Overview

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

SUNDAY, MAY 18, 2014
Registration (7 am – 6 pm) – East Registration
Speakers Breakfast (7 – 8 am) – Americas B
Education Courses (8 am – 5 pm)
• Basic Lubrication 101: Fundamentals of Lubrication – Fantasia K/L/M
• Bearings and Their Lubrication (Co-hosted with ABMA) – Fantasia E/F
• Condition Monitoring 301: 21st Century Condition Monitoring – Fantasia N/P/Q
• Grease 101 (Co-hosted by NLGI) – Nutcracker 2
• Hydraulics 102: Basic Hydraulic Components and Systems – Nutcracker 1
• MWF 125: Health, Safety, and Introduction to GHS – Republic A
• Synthetic Lubricants 203: Non-Petroleum Fluids & Their Uses – Nutcracker 3
Education Courses (1:30 – 5 pm)
• Nanotribology Special Session – Republic B
Student Gathering (7 – 10 pm) – Room TBD

MONDAY, MAY 19, 2014
Registration (7 am – 6 pm) – East Registration
Speakers Breakfast (7 – 8 am) – Americas B
Technical Sessions (8 – 10 am)
1A Lubrication Fundamentals I – Panel Discussion on Ionic Liquids Lubrication – Nutcracker 1
1B Practical Lubrication Practices I – Nutcracker 2
1C Seals I – Nutcracker 3
1E Synthetic and Hydraulic Lubricants I – Fantasia C/D
1F Nanotribology I – Fantasia E/F
1G Power Generation I – Fantasia K/L
1H Ceramics & Composites I – Fantasia M/N
1I Rolling Element Bearings I – Fantasia P/Q
1J Environmentally Friendly Fluids I: Biodegradability and Environmentally Acceptability – Republic A
1K Metalworking I: The Chemistry of Metalworking – Republic B
1L Commercial Marketing Forum I – Republic C/D
Keynote Address (10:30 am – Noon) – Americas A
Lunch on your own (Noon – 1:30 pm)
Commercial Exhibits and Student Posters (Noon – 5 pm) – Fantasia
Exhibitor Appreciation Hour (3 – 4 pm)
Technical Sessions (1:30 – 6 pm)
2A Lubrication Fundamentals II: Ionic Liquids Lubrication and More – Nutcracker 1
2B In Situ Tribology I: Material Tribology and Tribotesting Joint Session – Nutcracker 2
2C Seals II – Nutcracker 3
2D Molecular Chemistry and Lubricant Rheology: Special Symposium I– Fantasia A/B
2E Synthetic and Hydraulic Lubricants II – Fantasia C/D
2F Nanotribology II – Fantasia E/F
2G Power Generation II – Fantasia K/L
2H Grease I – Fantasia M/N
2I Rolling Element Bearings II – Fantasia P/Q
2J Environmentally Friendly Fluids II: Development and Performance – Republic A
2K Metalworking II – Republic B
2L Commercial Marketing Forum II – Republic C/D
Welcome Reception (6:30 – 8 pm) – Americas A

Beverage Breaks are scheduled at 10 am and 3 pm daily.
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<td>Two Phase Flow in a Mechanical Seal, N. Brunetiere, p.31</td>
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- **Novel, Hydrothermally Stable, Polyhedral Synthetic Lubricants Basestocks**, A. Kurchan, p. 31
- **Oil Soluble Polyalkylene Glycol Hydraulic Fluid: Equipment Performance Testing and Case Study**, A. Larson, p. 31
- **Novel High Performance Synthetic Base Stocks**, S. Rizvi, p. 32

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#### Fantasia M/N

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<td>11 – 11:30 am</td>
<td>Fantasy P/Q</td>
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<td>2 – 3 pm</td>
<td>Fantasia P/Q</td>
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Society of Tribologists and Lubrication Engineers
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- Hydraulics
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Monday, May 19

Session 1A • Nutcracker 1

LUBRICATION FUNDAMENTALS I – PANEL DISCUSSION ON IONIC LIQUIDS LUBRICATION

Session Chair: J. Qu, Oak Ridge National Laboratory, Oak Ridge, TN

8 – 8:30 am
New Protic and Aprotic Ionic Liquid Lubricants
Maria-Dolores Bermudez, Universidad Politecnica de Cartagena, Cartagena, Spain, Patricia Iglesias, Rochester Institute of Technology, Rochester, NY

8:30 – 9 am
Tribofilm Formation from Ionic Liquids
Pranesh B. Aswath, University of Texas – Arlington, Arlington, TX

9 – 9:30 am
Chemical Reactivity of Ionic Liquids
Ichiro Minami, Lulea University of Technology, Lulea, Sweden

9:30 – 10 am
Ionic Liquids as Lubricant Additives
Jun Qu, Oak Ridge National Laboratory, Oak Ridge, TN

10 – 10:30 am – Break

Session 1B • Nutcracker 2

PRACTICAL LUBRICATION PRACTICES I

Session Chair: C. Paxton, GM Tech Center, Warren, MI
Session Vice Chair: D. McCoy, The Elco Company, Cleveland, OH

8 – 8:30 am
Soft Deposit Formation of Oil at Lower Temperatures Below 200 Degree Centigrade
F. Yokoyama, Y. Iwama, Machine Elements Dept., Research Laboratory, IH Corporation, Yokohama, Japan

In compressor housing of oil mist atmosphere, even at the lower temperatures below 200 degree centigrade, soft deposit could be observed. Sticky or hard deposit at higher temperatures above 300 degree centigrade is well-known, which can be demonstrated by Panel Coker Test. However, the soft deposit formation is not understood well. In this research, the deposit in the compressor housing was analyzed and the formation mechanism was presumed based on the composition of the deposit. To validate the presumption, the formation mechanism was demonstrated using a new method. The effect of temperature and oxygen pressure on the formation is also considered.

8:30 – 9 am
Tribology & Lubrication of Rotating Machinery in Oil & Gas Onshore and Offshore Environment
J. Choo, Z. Ariffin, PETRONAS Group Technical Solutions, Kuala Lumpur, Malaysia

O&G production, processing and petrochemical facilities operate for up to 40 years where their design life are sometimes doubled. Aged rotating machinery become stretched by being operated closer to their limits to meet production targets, and by operating for prolonged periods in marine environment. This paper illustrates performance and degradation issues of critical rotating equipment in O&G (gas turbines, steam turbines, engines, compressors, pumps) where sound lubrication practices play a key role in their life extension. Whole-cycle lubrication management from lubricant selection, condition monitoring, changeout, to brand replacement employing international standards converge on addressing lubricant degradation, mishandling and contamination. Inadvertently, lubricants do become contaminated and case study on mitigation solutions such as on-line lube oil purification for water contamination is presented against the ideals of lubricant changeout – for both onshore and offshore.

9 – 9:30 am
Complete Guide to Starting a Lubrication Program
J. Wright, Noria Corporation, Tulsa, OK

For those who have been thrust into a position as a lube champion but don’t know where to begin, this session will discuss how to kick-start your lubrication program to ensure future success. From quality lubricants and lubrication to metrics and analysis, contamination control, and people and training, discover all the key components that go into creating an effective lube program.

9:30 – 10 am
The Secrets to Achieving Lubrication Excellence
J. Wright, Noria Corporation, Tulsa, OK

Have you ever wondered what industry leaders are doing and what makes them the leaders? In this presentation, the five main attributes of world-class organizations will be revealed. You will also learn what many companies do wrong when trying to transform to lubrication excellence so you can be free from the same mistakes and reap the benefits of becoming a top performer in the lubrication field.

10 – 10:30 am – Break

Session 1C • Nutcracker 3

SEALS I

Session Chair: K. Malik, Ontario Power Generation, Pickering, ON, Canada
Session Vice Chair: N. Brunetiere, Universite De Poitiers, Futuroscope Chasseneuil, France

8 – 8:30 am
Experimental Study of the Thermal Behavior of Mechanical Face Seals
A. Khouloud, B. Noel, T. Bernard, Département Génie Mécanique et Systèmes Complexes, Institut Pprime, Futuroscope Chasseneuil, France

Good operating conditions of mechanical face seals are reached when a thin lubricating liquid film separates the two faces providing a high wear resistance. This film can be strongly sheared leading to high energy dissipation in the contact. In this paper, an experimental study quantifying the thermal behavior of a mechanical seal is performed. Thermal gradients are measured using thermocouples installed in the stator at different locations. The tests were carried out at different operating conditions. The amplitude of the thermal effects is highly dependent on the operating conditions. Generally speaking, the temperature increases with the pressure of the fluid. It also increases with the speed when the lubrication regime is hydrodynamic. But, in mixed lubrication regime, the temperature decrease when the speed increases. Furthermore, the experimental data is used to calculate the heat that is generated at the seal faces and also the heat exchanged with the sealed fluid.
8:30 – 9 am
A Robust Safety Containment Face Seal
T. Lai, John Crane Inc., Morton Grove, IL

Safety containment face seal is used to restrict process fluid leakage and minimize polluting environment when the inboard seal fails. If a contacting plain face seal is used for safety containment, it usually has low spring force in order to minimize frictional heating and face wear. The low spring force may cause seal hang-up if oil/dirt deposit starts to build up in dynamic O-ring area. Face seals with hydrodynamic lift features such as spiral groove have been successfully applied as safety containment seals. They run reliably during normal dry running operation, without special buffer fluid other than air, in a non-contacting mode. But during the upset condition, they tend to leak more. This presentation will review how a robust alternative seal design can be applied to overcome such leakage problem while keeping the advantage of non-contacting running during normal operation.

