducibility (multiple laboratory) variability of ATP test data obtained using ASTM E 2694. The ILS included samples of low-end and high-end emulsifiable oil, semi-synthetic and synthetic metalworking fluid formulations with ATP bioburdens ranging from 0.3 Log10 pg ATP mL⁻¹ to >5.0 Log 10 pg ATP mL⁻¹. This presentation discusses the ILS test plan design and results.

3 – 3:30 pm  •  Break

3:30 – 4 pm

Development and Application of Green Bioresistant Semi-Synthetic Coolants with No Bactericide and No Secondary Amine

Y. Zhao, Chemetall US, New Providence, NJ

With the movement of green chemistry and sustainability in MWF industry, and the regulation pressure from EPA and NTP on formaldehyde condensed bactericides, it is necessary to look into the development of new type of MWF chemistry and products which do not contain or generate toxic and hazardous substances to coolant users and their environment. In this paper we will discuss some strategies to develop green bioresistant semi-synthetic coolants with no bactericide and no secondary amine such as DCHA. We will also discuss some comparison biochallenge results of these bioresistant products with traditional MWF formulas from both internal and outside
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Metalworking fluids (MWF) provide an excellent environment for the growth of various types of microorganisms. Effective microbial control is required to maintain fluid quality, tool life, and to minimize potential adverse health effects from microbial contaminants. Selecting a biocide program to control microbial growth involves balancing the properties of the selected actives including antimicrobial efficacy, chemical stability, worker safety, system compatibility, treatment cost, regulatory compliance, and environmental impact. The recent proposal by EPA to limit the use level of triazine in use diluted fluids has triggered formulators to reexamine their use of and selection criteria for MWF biocides. This paper provides a brief update on the proposed triazine restriction and a detailed comparison of biocide features and properties which could be used as triazine and/or formaldehyde replacements in MWF concentrate and tankside treatment.

4:30 – 5 pm
Pseudomonas Oleovorans Subsp. Lubricantis, a Newly Described Bacterium in Contaminated Metalworking Fluids
R. Saha, R. Donofrio, NSF International, Ann Arbor, MI
Metalworking fluids (MWFs) used as cooling and lubricating agents are highly prone to microbial contamination. Microbial contamination in MWF is associated with both degradation and health hazards. Among the different microorganisms present in MWFs, species of Pseudomonas act as primary colonizers. Pseudomonas oleovorans subsp. lubricantis, a newly described bacterium recovered from used MWF was found to be important to MWF fouling. It was capable of growing in MWF, dropping its pH from 9.2 to 8.0 within 96 hrs indicating its potential as a deteriorgen. However, the distribution of this organism in MWF is difficult to study using standard culturing techniques and therefore a real-time PCR assay using TaqMan-MGB technology was developed for its specific identification and estimation. It was also capable of forming biofilm within 72 hrs under static condition. Based on its biofouling and biofilm forming capabilities further research is recommended to investigate its impact on MWFs.

5 – 5:30 pm
Metalworking Business Meeting

ROLLING ELEMENT BEARINGS I
Session 4F • Room 231
Session Chair: N. Weinzapfel, Purdue University, West Lafayette, IN

2 – 2:30 pm
General Bearing Load-displacement Relationships Respecting Point to Line Contact Transition
L. Houpert, Timken Europe, Colmar, France
A simple set of relationships is given for calculating the three bearing loads and two moments as a function of five relative race displacements (three translations and two rotations). A full coupling between all these parameters is respected, as well as a transition from point to line contact as the loads increase, meaning that use is made of the roller and race crown radii. Such a set of relationships can be used for programming any bearing type element in FEA packages using two nodes only (inner and outer race center).