9 – 9:30 am
Improving the Performance of a Mechanical Seal by Surface Texturing
M. Adjemout, B. Noel, J. Bouyer, GMSC, Institut Pprime, Futuroscope Chasseneuil, France

In this work, a theoretical model is used to investigate the performance of a mechanical seal operating in hydrodynamic lubrication when one of its friction surfaces is micro-textured with triangular pattern. The model is based on the 2D-Reynolds equation coupled with a mass conservative cavitation algorithm. A finite volume method is used to discretize the studied domain while a direct method is adopted to solve the equations. The inner and the outer radii of the mechanical seal are respectively 0.02575m and 0.02875m. The mechanical seal is unbalanced and is used to seal pressurized water at 2 MPa. The nominal rotational velocity is 3000 rpm. An optimization of the implementation of triangular patterns on the matting ring is performed in order to minimize friction and leakage. Results of a parametric study are presented: the effects of the main design parameters and of the distribution of the artificial texture on the seal performance are shown and analyzed.

9:30 – 10 am
Two Phase Flow in a Mechanical Seal
N. Brunetiere, Mechanical engineering and complex systems, Institut Pprime, Futuroscope Chasseneuil Cedex, France

This paper presents a numerical analysis of a two-phase flow analysis in a mechanical seal. Usually, mechanical seals are used to separate two mediums containing different fluids: for example water and air. Even if there is pressure gradient from one side to the other, the fluid located at the low pressure side can enter the contact because of local depressions in the fluid film which can suck the fluid inside. In the present model, the Reynolds equation for a homogeneous mixture is solved as well as a transport equation used to determine the proportion of both fluids at each point. The effect of the two phase flow on the seal performance is analysed through a parametric study.

10 – 10:30 am – Break

8:30 – 9 am
SYNTHETIC AND HYDRAULIC LUBRICANTS I

Session Chair: P. Cusatis, BASF Corporation, Tarrytown, NY
Session Vice Chair: J. Sherman, BASF Corporation, Wyandotte, MI

8 – 8:30 am
Metalloocene Based Polyalphaolefins As High Performance Lubricant Base Stocks
A. Patil, ExxonMobil, Houston, TX

Typically, the highest performance lubricants are formulated with Polyalphaolefins (PAOs). Conventional high viscosity PAOs are made using strong acid catalysts that produce oligomers having a high degree of isomerization and broad molecular weight distribution, which directly affects viscometrics and shear stability.

The “Metalloocene Revolution” has changed the polyolefin business. Use of single site metallocene catalysts provide hitherto unprecedented control over polymer microstructure, properties, and molecular weight. They are capable of making products with narrow molecular weight distribution and controlled tacticity. As a result, metallocene based PAO (mPAO) base stocks provide enhanced performance including: higher Viscosity Index, lower pour points, and better shear stability compared to conventional PAO. The presentation examines the relationship between metallocene catalysts, the structural features of the mPAOs, and the unique performance advantages that they provide.

8:30 – 9 am
Novel, Hydrolytically Stable, Polar Synthetic Lubricants Basestocks
A. Kurchan, Croda Inc, New Castle, DE

Esters are the preferred basestock in many severe applications. For systems where water is present, use of esters can be restricted due to hydrolysis. This has to be controlled by optimizing the chemistry of esters, chemical additives, or through mechanical means. Croda has developed novel fully synthetic products with far superior hydrolytic stability compared to esters, while retaining similar benefits due to polarity. In this presentation we will compare hydrolytic stability of the novel basestock with different types of esters in single component studies and in a typical gear/driveline fluid formulation. We will present data on benefits of this basestock: solubilize additives, volatility, seal compatibility, and potential durability and lubricity benefits, similar to esters. Due to greatly improved hydrolytic stability, these novel synthetic products have potential to expand formulation options and lubricant performance beyond what ester-based lubricants esters are capable of.

9 – 9:30 am
Oil Soluble Polyalkylene Glycol Hydraulic Fluid: Equipment Performance Testing and Case Study
A. Larson, The Dow Chemical Company, Midland, MI, M. Greaves, The Dow Chemical Company, Horgen, Switzerland

As the requirements of hydraulic systems increase including higher temperatures and pressures and smaller components (e.g. reservoirs), there is a need for fluids that can allow the end-user to continue to operate with minimal downtime. Oil soluble polyalkylene glycols (OSPs) offer formulators the building blocks in developing synthetic hydraulic fluids. OSPs offer exceptional air release, oxidation stability, wear properties, and deposit control. Physical properties are not the only attributes that need to be examined when looking at a hydraulic fluid. It is also important to test the fluid against the required performance testing common among many OEM specifications. An in-depth look at one specific OSP-based hydraulic fluid and how it performed against OEM specification will be examined. Also, the data for a case study will be shared with an emphasis on the varnish-free performance of the fluid and what benefits this provided.
9:30 – 10 am
Novel High Performance Synthetic Base Stocks
S. Rizvi, Y. Liang, Elevation Renewable Sciences, Woodridge, IL
We will describe the performance characteristics of novel API Group V base stocks that utilize materials derived from natural oil metathesis and their use in designing engine oils, gear oils, and industrial fluids. The advantages of these stocks and the derived lubricants include high viscosity indices, greater solvency, high bio-content, and the ability to formulate multi-grade oils without the use of the viscosity modifiers. Physical, chemical, and tribological performance data for base stocks and the derived lubricants will be compared with those of the commercial base stocks/base oils and lubricants.

10 – 10:30 am – Break

Session 1F • Fantasia E/F

NANOTRIBOLOGY I

Session Chair: K. Sinha, Chevron Oronite Co. LLC, Bellaire, TX
Session Vice Chair: J. Choo, Petronas Group Technical Solutions, Kuala Lumpur, Malaysia

8 – 8:30 am
ADDNANO: From the Nanoparticle to the Nanolubricant
F. Dassenoy, Ecole Centrale de Lyon, Ecully, France
Advanced nano-materials recently developed, such as inorganic fullerene materials (IFs) and others, have shown some initial promise for their contribution to reducing friction and enhancing protection against wear. However, the transfer of promising nanotechnology research results into new nanolubricants still represents a bottleneck. IFs can be manufactured at commercial-scale, incorporated in a stable fashion into full formulations, and their performance benefits can be sustained under those circumstances, they offer the prospect for some performance breakthroughs not seen since the development of the anti-wear additives (ZDDP), 70 years ago. The overall objective of the AddNano project (funded by European Commission within the 7th Framework Programme) is to overcome the technological barriers involved in the development of large scale market introduction of a new generation of lubricants incorporating nanoparticles. This project and the latest advances will be presented.

8:30 – 9 am
Nanoengineered Lubricants to Improve Wear Resistance, Reliability, and Lubrication Efficiency of Wind Turbine Gearboxes
A. Malshe, NanoMech, Fayetteville, AR
Detailed investigations of advanced nanoengineered lubricants 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 nanoengineered packages 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 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 nanoengineered lubricants. These tests were used to demonstrate consistent performance meeting the demanding requirements for lubrication of wind turbine gearboxes.

9 – 9:30 am
Synthesis of Efficient Nanoparticles for Boundary Lubrication: Influence of the Size and Structure of Inorganic Fullerene-like MoS2 Nanoparticles
P. Rabaso, F. Ville, France, J. Cavoret, LaMCoS-INSa Lyon, Université de Lyon, Villeurbanne Cedex, France, F. Dassenoy, France, B. Vacher, LTDS-Ecole Centrale de Lyon, Université de Lyon, Ecully, France, M. Diaby, Centre Technique de Belchamp, PSA Peugeot Citroën, Belchamps, France, P. Afanasiev, IRCELYON, Université de Lyon, Villeurbanne
The use of nanoparticles as lubricant additives has been widely explored in recent years, and inorganic fullerene-like particles such as IF-MoS2 and IF-WS2 have spiked special interest due to their great friction and wear reducing capacities. In this study, various synthesis techniques were used to produce inorganic fullerene-like MoS2 (IF-MoS2) nanoparticles of different sizes and morphologies. Boundary lubrication testing of these various samples dispersed in base oil revealed an influence of nanoparticle crystallinity on the durability of the additive, even though the nanoparticles containing fewer structural defects achieved the same maximum friction reduction as the more crystalline IF-MoS2. Although nanoparticle size may be perceived as an important parameter for efficient lubrication, particles as large as 400 nm in diameter provided the same friction reduction as the smaller particles for a given morphology. The importance of using ultra-fine and perfectly structured fullerene-like nanoparticles is discussed in the light of these results.

9:30 – 10 am
Effects of Nano-Scale Surface Texture and Lubricant Molecular Structure on Boundary Lubrication in Liquid
A. Al-Azizi, S. Kim, Chemical Engineering, Pennsylvania State University, University Park, PA, O. Eryilmaz, A. Erdemir, Argonne National Laboratory, Argonne, IL
Effects of liquid lubricant molecular structure on the friction of elastically deforming nano-scale surface texture was studied in the boundary lubrication regime on flat and nano-textured diamond-like carbon. Friction tests in liquid lubricants with linear and branched molecular structure revealed that nano-texture reduces friction in the presence of linear lubricant molecules. Nano-confinement can significantly affect the friction behavior of textured solid interfaces by forming a long-range ordered structure between flat surfaces. When the deformation of solid surfaces under contact pressure is larger than the surface roughness, even rough surfaces can exhibit nano-confinement effects. However, liquid entrapped in the depressed region of nano-textured surfaces would not solidify which effectively reduces the solidified lubricant area and reduces friction. Surface texture has insignificant effect on the boundary lubrication of branched molecules as they hinder long-range ordering.

10 – 10:30 am – Break
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8 – 8:30 am Non-Varnishing PAG-Based Turbine Fluid and GEK Spec 32568h Recommendations
G. Khemchandani, The Dow Chemical Company, Freeport, TX
Polyalkylene glycol (PAG) based synthetic gas turbine fluid has given varnish free performance in many utility plants since 2007. Critical to optimizing trouble free performance was the need to monitor oxidative health of the lubricant during its use in 7FA/7EA turbines. After six years of varnish free performance PAG based synthetic gas turbine fluid has been included in recently issued GEK specification 32568h under lubricating oil recommendations for gas turbines. The well known three main reasons of varnish formation are: micro diesel, electrostatic discharge and sludge and varnish formation by hydrocarbon oils under oxidation. The present paper will describe how PAG based turbine oil combat these varnish formation processes due to its inherent non varnishing properties. Author will highlight important features of GEK specs.32568h in this paper.

8:30 – 9 am Development of Oxidative Degradation Diagnosis Method for the Turbine Oils by the Membrane Patch Color
A. Sasaki, Y. Iwai, University of Fukui, Fukui, Japan, T. Honda, Maintek Consultant, Yokohama, Japan, K. Matsumoto, Honda R and D Co., Ltd., Utsunomiya, Japan
Oxidation of turbine oils used in the combined cycle power plants has become a serious problem. In our laboratory, the relations between color of contaminants and lubricating oil degradation have been investigated. In this study, we prepared sample oils which were oxidized in the laboratory. Color parameters of membrane patches produced from the sample oil were measured by using a colorimetric patch analyzer. We examined the changes in the properties of the sample oil by the progress of the oxidative level. As a result, when the sample oil to which the oxidation doesn't progress so much is filtered, the oxidation product mainly captured in the filter. On the other hand, when the sample oil to which the oxidation progress so much is filtered, the oxidation product captured in the filter and on the filter. The oxidation product captured on the surface of the filter also works as a filter.

9 – 9:30 am Investigation Into the Effects of Ozone Exposure on Several Candidates for Turbine Oil Replacement in a Primary Heat Transport (PHT) System within a Nuclear Station
G. Pereira, Kinectrics, Toronto, ON, Canada, G. Staniewski, Ontario Power Generation, Toronto, ON, Canada
Primary heat transport (PHT) sinks are the main source for heat removal from a nuclear reactor core in a generating station. A recent problem will be discussed; ozone (O3) has been forming in several of the primary heat transport (PHT) pump motors within several reactors within one specific nuclear station. This O3 is detrimental to the surrounding equipment, aging the motor pump oil, and also the health and safety of people working around the motors. This study investigates several possibilities for oil substitutions that have been exposed to ozone and their performances has been evaluated. The protocol, test methodology, rationale and results will be discussed. A brief overview of nuclear reactors in Canada and USA will be discussed.

9:30 – 10 am Electron Spin Resonance Spectra of Butylated Hydroxytoluene (BHT) as Evidence of Free Radical Formation in Electrostatic Discharge (ESD) Damaged Lubricating Oils
J. Duchowski, T. Lang, Werk 17, HYDAC Fluid Care Center GmbH, Sulzbach, Germany
ESD was generated in ISO VG 46 cSt turbine lubricating oil by passing the oil through a glass fiber filter element at a hydraulic load of 0.06 L/min-1cm-2. The oil exhibited an electrical conductivity of 8 pS:m-1 @25°C. The experiment was performed at room temperature and the amplitude of ESD arcing events recorded was on the order of ~500 V. The magnitude of ESD events was sufficient to generate free radical formation of the BHT additive generally employed as an antioxidant in turbine lubricating oils. The free radical formation was evidenced by a clearly observable ESR signal corresponding to the BHT radical as recorded on an X-Band MiniScope MS100 spectrometer with a resonant frequency of 9.43 GHz and a maximum field sweep of 400 mT. These results indicate that ESD can well be responsible for initiating the free radical polymerization process postulated to result in varnish formation in turbine lubricating oils.

10 – 10:30 am – Break

Session 1H • Fantasia M/N

CERAMICS & COMPOSITES I

Session Chair: C. Korach, University of Mount Union, Alliance, OH

8 – 8:30 am Tribological Background for the Use of Niobium Carbide as Cutting Tools and Wear Resistant Tribosystems
M. Woydt, 6.3 Tribology&Wear Protection, BAM, Berlin, Germany
The tribological profiles of rotating disks in binder-less niobium carbide (hot-pressed) or in Co-bonded NbC (SPS) sliding against stationary toroids in alumina (99.7%) were determined (0.1-8.0m/s;22/400°C) as well as in oscillation tests (f=20Hz, dx=0.2mm, 2.5/5000% r.p.m, n=105/106cycles) under dry conditions. Microstructure and mechanical properties were determined, including the elastic modulus up to 1,200GPa. The RT wear rates of HP-NbC were low and less sensitive to increasing sliding speeds. Increasing sliding speeds to 8.0m/s decreased the wear rates of NbC-8Co down to outstanding low values of k of 1-5 10-7 mm3/Nm. Wear rates at 400°C of NbC grades remained generally below 10-6 mm3/Nm independent from sliding speed. Cutting tests underlined the suitability of NbC as a cutting tool material. Niobium carbide is today still a forgotten carbide with hidden properties, such as wear resistance, thus qualifying NbC for the group of tribological materials with enhanced wear resistance.

8:30 – 9 am Material Degradation of Titanium Matrix Composite (TiB+TiC)/Ti-6Al-4V under Contact Fatigue: A Micromechanical Investigation
X. Jin, F. Duan, R. Zhang, F. Niu, Q. Zhou, Chongqing University, Chongqing, China, Q. Wang, Mechanical Engineering, Northwestern University, Evanston, IL
Our recent rolling contact fatigue (RCF) experiments on titanium matrix composite (TiB+TiC)/Ti-6Al-4V reported that the variation of the volume fraction of the titanium constituent may cause noticeable changes of the fatigue life. This work presents both experimental investigation and theoretical exploration on the microstructural evolution in rolling contact fatigue. The morphology and
microstructure of the composite alloy after RCF are examined by focus ion beam (FIB) and scanning electron microscopy (SEM), where the resulting data are then used to digitally regenerate the microstructures during various stages of the RCF. A computational study is conducted to explore the influences of the microstructure on the stress field distribution. Finally, to correlate with the experimental observations, a phenomenological damage model incorporating micromechanics analysis is proposed to predict the microstructural evolution.

9 – 9:30 am
Cutting and Grinding Fluids for Ceramics and Composites
E. Jones, Hangsterfer’s Labs Inc., Mantua, NJ
Ceramics and Composites pose some unique challenges when cutting and grinding them into various shapes and sizes. Successful means to overcome these challenges will be discussed in great detail. Traditional cutting and grinding fluids may not be suitable for these processes and alternative cutting and grinding fluid technology may be required. The fact is that many of the benefits of using a cutting and grinding fluid for traditional materials such as ferrous and non-ferrous alloys are still required and beneficial when cutting and grinding ceramics and composites. The cutting and grinding fluids’ chemical compositions, compatibilities, maintenance, filtration, health, safety and environmental issues will be discussed. In addition to cutting and grinding fluids, cutting tools and abrasives will be discussed. Ceramics and Composites are a rapidly growing sector and the need to improve productivity and component integrity is imperative to implementing their success.

10 – 10:30 am – Break

Session 1I • Fantasia P/Q

ROLLING ELEMENT BEARINGS I
Session Chair: A. Ashtekar, Cummins, West Lafayette, IN
Session Vice Chair: J. Lai, SKF, Nieuwegein, Netherlands

8 – 8:30 am
Investigation of Residual Compressive Stresses in Rolling Bearing Components and Their Impact on the Rating Life
A. Pabst, Schaeffler Technologies AG & Co. KG, Herzogenaurach, Germany, S. Tremmel, S. Wartzack, Chair of Engineering Design, Erlangen, Germany
An option to increase efficiency in drive train applications is the downsizing of rolling bearings. However it must be taken into account that this will reduce the load carrying capacity of the bearing. Therefore, it is necessary to increase its fatigue life. Based on this approach, this paper focuses on the selectively introducing of residual compressive stresses in rolling bearing components to increase the rating life. Several methods which introduce residual compressive stresses will be presented and compared. With the aid of different equivalent stress analyses, the calculative impact on the contact will be identified and the effect on the rating life qualitatively assessed. In addition to theoretical observations, the results of tests on rolling bearing rating life will be presented. This will prove experimentally that the rating life was increased by means of residual compressive stresses in areas subjected to rolling contact fatigue.

8:30 – 9 am
Case Depth and Load-Carrying Capacity of Surface Induction Hardened Bearings
J. Lai, SKF Engineering & Research Centre, Nieuwegein, Netherlands
Surface induction hardening (SIH) is an attractive heat treatment process in view of the benefits like efficient energy utilization, short cycle time, integration in the channel, better distortion control, and environmental friendliness. The load-carrying capacity of an SIH bearing is dependent on, among others, the depth of the hardened layer, i.e., the case depth (CD). A well-accepted method is lacking for evaluating the minimum CD and load rating of SIH bearings. This is especially so for large size bearings when considering reliability and cost-efficient production. New theoretical models are developed for evaluating the static and dynamic load-carrying capacities of SIH bearings that account for CD, strength of the core, steel cleanliness and bearing size or volume at risk. The models enable design of SIH bearings that meet requirements on life expectancy and the avoidance of intolerable raceway indentation or severe “core crushing” failures as a result of extreme load conditions.

9 – 9:30 am
Contact Plastic Deformation in the Cycle of a Ball Rolling
D. Li, Z. Wang, X. Jin, Mechanical Engineering, Chongqing University, Chongqing, China, Q. Wang, Mechanical Engineering, Northwestern University, Evanston, IL
The information of rolling contact plastic deformation is of significance for ball bearing design. A three-dimensional (3D) spherical numerical elasto-plastic contact model and the analysis of the ball plastic deformation in one cycle of ball motion in a bearing contact are reported in the presentation. Ball rotation kinematics and the contact load variation are considered in the plastic strain and residual stress calculations by means of a return mapping algorithm in the cycle of a ball rolling. The elasto-plastic characteristics, such as residual stress and shakedown, of balls with 3D roughness topography are numerically investigated.