2:30 – 3 pm
Effect of Roller Geometry on Roller Bearing Load-Life Relation
F. Oswald, E. Zaretsky, NASA Glenn Research Ctr., Cleveland, OH, J. Poplawski, J.V. Poplawski & Associates, Bethlehem, PA
Cylindrical roller bearings employ roller profile modification to equalize load distribution, minimize stress concentration at roller ends and allow for misalignment. The 1947 Lundberg-Palmgren analysis reported an inverse fourth power relation between load and life for roller bearings. In 1952, Lundberg and Palmgren changed the load-life exponent to 10/3 for roller bearings. The effect of roller-crown profile was reanalyzed in this paper to determine the actual load-life relation for modified roller profiles. For uncrowned rollers (line contact), the load-life exponent is $p=4$. This is in agreement with 1947 analysis. For fully crowned rollers $p=3.08$ to 3.20, depending on the radius of curvature. For an aerospace profile $p=3.55$. For chamfered rollers, $p=3.53$. Based upon these results, using conventional $p=10/3$ rather than the actual roller profile results in life calculation errors ranging from $-420$ percent for uncrowned rollers to $+47$ percent for crowned rollers.

3 – 3:30 pm • Break

3:30 – 4 pm
Calculations for Rolling Bearing Cages
J. Binderszewsyky, B. Hahn, O. Koch, W. Kruhoeffer, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany
The main functions performed by rolling bearing cages are separating and guiding the rolling elements. Thereby the most important requirement of the cage is to ensure safe operation for the required rating life. The dynamic forces that act between the individual components of the bearing must be determined in order to design the cage. The stresses must be calculated and a comparison made with the material strength limits of the cage in order to generate a strength assessment. Both, the resistance of the material to fatigue and the resistance to wear of the sliding contacts are important here. Special demands are placed on the strength of the cage if high acceleration, vibrations or shocks act on the bearing. The combined use of dynamic simulation of the rolling bearing and FE calculations as well as the availability of strength assessment parameters facilitates the design of rolling bearing cages with high operational reliability.
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4 – 4:30 pm  
**Modeling of Four Contact-point Ball Bearing with Deformable Rings**

S. Lacroix, D. Nelias, INSA Lyon, Villeurbanne, France; A. Leblanc, Faculté des sciences Appliquées, Béthune, France

Reducing ball bearing weight and size implies new ring geometry, thinner rings. By using such a ball bearing with high loads, housing and ring geometry flexibility is no longer negligible. These deformations are considered by each contact-point both as a modification of conformity and as a raceway curvature center displacement. Since conformity have a great influence on contact geometry, it is important to quantify and study this influence on the ball bearing behaviour. In order to investigate the impact on ball bearing equilibrium, we implemented a coupling method between a semi-analytical code for four-contact point ball bearing and a FEM solver. The semi-analytical code drives the computation in which the FEM solver is used to compute new conformity. Here we study the implementation of this coupling method and present some results.

4:30 – 5 pm  
**Extraction of Micro-Pillars for Characterizing Constitutive Response of Bearing Steels Subject to Rolling Contact Fatigue**

N. Arakere, G. Subhash, University of Florida, Gainesville, FL; B. Boyce, Sandia National Labs, Albuquerque, NM; D. Anthony, SKF Aeroengine Division, Falconer, NY

Micro compression pillars (1-mm dia, 2-mm length) were extracted from 57-mm (2.25-in) through hardened M50 balls subjected to rolling contact fatigue (RCF). RCF testing was performed using a single ball loaded in compression and rotated between two V-grooves. The ball was sectioned and polished to the centerline of the RCF track. Micro pillars extracted via EDM inside the RCF-affected zone and also the virgin material. Compression testing of the micro pillars yields the stress-strain response of virgin and RCF-affected material. Microindentation hardness mapping within the RCF zone gives the yield strength changes. The isotropic and kinematic cyclic hardening parameters are extracted from localized hardness and monotonic and cyclic stress-strain response. We present hardness and stress-strain data of the RCF-affected material that represents the first meaningful attempt at characterizing RCF response of high strength bearing steels.