9:30 – 10 am
Internal Loading Distribution in High-Speed Ball Bearings, Subjected to a Combined Radial, Thrust, and Moment Load, Including the Effects of Temperature and Fit
M. Ricci, ETE/DMC, INPE, São José dos Campos, Brazil
A numerical procedure for internal loading distribution computation in high-speed, single-row, angular-contact ball bearings, subjected to a known combined radial, thrust, and moment load, is revisited and used to find the load distribution differences between a loaded unfitted bearing at room temperature, the same loaded bearing at the same temperature but fitted with interference fits, and the same loaded bearing such might experience radial temperature gradients between inner and outer rings. For each step of the procedure it is required the iterative solution of several simultaneous nonlinear equations to yield exact solution for axial, radial, and angular deflections, and contact angles.

10 – 10:30 am – Break
Monday, May 19

Session 1J • Republic A

ENVIRONMENTALLY FRIENDLY FLUIDS I: BIODEGRADABILITY AND ENVIRONMENTALLY ACCEPTABILITY

Session Chair: B. Sharma, UIUC/PRRI/ISTC, Champaign, IL
Session Vice Chair: J. Perez, Pennsylvania State University, University Park, PA

8 – 8:30 am
The Conflict Between Biodegradability and Environmentally Acceptability of Lubricants
W. Bartz, Tribology, Technische Akademie Esslingen, Ostfildern, Germany

Often the environmentally acceptability is equated with the fast biodegradability. But for the biodegradation process oxygen is necessary. If large amounts of lubricants will be introduced into the environment, for instance as an accident, so much oxygen has to be taken from the surrounding that other organisms will suffer.

Nevertheless the regulations to define environmentally acceptable lubricants, which are listed in the framework to receive the European Eco-Label do not consider this aspect. The criteria for the Eco-Label include environmentally and human health hazards, aquatic toxicity requirements, biodegradability, exclusion of specific substances, the imperative use of renewable raw materials and of course the technical performance. Details of these criteria will be explained in the presentation.

8:30 – 9 am
Biodegradable Lubricants – Performance Counts
M. Miller, RSC Bio Solutions – Terresolve Technologies, Mentor, OH

This paper compares the performance of several types biodegradable hydraulic fluids as well as that of petroleum. Testing was done by a variety of different test protocols. This testing shows that there are major performance differences among types of biodegradable lubricants some of which can offer superior performance to petroleum. Commercially available biobased, biodegradable synthetic and petroleum fluids were tested for physical and chemical characteristics; application performance: low temperature properties; thermal and oxidative stability; hydrotropic stability; and filterability. Each parameter was evaluated utilizing industry recognized testing protocol as well as those of major equipment manufacturers. The results of each test is reviewed and supported with the original data, and tables or graphs as is appropriate.

9 – 9:30 am
Test Methods for Testing Biodegradability of Lubricants – Complete or Not Complete?
B. Mueller-Zermini, Laboratory, Hermann Bantleon GmbH, Ulm, Germany, G. Gaule, Hermann Bantleon GmbH, Ulm, Germany

The mineralization methods are often called “complete degradation” because the molecules of the sample are broken down to the final product carbon dioxide which is an indicator for how much of the test substance is already degraded. But this doesn’t mean that all molecules of the sample are broken down to carbon dioxide, because a biodegradation rate of 60% is enough to be considered as biodegradable. In case of a sample which contains only one kind of molecules (pure substance), this interpretation may be right. But in case of a mixture an interpretation of a positive test result (>60%) is impossible, as there could be components which are not all biodegradable. In this case the term “complete degradation” is a misleading description. In the presentation we want to compare different test methods concerning their precision and the quality of their test results.

9:30 – 10 am
Environmentally Acceptable Fluids for Ultra Deep Water
B. Roell, Research and Development, RSC Bio Solutions, Indian Trail, NC

Since all fluids compress at high enough pressures, this technical session would review challenges and requirements of lubricants in ultra deep water applications, outlining the relationship between pressure, volume and viscosity. The effects of fluid compression include increased viscosity, reduced system efficiency, delayed response, power loss, reduced flow and system starvation. These effects require exact lubricant formulation and an understanding of compressibility in terms of the fluid’s bulk modulus of elasticity – expressed V = f(P/V0,K) where P = pressure, V = fluid volume, K = compressibility (1/in.2/lb.) and (V-V0)/V = specific volume. The session would also include the relationship of bulk modulus to air and temperature, and testing information on various lubricant categories. Finally, the session would deliver information on not only effective and ineffective fluid categories based on their inherent properties, but also apparatus design criteria to enhance overall systemic success.

10 – 10:30 am – Break

Session 1K • Republic B

METALWORKING I: THE CHEMISTRY OF METALWORKING

Session Chair: K. Eisenhauer, Integrilube, Bonita Springs, FL

8 – 8:30 am
“Tripod” Emulsifiers: Reducing the Tension between Oil and Water
M. McGuiness, T. Oleksiak, Lubrizol Corporation, Wickliffe, OH

Nonionic surfactants are used in metalworking applications to provide emulsification properties, which include pH stability and hard water tolerance. In 2011, a few key metalworking nonionic emulsifiers were threatened by supply issues. In response to this, a novel class of emulsifiers has been developed to address this market need. These emulsifiers are formed from the reaction between a multi-functional ethoxylation and a capping hydrophobe. The resulting structure has multiple hydrophobes and has been nicknamed “tripod.” As with conventional alcohol alkoxylates, this chemistry offers the flexibility to tailor the HLB of the surfactant. Additionally, these emulsifiers demonstrate unique properties which include significantly improved emulsifier efficiency, low critical micelle concentration (CMC) and very low interfacial tension.

8:30 – 9 am
Fatty Alkanolamines, Fatty Alkanolamides and Mixed Amino-Amide Molecules as Performance Enhancers in Emulsion Metalworking Fluids
M. Gernon, K. Buyse, Tamincos Research, Taminco, Allentown, PA

Fatty alkanolamides are commonly used as rheology modifiers, corrosion inhibitors and emulsifiers in semi-synthetic metalworking fluids. The structurally similar fatty alkanolamines are also effective as fluid emulsifiers, corrosion inhibitors and biostabilizers. Secondary alkanolamides (i.e., amides produced with a primary alkanolamine) may exist as “normal” amides, or, under certain conditions, may be converted by dehydrative cyclization to 2-oxazolines. The oxazoline form, versus the amide form, of certain secondary alkanolamides is known to provide for significantly improved stabilization of macroemulsions. This talk will present a summary of the preparation, properties and functioning of relevant alkanolamines, alkanolamides and mixed...
amide/amine compounds in metalworking fluids. The benefits of certain types of structures with respect to enhanced activity, improved stability and low volatility will be highlighted.

9 – 9:30 am
Study Amines as an Additive for Metalworking Fluids
K. Koh, Chrysyan Industries, Inc., Plymouth, MI
Ten amines (Alkanol Amines, Cyclic Amines, Amino Alcohols, Ethoxylated Fatty Amines) and a Cataionic Compound (Dodecyl Dimethyl Ammonium Compound) were studied for metal corrosion inhibitors; such as Cast Iron, Copper, 6061 and 7075 Aluminum and Magnesium. The study of their bioreistance and lubricity characteristics were included. The modified McDonnell Douglas method for bioactivity and Falex Pin and Block tester for lubricity were used. DDAC has excellent corrosion protection for Aluminum, Copper and Magnesium. But Cast Iron corrosion inhibition was the worst among the ten additives. One Ethoxylated Fatty Amine has the highest lubricity but bioreistance was the worst. The other amines have good Cast Iron corrosion protection, but Aluminum and Magnesium corrosion were not acceptable. Based on the performance of corrosion, lubricity and bioreistance, DDAC was chosen as the candidate for further study in formulation of Semi-Synthetic and Synthetic Coolant application.

9:30 – 10 am
New Tool Box for Superior Foam Control in Metalworking Fluids
M. Stapels, R&D, Kao Chemicals GmbH, Emmerich, Germany
One of the crucial components utilized to formulate soluble and semisynthetic oils are emulsifiers. Natural sodium sulfonates have been the traditional choice because they combine emulsification and rust inhibition performance. Since the closing of the Shell Martinez plant in 2003 at the latest the emulsifier market is in a state of flux. Alternate chemistries such as synthetic sodium sulfonates and PIBSAs appeared on the scene. One of the most promising alternate chemistry for this application is the class of ether carboxylates as they enhance significantly the stability of the concentrate as well as the resulting emulsion – furthermore they increase the robustness of the fluids overall performance. A new group of ethercarboxylates with an additional block of propylene oxide shows significantly reduced foaming potential properties which makes them highly attractive for foam critical applications like high pressure coolants.

10 – 10:30 am – Break
Session 1L • Republic C/D

COMMERCIAL MARKETING FORUM I

8 – 8:30 am
Sentient Science Corporation
Computational Tribology & Life Extension Solutions
E. Wagner, Sentient Science Corporation, Buffalo, NY
Sentient Science is the newest commercial company in tribology. You may not know our name yet, but we are already managing the prognostic health performance of more wind turbine gearboxes than any new technology company in the US. Sentient Science is offering asset management services for gearboxes in the energy, rotorcraft, and vehicle markets – specifically for life extension of new and fielded assets. We are providing asset remanufacturing services by computational testing gearbox components, and asset surface treatment design & testing services for drivetrain component life extension including texturing, superfinish and coatings. Our customers include Boeing, BP, Sikorsky, Army, Navy, Air Force, Moog, Deere, Dana, GE, and others. If you’re looking for computational testing as a way to optimize your overall testing budget, or a condition based maintenance application especially for high value assets, make sure to see a demonstration of Sentient Science’s DigitalClone Live application at Booth 507.