**ENGINE & DRIVETRAIN III**

Session 4G • Room 232

**2 – 2:30 pm**  
**Analysis of Dynamic Viscosity Affects Associated with Internal Combustion Engines Due to Engine Oil contamination**

J. Hennings, J. Wallace, A. Mitra, V. Soloiu, Georgia Southern University, Statesboro, GA

Oil viscosity is an essential factor for reliable and efficient operation of the hydrodynamic bearings in internal combustion engines. While proper engine lubrication is essential, the engine oil progressively becomes contaminated by bio-fuel in cold-start operating conditions. The objective is to quantify the engine oil viscosity when contaminated with E85/Ethanol, perform an efficient 3-D semi-elasto-hydrodynamic bearing cranktrain simulation using FEV Virtual Engine software for comparison to future experimental testing, and to discover the contamination effects of common engine oil on the bearings. Simulation results for a small displacement SI engine indicate that the bearing stress in the HD crankshaft main bearings, HD crank-pin bearing, and the HD thin film piston skirt-to-cylinder interaction, are affected by the contaminated oil viscosity changes. The resultant HD bearing stress and the oil viscosity have an inverse relationship at engine oil contamination levels tested.

**2:30 – 3 pm**  
**The Relationship Between Oil Condition and Measured Piston Ring and Cylinder Liner Wear for Several Heavy Duty Diesel Engines**

J. Truhan, P. Kodali, Caterpillar Inc, Mossville, IL

Oil analysis, particularly wear metals, is often used to monitor engine health. However, it is only occasionally related to actual measured wear of critical components such as piston rings and cylinder liners. This study tracks oil degradation during multi-mode tests in an engine test cell. Oil condition in this study includes the concentration and size-distribution of particulate contamination. The relationship between particle concentration and wear metals and the relationships between wear metals and post-test measurements of ring and liner wear are established. The sensitivity to wear for each of several engines to oil condition is compared and the possible reasons for the different sensitivities among the various individual tests are discussed.

3 – 3:30 pm • Break

**3:30 – 4 pm**  
**Mixed EHD Analysis of Lip Seals Based on Measured Seal Surfaces**

F. Shi, Y. Liu, B. Yang, P. Sharma, GM, 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 transmission seal reveals the roughness effect on the performance of the seal, especially reverse flow rate and frictional loss.
4 – 4:30 pm  
**Rudder Speed Brake Actuator Probabilistic Fatigue Life and Reliability Analysis**  
F. Oswald, NASA Glenn Research Center, Cleveland, OH, M. Savage, University of Akron, Akron, OH, E. Zaretsky, NASA Glenn Research Center, Cleveland, OH  
The method of probabilistic design was applied to the Space Shuttle rudder speed brake actuator gear box. A life and reliability assessment of the gears was performed in two stages: a contact stress fatigue model and a gear tooth bending fatigue model. The two-parameter Weibull life distribution was used for both models. For the contact stress analysis, the Lundberg-Palmgren bearing life theory has been expanded to include gear-surface pitting and the gear box as a system. The mission spectrum of the Space Shuttle rudder speed brake gear box was combined into equivalent effective hinge moment loads for the contact stress fatigue model and for the tooth bending fatigue model. Gear system reliabilities are reported for both methods and their combination with and without a 5.6 Nm input preload. Reliability of the bearings in the gearbox was analyzed separately, based on data provided by the actuator manufacturer.

4:30 – 5 pm  
**The Influence of Viscosity Modifier Structure on the Performance of Fuel Efficient Engine Oils**  
D. Gray, Evonik Oil Additives, Horsham, PA, F. Lauterwasser, P. Hutchinson, C. Wincierz, S. Ulzheimer, Evonik Oil Additives, Darmstadt, Germany  
Energy efficiency, fuel economy and the desire for lower total emissions are now vital considerations for the lubricants industry. Accordingly, engine oil developments have become strongly focused on reducing CO2 emissions via improved fuel economy without compromising engine durability. It is widely accepted that lowering the viscosity of the lubricant and therefore the internal fluid friction can improve fuel economy.