8:30 – 9 am
ALS Tribology
The Quick and Dirty on Turbine Oil Testing
M. Holloway, ALS Industrial Division, Tribology, Houston, TX
This presentation offers a quick general overview of turbine oil and associated testing for reliability. The subject provides reference to industry standards such as ASTM 4378 and product formulation requirements, with a focus on key laboratory tests applicable to turbine oil formulation performance and in-service reliability in relation to formulations, testing frequency, machine design, oil compatibility and cleanliness. The presentation provides an excellent primer and promotes discussion around a timely subject. Michael Holloway of ALS Tribology will present and facilitate questions and answer.

9 – 9:30 am
The Lubrizol Corporation
High Performance Hydraulic Fluids – Lubrizol’s New Biodegradable Hydraulic Technology
K. Work, The Lubrizol Corporation, Wickliffe, OH
In recent years, the demand for eco-friendly, biodegradable, hydraulic fluids with high renewable content have increased. Biodegradable hydraulic fluids need to exhibit low toxicity, and biodegrade readily. Biodegradable hydraulic fluids must also deliver the same level of performance as mineral oils. Historically, formulators have been challenged when formulating biohydraulic fluids. Balancing critical performance attributes such as oxidation stability and anti-wear performance, while maintaining an excellent biodegradability and toxicity profile has been extremely difficult for formulators. A low toxicity, biodegradable product line with high renewable content was developed that exhibits excellent performance in bench tests against industry specifications. These synthetic ester based fluids have received EU Ecolabel approval, are listed as United States Department of Agriculture (USDA) BioPreferred® for their high renewable content, and also meet the new Vessel General Permit (VGP) requirement released by the Environmental Protection Agency (EPA). The fluids also exhibit excellent antitrust performance, load-carrying capacity, corrosion and oxidation properties, and exhibit high levels of thermal and hydrotlatic stability. The presentation will summarize efforts to develop biodegradable hydraulic fluid technology delivering equipment protection, performance and eco-friendly properties.

9:30 – 10 am
The Dow Chemical Company
Differentiate Your Lubricant with UCON™ Oil-Soluble Polyalkylene Glycol Technology
C. Walker, The Dow Chemical Company
Dow’s UCON™ Oil-Soluble Polyalkylene Glycols (OSPs) are quickly gaining marketplace interest as a true differentiator in various lubricant applications! Whether used as a primary base oil or as an additive, OSPs deliver significantly improved characteristics in areas such as friction reduction, deposit and varnish control, hydrotlatic stability, air release, and elastomer swell. Join us to see how Dow’s technology is advancing the world of lubricants and learn more about how UCON™ OSPs can help provide a positive and direct impact on your equipment performance as well as an extension of your fluid life!

10 – 10:30 am – Break
Monday, May 19

LUBRICATION FUNDAMENTALS II: IONIC LIQUIDS LUBRICATION AND MORE

Session Chair: I. Minami, Luleå University of Technology, Lulea, Sweden
Session Vice Chair: N. Doerr, AC2T research GmbH, Wiener Neustadt, Austria

1:30 – 2:00 pm
Ionic Liquids and Their Interaction with Ashless Alkylphosphorofluoridothioate Additives to Improve Friction and Wear Behavior
V. Sharma, P. Aswath, Materials Science and Engineering, UTA-Materials Science and Engineering, Arlington, TX, N. Doerr, Lubricants and Surface Interactions, AC2T research GmbH, Wiener Neustadt, Austria

Possibly synergistic interactions of ionic liquids with the alkylphosphorofluoridothioate (FTPs) were studied to evaluate their friction and wear behavior. Six different ionic liquids were assessed in blends of group I base oil using a cylinder-on-disc oscillating tribometer. The three best performing ionic liquids were then further examined with the addition of 20%FTPs ashless antiwear additive. The nano-mechanical properties of tribofilm formed were studied using nano-indentation. The chemical nature of the films was explored using advanced surface characterization techniques such as XANES (x-ray absorption near edge structure spectroscopy), SEM and EDAX. Base oil and ZDDP in base oil tests were also run for baseline comparison. Ionic liquids with addition of alkylphosphorofluoridothioates exhibit equivalent or improved wear protection on the rubbed surfaces in comparison to ZDDP.

2 – 2:30 pm
Ionic Liquids Composed of Phosphonium Cations and Organophosphosphate, Carboxylate, and Sulfonate Anions as Novel Lubricant Anti-Wear Additives
Y. Zhou, H. Luo, D. Leonard, J. Qu, Oak Ridge National Laboratory, Oak Ridge, TN, J. Dyck, T. Graham, Application Technology Group, Cytec Canada, Ontario, Canada

Oil-soluble ionic liquids (ILs) are potentially next-generation lubricant additives. In this study, three groups of phosphonium-based ILs containing an organophosphate, carboxylate, or sulfonate anion were synthesized and characterized for their feasibility as anti-wear (AW) oil additives. Density, viscosity, oil solubility, thermal stability, and corrosion were measured and used to screen the ILs. Five ILs were selected for tribological evaluation based on the oil-solubility and corrosion behavior. When added into a synthetic base oil, various treat rates were used for the ILs to achieve a similar level of phosphorus content of ~800 ppm. All selected IL additives substantially reduced the wear rate by ~80% compared to the base oil, and the phosphonium-phosphates were the most effective. Nevertheless, all five ILs outperformed a commercial amine-phosphate AW additive in wear protection. Surface characterization from top and cross-section revealed the nanostructure and composition of the tribofilms formed by the ILs and help correlate the IL chemistry with the wear protection mechanism.

2:30 – 3 pm
Development of Oil-Miscible Phosphonium-Based Ionic Liquids as Anti-Wear Lubricant Additives
Y. Zhou, J. Dyck, T. Graham, Materials Science and Engineering, Texas A&M University, College Station, TX, H. Meyer, W. Barnhill, J. Qu, Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, TN

This study reports the latest results of a joint effort between ORNL and Cytec to develop phosphonium-based ionic liquids (ILs) as anti-wear lubricant additives. Three groups of phosphonium-based ILs containing phosphate, carboxylate, or sulfonate anions were designed and synthesized. Different treat rates were used for the ILs when mixed with a PAO base oil to ensure 800 ppm levels of phosphorus. A linearly reciprocating ball-on-flat sliding test using an AISI 52100 steel ball against a cast iron flat was performed at 100 °C to evaluate the anti-wear performance of the ILs. All tested IL additives exhibited wear reduction, though to varying extents. Molecular dynamic simulations were conducted to understand the interactions between ILs’ ions, oil molecules and metal surfaces. The molecular structures of ILs are correlated with their oil-solubility, thermal stability, and lubricating performance and will be used to guide further development and optimization.

3 – 4 pm – Exhibitor Appreciation Hour
(Evonik Raffle 3:30 pm)

4 – 4:30 pm
Long-term Performance of Model Oils Containing Ionic Liquid Additives
N. Doerr, AC2T research GmbH, Wiener Neustadt, Austria, P. Aswath, University of Texas at Arlington, Arlington, TX

Ionic liquids are more and more noticed as lubricant compounds both as base oils and additives. While the fundamental performance of some ionic liquids in lubricants is available, their long-term properties are widely unknown. In this work, model oils containing ionic liquids as additives were analysed before and after artificial alteration. Lab-based alteration under defined conditions – typically elevated temperature, air flow, and presence of catalysts – provided samples of different degrees of deterioration. These samples were supplied to physical-chemical, e.g. ionic liquid solubility, and tribometrical characterisation. This way, an additional tool is provided for 1) benchmarking of ionic liquids against conventional chemistries, 2) selection of appropriate ionic liquids and 3) improvement of oil formulations.

4:30 – 5 pm
Ionic Liquids and Ionic Liquid-Mediated Dispersions of Nanomaterials as High Performance Additives for Lubricants

Due to unique properties ionic liquids(ILs) possess great potential in a variety of industrial applications: some are already identified, in particular in high vacuum or extreme temperature applications. Low vapor pressure, incombustibility, thermal stability, low friction in mixed lubrication and better scuffing protection in boundary lubrication make ILs promising candidates for the use in lubrication. Highly surface active ILs can be used to prepare stable dispersions of nanoparticles(NPs) that show itself good tribological performance. Anti-wear properties of the base oil can be improved by addition of carbon allotropes. These dispersions can be obtained by using ILs to design tailor-made lubricants, since the tribological performance could be improved by a combination of specific properties of ILs and NPs. We will present our latest results on the use of ILs as performance additives for lubricants and on the preparation of dispersions of tribologically interesting NPs by using ILs.
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Visit us at Booth 419 at STLE 2014
5 – 5:30 pm
Superlubricity with Acid Based Solution:
Hydrodynamic Lubrication or Boundary Lubrication?
C. Zhang, M. Deng, J. Li, J. Luo, State Key Laboratory of Tribology,
Tsinghua University, Beijing, China
Superlubricity is defined as the sliding friction coefficient in the 0.001
order of magnitude. The superlubricity can be achieved either by solid
self-lubrication films or by the chemical or physical effects coming
from the inter action between the solid surfaces and the water
molecules. In 2011, we found that a super low friction coefficient of
0.004 can be obtained when lubricated the glass plate and Si3N4 ball
with phosphoric acid solution. After that, more solutions were found to
obtain superlubricity, such as acid and glycerol mixed solutions and
acid and polyhydroxy alcohols solutions. However, the mechanism of
the superlubricity is still under debate. In this paper, the hydrodynamic
effect and the hydration effect on the superlubricity are discussed in
detail. The calculational and experimental results indicated that water
film cannot be established by the hydrodynamic effect. The super low
friction is attributed to the hydrated water molecules in the hydrogen
bonding network.

5:30 – 6 pm
The Expected Laws on the Change of Colors
of Contaminants of Used Lubricating Oils
A. Sasaki, Maintek Consultant, Yokohama, Japan, T. Honda, Y. Iwai,
University of Fukui, Fukui, Japan, K. Matsumoto, Honda R & D Co.,
Ltd, Utsunomiya, Japan
There are many beautiful things with colors around us. We want to see
and touch beautiful things. When we talk about colors on tribology, we
will immediately think of colors of oils. But contaminants in used
lubricating oils are dirty. Therefore we do not want to touch them. Even
such contaminants have color but we do not pay any attention to
colors of contaminants. The authors have studied colors of
contaminants of lubricating oils. In the course of studies, we have
noticed that the color of contaminants of used lubricating oils is also
governed by the laws of nature. We consider that we may expect the
conditions of lubricating oils by examining the change of colors of
contaminants of lubricating oils. This paper reports our findings on the
laws of color change of contaminants in used lubricating oils.

3 – 4 pm – Exhibitor Appreciation Hour
(Evonik Raffle 3:30 pm)
4 – 4:30 pm
Tribological Aspects of Nanomanipulations
of Nanostructures Inside a Scanning Electron
Microscope
R. Lohnus, M. Antsov, L. Dorogin, M. Umalas, Institute of Physics,
University of Tartu, Tartu, Estonia, S. Vlassov, B. Polyakov, Institute of
Solid State Physics, University of Latvia, Riga, Latvia, I. Kink,
S. Oras, M. Vahtrus, Estonian Nanotechnology Competence Centre,
Tartu, Estonia
Real-time manipulation technique employed for measurements of
static and kinetic friction of nanoparticles and nanowires on substrates
with different roughness is demonstrated. The experiments are
performed inside a scanning electron microscope (SEM) equipped with

Session Chair: K. Rowe, University of Florida, Gainesville, FL
Session Vice Chair: M. Schirru, The University of Sheffield,
Sheffield, United Kingdom
1:30 – 2 pm
In Situ Determination of Interfacial Wear
Temperatures Using an Inverse Approach
A. Segall, Penn State University, University Park, PA
During tribotesting and machining, frictional temperatures are of
interest. Unfortunately, it is difficult to directly interrogate interacting
surfaces, especially when the interface recedes. While remote
measurements of temperature are obtainable, they only hint of the
frictional temperatures unless just below the surface and thus,
vulnerable to wear. To overcome these difficulties, a least-squares
enforcement of remote temperature (or strain) data was used with a
solutions for useful geometries including a slab, hollow cylinder, and
solid cylindrical with a receding end at a constant rate. Comparisons
between the resulting interfacial predictions and existing data showed
excellent agreement and verified the ability of the method to determine
temperatures based on remote data. Stray transfer, dimensions, and recession velocity clearly influenced the interfacial
temperatures and has important ramifications for tribotesting.

2 – 2:30 pm
Frictional Heating of Sliding Elastomer Contacts
Due to a Prescribed Heat Source
A. Bennett, K. Rowe, W. Sawyer, T. Angelini, Mechanical and
Aerospace, University of Florida, Gainesville, FL
Problems in the subject of frictional heating have been studied
extensively yet their complexity remains a barrier to further
understanding. This study simplifies the frictional heating problem by
examining the temperature rise due to a heat source of prescribed
geometry. A single positive feature on the sliding face of the counter-
surface causes a local temperature rise. The cylindrical feature is 18 µm
tall with a diameter of 150 µm and it slides under the larger contact
area whose diameter is ~600 to ~750 µm. An infrared camera, acquiring
at 870 Hz, observed the temperature rise at the contact surface
between the feature and the rubber pin. The applied force for all tests
was 200 mN and the sliding velocity was varied from 10 to 200 mmps.
Maximum temperature rises ~1 to 17 °C and average temperature rises
of ~1 to 8°C were measured. Measured values were compared to the
Jaeger frictional heating models for sliding contacts.

2:30 – 3 pm
In Situ Nano-Tribology Experiments in TEM:
Examinations of the Behavior of Single
Nanoparticles
A. Molza, J. Mansot, Universite des Antilles et de la Guyane,
Guadeloupe, France, M. Guinel, Departments of Chemistry and
Physics, , University of Puerto Rico, San Juan, , United States Minor
Outlying Islands
The present work is concerned with the study of the behaviour of
individual aggregates of fluorinated carbon nanoparticles when
submitted to compressive and shear stresses. In situ TEM experiments
were carried out using a high resolution transmission electron micro-
scope (JEOL JEM-2200FS), operated at 200 kV using a Nanofactory
Instruments AFM holder. The nanoparticles studied are fluorinat-
graphitized carbon blacks prepared at the Institut de Chimie de
Clermont-Ferrand (France). They are constituted of a graphitized core
surrounded by a fluorinated shell (10 nm thickness) and had sizes
ranging from several nanometers to several micrometers. They present
a fluo to carbon atomic ratio of 0.16. The aggregates showed remarkable
stability during the in situ nano-tribology experiments. The particles
remained strongly bonded to each others. Individual aggregates behave
elastically when relatively large compressive stresses were applied.
In Situ Observations of the Transfer and Wear of Gold on Nickel in Vacuum
K. Rowe, K. Harris, W. Sawyer, Mechanical and Aerospace Engineering, University of Florida, Gainesville, FL, N. Argibay, Sandia National Laboratories, Albuquerque, NM

A compact pin-on-disk micro tribometer was constructed for use inside of an environmental scanning electron microscope (SEM) with elemental analysis capabilities. The design allows for the uninterrupted sequential imaging of the evolving wear surface without compromising the environment. The instrumentation is capable of applied normal loads from 1-1,000 mN, rotational speeds up to 720 °/s, and environmental pressures of < 9E-3 to 20 Pa. The evolution of material transfer between high purity gold and nickel illustrates the imaging and tribological capabilities of the instrument and has implications in enhancing the understanding of wear mechanisms.

In Situ Examination of Fluoropolymer Transfer Film Generation Using Scanning Electron Microscopy
A. Pitenis, K. Harris, K. Rowe, W. Sawyer, Mechanical and Aerospace Engineering, University of Florida, Gainesville, FL, B. Krick, Mechanical Engineering and Mechanics, Lehigh University, Bethlehem

Polytetrafluoroethylene (PTFE) is an excellent candidate material for solid lubrication applications due to its low friction coefficient and vacuum compatibility, but it suffers from a high wear rate. This work investigates the wear mechanisms of PTFE when sliding against a metal countersample using an in situ environmental scanning electron microscope (ESEM) pin-on-disk tribometer. Backscattered electron imaging showed the morphological and compositional evolution of a dynamically formed PTFE transfer film. Several different sliding conditions, including varying countersample surface roughnesses, were explored. These experiments are compared to results from PTFE sliding against metal in an in situ surface plasmon resonance (SPR) tribometer, which revealed transfer of PTFE occurring after as early as one cycle of sliding. This further reveals the multi-scale mechanisms involved in wear of PTFE, which spans from molecular scale chain scission and transfer to large scale delamination.

The Mechanism of a Wavy-Tilt-Dam Mechanical Seal in Reactor Coolant Pump
W. Liu, Y. Liu, Y. Wang, Mechanical Engineering, Tsinghua University, Beijing, China

A three-dimensional thermal-elastic-hydrodynamic model of a wavy-tilt-dam mechanical seal is established to study the multi-field coupling mechanism. The quasi-start-up and steady state working conditions are investigated. The results show that during the speed-up period, the minimum film thickness and maximum temperature obviously increase due to the shear force in the circumferential direction, and the maximum temperature located near the inlet where the maximum pressure appears, as well as the reflow. When in the pressure-up duration, attributing to the increase of radial velocity, the location of seal face fluid maximum temperature moves from near the inlet to the outlet. Even though no cavitation occurs under steady state condition, the waves on the seal face by affecting the pressure and temperature distribution, increasing the thermal-elastic deformations. This in turn will increase the convergence in the radial direction and the wave amplitude in the circumferential direction.

Simulation of a Hydraulic Rod Seal with a Micro-Patterned Rod
Y. Huang, R. Salant, Georgia Institute of Technology, Atlanta, GA

A numerical analysis of a reciprocating hydraulic rod seal operating with a rod containing a pattern of triangular micro-cavities has been performed in an effort to reduce the friction force produced by hydraulic seals. It consists of coupled fluid mechanics, contact mechanics and deformation analyses. The fluid mechanics analysis consists of a 2-D finite volume solution of the Reynolds equation. The deformation is computed with influence coefficients obtained from a finite element analysis. The dynamic contact mechanics analysis utilizes the Greenwood-Williamson model, while the static contact mechanics analysis utilizes the finite element analysis. The 3-D finite element analysis makes use of a unique approach to reduce the number of required elements to a manageable level. The fluid transport, friction force, contact pressure distribution and fluid pressure distribution in the sealing zone have been computed for a typical U-cup seal.

Preventing Ingress Contamination by Providing Bearing Cavity Pressurization
H. Dombroski, Air-Tight LLC, Boynton Beach, FL

This presentation relates to bearing cavity protection where the bearing cavity may be submerged underwater or operates in a harsh environment. What we will discuss is the prevention of ingress contamination by means of: 1. Hermetically sealing the bearing cavity; 2. Pressurizing the bearing cavity with low air or nitrogen; 3. Controlling the pressure in the bearing cavity 24/7; 4. Giving a visual and physical indication of the amount of pressure; 5. Indicate bearing cavity integrity 24/7. For an attendee that has current contamination issues and has tried everything, this presentation will give them an alternative method to prevent ingress contamination with indication of bearing cavity integrity 24/7.

Exhibitor Appreciation Hour
(Evonik Raffle 3:30 pm)
An Experimental Investigation on Brush Seal Hysteresis
K. Du, Y. Li, S. Suo, Y. Li, Y. Wang, Mechnical Engineering, Tsinghua University, Beijing, China

Brush seals represent a compliant seal configuration. Brush seal offers better leakage performance than traditional labyrinth seal. It is applied between the rotating and the stationary on the aero-engine and the aero-engine and the plate on the brush seal hysteresis was investigated by contact force testing. The results show that the simulation gives a very good qualitative agreement to the measurements. This leads to the conclusion that this tool is very well suited for quick assessments of seal designs.