Reducing HTHS viscosity at 150 °C is an effective means of improving fuel economy but it is also a critical parameter of engine durability so any reductions in HTHS must not impair engine life. It is therefore desirable to reduce oil viscosity throughout much of the temperature range without compromising HTHS Viscosity at 150 °C and high VI polymers can enable the formulator to do this. In this publication we investigate the impact of different VII architecture on kinematic viscosity, HTHS viscosity at 150 °C and fuel efficiency.

5 – 5:30 pm  
**Engine & Drivetrain Business Meeting**
Effects of Water in Wind Turbine Oils on the Gear Load Capacity

T. Tobie, B. Höhn, K. Stahl, J. Witzig, Gear Research Centre (FZG), Garching, Germany

Wind turbine gear boxes are often operated under rough climatic conditions. In some cases water will condensate in the gear housing and may contaminate the lubricant. A water contamination of the gear oil can affect the bearing lifetime but also the gear load carrying capacity. Within a research project the effects of water contamination on different gear damages as abrasive wear, micro-pitting and pitting were systematically investigated. Gear running tests under different test conditions with fresh and contaminated oils were performed. Especially several typical wind turbine gear oils with different base lubricants (PAG, PAO, ester, mineral oil) were examined. The results prove that the influence of water contamination is depending also on the kind of base oil and that several gear damages are influenced in different ways. Based on the experimental results possible failure mechanisms on the gear flanks due to water in wind turbine gear oils are discussed.
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2 – 2:30 pm
Oil Soluble Polyalkylene Glycols and Aspects of Their Benefits for Hydraulic Fluids
M. Greaves, Dow Chemical Company, Horgen, Switzerland
Oil soluble polyalkylene glycols (OSP) are a new type of Group V base oil and performance enhancing additive that are finding use in a broad range of automotive and industrial lubricant formulations. Two of their performance benefits are their excellent deposit control and friction control. This paper will highlight the versatility of OSPs and show how they can be used to upgrade hydrocarbon based hydraulic fluids. Furthermore some of the practical benefits in choosing an OSP as a primary base oil in hydraulic fluid formulations will be illustrated. Performance comparisons to other synthetic hydraulic fluid technologies will be made.

2:30 – 3 pm
Fluid-Structure Interaction – Key for the Operation of Piston Machines
M. Ivantysynova, Purdue University, West Lafayette, IN
Major breakthroughs in modelling of the various fluid-structure interaction phenomena taking place in piston pumps and motors will be discussed in this presentation. Examples from the author’s research team documenting the progress in understanding and modelling of the three main tribological interfaces of axial piston machines will be given. The theoretical study and modelling of fluid-structure interaction phenomena has been supported by extensive experimental work using several very special test rigs to measure piston friction, dynamic fluid film pressure and surface temperature fields. One of the recent discoveries about the impact of thermal expansion of pump parts on the fluid film load carrying ability will be presented.

3 – 3:30 pm • Break

3:30 – 4 pm
Synthetics and Hydraulics Business Meeting

2 – 2:30 pm
Impact of Temperature on Long Term Elastomer Testing
B. Carfolite, G. Christensen, S. Flores-Torres, Paulsboro Research and Technology, Paulsboro, NJ
Elastomer/oil compatibility is a key requirement for lubricants development. Understanding of how oils interact with elastomers over an extended period of time is an area of growing interest in the industry. Fundamental to performing long term tests is to establish conditions that are relevant to the application without causing degradation by heating the elastomer beyond its design capability. This paper will present research that evaluates the influence of temperature on elastomer performance using the ISO 1817 method. Observations have highlighted the influence of temperature on the degradation of the polymer crosslinking compared to the impact the oil has on the elastomer.