4:30 – 5 pm
Experimental Validation of Fluid Film Simulation of a Hydraulic U-cup Seal
F. Kaiser, S. Eckert, E. Bock, Advanced Product Technology, Freudenberg Sealing Technologies, Weinheim, Germany, B. Sauer, Institute of Machine Elements, Gears and Transmissions, University of Kaiserslautern, Kaiserslautern, Germany

A model to solve the steady-state, smooth-surface elastohydrodynamic problem of flexible seals has been developed. The model uses a modified inverse-hydrodynamic-lubrication (IHL) approach with a special treatment of the booster zone just in front of the contact. This approach results in a very fast and stable program for an approximate solution of the EHL sealing problem. The tool enables the user to analyze the influence of various parameters in a relatively short time. In the presentation, the impact of the coefficient of friction and the seal lip radius is demonstrated. The findings are compared to test results which have been obtained on a test rig set up to closely represent the conditions assumed in the simulation model. The results show that the simulation gives a very good qualitative agreement to the measurements. This leads to the conclusion that this tool is very well suited for quick assessments of seal designs.

5 – 5:30 pm
An Experimental Investigation on Brush Seal Hysteresis
K. Du, Y. Li, S. Suo, Y. Li, Y. Wang, Mechnical Engineering, Tsinghua University, Beijing, China

5:30 – 6 pm
Elastohydrodynamic Model as Applied to the Actual Surface Topography of a Radial Lip Seal
L. Stephens, J. Wenk, D. Weatherly, W. Li, Mechanical Engineering, University of Kentucky, Lexington, KY, S. Lattice, Timken Technology Center, The Timken Company, Canton, OH

An elastohydrodynamic model of the contact zone between the elastomer of a radial lip seal and a shaft surface has been developed that considers both the fluid mechanics of the lubricating film and the elastic behavior of the lip including the actual surface topography of the elastomer in a compressed state under an interference fit with the shaft surface. The inclusion of actual elastomer surface roughness greatly enhances correlation between analytical performance predictions and experimental measurement of power loss and pumping rate.
the Ree-Eyring shear thinning model was favoured and widely used. More recently the Carreau-Yasuda model, based on high pressure rheological measurements has been very strongly propounded. The paper will discuss and compare the two models in terms of their effectiveness in predicting EHD friction.

2:30 – 3 pm
Elastohydrodynamic Properties of Heat-bodied Oils
G. Biessaw, G. Banchev, T. Kurth, K. Doll, Bio-Oils Research Unit, USDA-ARS, Peoria, IL, B. Sharma, Illinois Sustainable Technology Center, University of Illinois, Urbana–Champaign, IL, S. Erhan, Eastern Regional Research Center, USDA-ARS, Wyndmoor, PA

Heat bodied oils are biobased oils obtained via thermal treatment of vegetable oils, under inert (N2) atmospheric conditions. Most heat bodied oils are based on soybean oil but other vegetable oils and blends of vegetable oils can also be utilized to obtain specific properties. Depending on the temperature and duration of the thermal treatment, various viscosity grades of high molecular weight heat bodied oils can be produced. In this work a series of soybean based heat bodied oils of wide range viscosity grades (68 – 1250 mPa-s at 40 °C) were synthesized and their elastohydrodynamic properties investigated. The effect of heat-bodied oil structures on density, viscosity, viscosity index, film thickness and pressure viscosity coefficients will be discussed.

3 – 4 pm – Exhibitor Appreciation Hour
(Evonik Raffle 3:30 pm)

4 – 4:30 pm
Rheology of Engine Oil Viscosity Modifiers
M. Webster, R. Locker, J. Soulages, A. Tsou, CSR, ExxonMobil Research and Engineering, Annadale, NJ, Y. Yang, ExxonMobil Chemical Company, Baytown, TX

Viscosity modifiers (VMs) are used to optimize viscosity temperature characteristics. This has allowed modern engine oils to balance the need to limit the effects of increased viscosity at ultra low temperatures while maintaining the ability to generate good lubricating films at high temperature. The polymeric nature of VMs also imparts other rheological properties such as non-Newtonian viscosity versus shear behavior. Commercially available VMs are based on a wide range of polymer architectures. The rheological properties that these impart on the fluid can be related to the size and shape that the polymers adopt when added to the engine oil. By using a combination of rheology measurements and simple models, light scattering techniques and molecular dynamics simulations we have studied the effect of molecular structure on VM coil dimensions and solvent-VM interactions. The study included commercial VMs and laboratory synthesized model materials. We will also present examples showing the response of non-Newtonian effects such as shear thinning, permanent shear degradation and extensional viscosity to molecular structure.

4:30 – 5 pm
Relationship Between Oil Viscosity in the Ring Zone and Film Thickness Leading to Wear
S. Hsu, F. Zhao, George Washington University, Washington, DC

Oil viscosity decreases as a function of temperature, leading to thinner oil film between the sliding surfaces. To increase oil film thickness in the engine hot zones, viscosity modifiers (VII) are used. Oil film thickness is also influenced by surface roughness. When the sliding contact is under compressive stresses, the asperities of the contact surface will undergo elastic and plastic deformation, shrinking the relative composite roughness to allow “thicker” oil films to exist. There are many ways to increase the bulk viscosity of the lubricant: change the VII to a high temperature stable VII, change the base oil structures, change the surface textures, etc. Another approach is to increase the near surface viscosity by chemically modify the surface; introduce molecular brushes, and in situ polymerization to attach large molecules on the surface. This paper will discuss our approaches to control rheology for engine applications.

5 – 5:30 pm
Influence of Surface-Oil Polar Interactions on Friction Performance
M. Kalin, M. Polajnar, Laboratory for Tribology and Interfaces Nanotechnology, University of Ljubljana, Ljubljana, Slovenia

This work shows the influence of solid-liquid interactions between engineering surfaces (steel and several types of DLC coatings) and lubricating oil (polyalphaolefin; PAO) on the coefficient of friction in the elastohydrodynamic lubrication (EHL) regime. Both the spreading parameter and the surface energy correlate very well with the friction in the EHL regime and can predict its behaviour. In particular, the polar component of the surface energy was found to correlate almost perfectly with the friction behavior. By tailoring the wetting and surface energy of various DLC/DLC contacts the coefficient of friction was reduced by more than 30 % compared to steel/steel contacts. A “Slip-inducing interaction model based on surface forces” is presented to explain why oil-slip is promoted, particularly at surfaces with a low polar surface energy. Relations between solid-liquid interactions, wetting, surface energy, slip and friction are discussed.

5:30 – 6 pm
The Use of Estolides to Produce High Performance Lubricants – A Closer Look at Estolide Properties
J. Bredsguard, T. Thompson, Biosynthetic Technologies, Irvine, CA

Many lubricant companies are now developing a wide variety of products using estolides to enhance performance characteristics and reduce environmental impact. Estolides, a new type of environmentally friendly synthetic base oil often referred to as a “biosynthetic,” are synthesized from vegetable oil and are biodegradable and nontoxic. With respect to performance, they have low volatility, excellent hydrolytic stability, and in some applications such as PCMO have been found to offer valuable cleanliness credits by reducing piston deposits. Formulations containing estolides have been able to successfully pass all engine tests required for API SN approval with one of the highest piston deposit ratings among current synthetic motor oils on the market. The use of estolides will allow lubricant formulators to generate quality products that meet or exceed required performance standards while using more environmentally acceptable ingredients in their formulations.
SYNTHETIC AND HYDRAULIC LUBRICANTS II

Session Chair: J. Sherman, BASF Corporation, Wyandotte, MI
Session Vice Chair: P. Cusatis, BASF Corporation, Tarrytown, NY

1:30 – 2 pm
Measuring Total Energy Efficiency in a Hydraulic System
S. Basu, H. Zhao, A. Rajakumar, E. Akucewich, The Lubrizol Corporation, Wickliffe, OH
A typical hydraulic system consists of many components like a pump, motor, valves, filters, and hoses. When a fluid passes through the system, some power is lost in each of these components, which impacts the overall system efficiency. Measuring efficiency of any one component only gives a partial picture. To better understand the energy efficiency of a hydraulic system, it is important to measure the power loss in each component along with that of the overall system. Currently, there is no standardized test to measure the energy losses in the whole system.

This paper describes a specially designed test to measure the power losses in each of the components as well as the whole system. The effect of lubricant selection on the power loss can be realized by conducting the tests over a range of temperature and loads. This work indicates that selecting the right lubricant can lead to reduced component power losses and increased total system efficiency.

2 – 2:30 pm
An Investigation of Viscosity Effects on Axial Piston Motor Efficiency
P. Michael, Fluid Power Institute, Milwaukee School of Engineering, Milwaukee, WI
This paper examines the relationship between axial piston motor efficiency and dimensionless viscosity. The volumetric, mechanical, and overall efficiencies of hydraulic motors were measured under steady state conditions. Newtonian and non-Newtonian antweare hydraulic fluids were evaluated at 50°C and 80°C. Dimensionless viscosity values for mechanical, volumetric, and overall efficiency were compared to the classic Striebeck curves. The experimental curves for volumetric and overall efficiency were consistent with the classic efficiency model. Mechanical efficiency diverged from model behavior at low dimensionless viscosity; declining at low speeds and high pressures as contact conditions transitioned through the mixed-film lubrication regime. A new model for relating the dimensionless viscosity to volumetric and mechanical efficiency is presented.

2:30 – 3 pm
The Brugger Test and Hydraulic Fluids Performance
S. Legay, Industrial Lubricants, ExxonMobil Fuels and Lubricants, Fairfax, VA, W. Hum, Industrial Lubricants, ExxonMobil Research and Engineering, Paulsboro, NJ
The Brugger Test (DIN 51347-2) was developed to assess the high load carrying capacity of oils in mixed or boundary lubrication. While other lubricant industry performance specifications have moved away from laboratory tribo-testing in favor of rig tests, the Brugger test has been gaining acceptance as part of hydraulic fluid specifications. Like for any other lubricant, balanced performance is a key feature for hydraulic fluids in order to ensure equipment reliability, long oil life and maximized productivity. A balanced formulation approach is therefore required to deliver high performance hydraulic fluids. This paper presents the outcomes of a study focusing on comparative thermal stability of various hydraulic fluids in correlation with Brugger value. Results suggesting potential negative effects of specific additives required to achieve a high Brugger on keep clean properties of the hydraulic fluid are discussed.
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Monday 5.19.14

Computational Tribology & Life Extension Solutions
Edward Wagner, Vice President
8AM

Modeling to Quantify Improved Performance of Superfinished Gears
Nathan Bolander, PhD, Chief Technology Officer
8:30 - 9AM

Analytical Modeling of White Etching Phenomenon & Consequential Bearing Damage
Behrooz Jalalahmadi, PhD, Lead Scientist & Nathan Bolander, PhD, Chief Technology Officer
1:30 - 2PM

Tuesday 5.20.14

System Analysis for Roller Bearing Life Prediction
Adrijan Ribaric, PhD, Lead Scientist
3:30 - 4PM

Advanced Prognostic Health Management Technology for Wind Turbine & Rotorcraft Gearbox Systems
Raja Pulikollu, PhD, Lead Scientist
Adrijan Ribaric, PhD, Lead Scientist
Nathan Bolander, PhD, Chief Technology Officer
6 - 6:30PM

Wednesday 5.21.14

A Microstructural Damage Model for Coatings Under Fretting Wear and Fatigue
Behrooz Jalalahmadi, PhD, Lead Scientist
Nathan Bolander, PhD, Chief Technology Officer
11 - 11:30AM

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on the contact conditions, the friction is either unchanged or showed a slight increase with additive concentration. Compared to base-fluid, the nano-additives reduced wear and the effectiveness appears to increase with concentration.

3 – 4 pm – Exhibitor Appreciation Hour (Evonik Raffle 3:30 pm)

4 – 4:30 pm

Manipulation of Nanoparticles of Different Shapes Inside a Scanning Electron Microscope
S. Vlassov, B. Polyakov, Institute of Solid State Physics, Riga, Latvia, L. Dorogin, M. Antsov, S. Oras, M. Vahtrus, R. Lohmus, University of Tartu, Tartu, Estonia, I. Kink, Estonian Nanotechnology Competence Center, Tartu, Estonia

The forces needed to overcome static friction and move polyhedral-like (Au) and sphere-like (Ag) nanoparticles (NPs) on an oxidized Si substrate are measured with a specially designed manipulation setup inside a scanning electron microscope (SEM). The experimental setup consists of a quartz tuning fork (QTF) mounted onto a high precision 3D nanomanipulator used with a glued silicon cantilever or tungsten tip as a force sensor. Contact areas and static friction forces are calculated using different models depending on the particle geometry. The comparison with experimentally measured force is given and the effect of NP morphology on the nanoscale friction is discussed.

4:30 – 5 pm

Synergy of Lizardite and Carbon Nano Particles as Lubricant Additive
Q. Chang, Y. Cui, School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University, Beijing, China, P. Rudenko, Washington State University, Colfax, WA, A. Erdemir, Argonne National Laboratory, Westermont, IL

Lizardite as a kind of mineral has been proved to have great wear-resistant property, but normally the friction coefficient of the tribofilm is not as low as desired. Some carbon nano particles as lubricant additive present great low friction coefficient but without wear-repair function. In this paper we took advantage of these two kinds of nano particles and mixed them with base oil. The tribological results showed the friction coefficient was less than only one sort of powder and the wear rate of the frictional specimen was almost same as with only lizardite powder. The tribofilm composite detected with EDX revealed that the iron, oxygen, carbon, silicon and magnesium were included. Raman spectrum of the film showed different D and G peaks compared with only lizardite additive. From these results we concluded that lizardite and carbon nano particles presented better tribological property synergetically.

5 – 5:30 pm

The Tribological Properties of Nano-MoS2 as an Additive in Liquid Paraffin
Z. Chen, Y. Liu, J. Luo, State Key Laboratory of Tribology, Tsinghua University, Beijing, China

A novel kind of nano-MoS2 particle with its size of a few nanometers is synthesized via solvothermal route and can be well dispersed in liquid paraffin. The tribological properties of liquid paraffin containing nano-MoS2 are evaluated with a ball-on-disk tribometer. Results show that the nano-MoS2 as an additive largely improves the capability of pressure-loading of the lubrication oil at relatively high temperature. It is attributed that the size of the nano-MoS2 particles is so small that they can enter the contact region easily. Meanwhile, during the process of rubbing and with the help of pressure and heat, nano-MoS2 particles assemble and recrystallizing to form a layer of MoS2 on the solid surface. The excellent tribological properties indicate that this nano-MoS2 particle is a good oil additive and will be used in industrial application in the future.
The lower bearing was leaking oil and alarming on low oil level during operation. A temporary solution was provided to eliminate the rapid oil loss problem.

Heat Transport (HT) System to the reactor outlet headers to counteract reactor operation as they maintain pressurized heavy water flow in the reactor. Both upper and lower bearings are oil lubricated. The Pressurizing (Pr) pumps are very critical for CANDU Nuclear Power Plants safety. The ABFP operates at 3600 RPM. It has oil ring lubricated Tin-Babbitt (ABFS) has an important role in CANDU Nuclear Power Plants safety. The ABFP operates at 3600 RPM. It has oil ring lubricated Tin-Babbitt bearings at both drive and non-drive end sides. The Lubrication challenge is water ingress in the bearing oil housing effecting lubrication. The Pressurizing (Pr) pumps are very critical for CANDU reactor operation as they maintain pressurized heavy water flow in the Heat Transport (HT) System to the reactor outlet headers to counteract HT shrinkage. New Vertical AC Induction Pr. pump motors (400HP, 4KV) were installed in 2010. Both upper and lower bearings are oil lubricated. The lower bearing was leaking oil and alarming on low oil level during operation. A temporary solution was provided to eliminate the rapid oil loss problem.

**Tribological Effects of Nanofluids on Aluminum and Copper**

G. Molina, W. Stregles, V. Soloiu, M. Rahman, Department of Mechanical Engineering, Georgia Southern University, Statesboro, GA

Nanofluids are nano-size-powder suspensions that are studied for their enhanced thermal properties. But while promising alternatives to ordinary cooling fluids, the tribological effects of nanofluids on cooling-system materials are unknown. Work is presented on the interactions of selected nanofluids (of 2% of alumina nanopowders in distilled water, and in ethylene glycol in water) when low-speed jets impact aluminum and copper samples. Surface changes were assessed by roughness and wear measurements, and by microscopy observations. Comparative roughness measurements indicate that alumina nanofluids of water and ethylene glycol solutions can start surface changes on aluminum surfaces (roughness parameters were found to consistently increase for test time), but show little effects on copper for the same conditions. The possibility of nanoparticle deposition was studied by microscope techniques. These investigations provide a suitable method for tribology testing of nanofluids.

** session 2G • Fantasia K/L**

**POWER GENERATION II**

Session Chair: C. Soto, Fluitec, Jersey City, NJ

Session Vice Chair: S. Rea, Chemtura, East Hanover, NJ

**1:30 – 2 pm**

A Novel Approach at Accurately Measuring Turbine Oil System Volumes

G. Livingstone, C. Soto, Fluitec, Jersey City, NJ

We know that the volume of a turbine oil reservoir is lower than the actual volume of oil in the system. How do you know how much additional oil is in the system piping, accumulators, filters, heat exchangers, valve blocks are various other system components? Often, this volume is either estimated or based on previous oil purchases. Not having accurate information can result in inefficient purchases and challenges with flushing. This presentation presents a novel method to accurately and quickly determine system volume on site.

**2 – 2:30 pm**

Lubrication Challenges with Pumps and Motors in the CANDU Reactor

K. Malik, Ontario Power Generation, Pickering, ON, Canada

This presentation will provide an overview of the Auxiliary Boiler Feed Pump (ABFP) and Pressurizing Pump Motors lubrication related problems and operating experience. The Auxiliary Boiler Feed System (ABFS) has an important role in CANDU Nuclear Power Plants safety. The ABFP operates at 3600 RPM. It has oil ring lubricated Tin-Babbitt bearings at both drive and non-drive end sides. The Lubrication challenge is water ingress in the bearing oil housing effecting lubrication. The Pressurizing (Pr) pumps are very critical for CANDU reactor operation as they maintain pressurized heavy water flow in the Heat Transport (HT) System to the reactor outlet headers to counteract HT shrinkage. New Vertical AC Induction Pr. pump motors (400HP, 4KV) were installed in 2010. Both upper and lower bearings are oil lubricated. The lower bearing was leaking oil and alarming on low oil level during operation. A temporary solution was provided to eliminate the rapid oil loss problem.

**2:30 – 3 pm**

Root Cause Analysis (RCA) for Filter Non-performance

K. Farooq, SLS, Pall Corp, Port Washington, NY

Keeping the fluid cleanliness at required levels using well made, fine filters is a cost effective maintenance strategy. The design and construction of the filter element, the housing and its location in the system are critical in achieving the desired results. Even a properly designed filtration system, using high quality filters can experience problems that are not necessarily related to the filtration system itself. The Root Cause Analysis (RCA) for filter non-performance requires careful review of the failure mode, the contaminants captured by the filter, the fluid condition, operating conditions and the overall filtration system. The presentation discusses the analytical techniques used to determine root causes of the filter failure to identify the underlying reasons so that corrective actions can be taken to avoid future occurrences.

**3 – 4 pm – Exhibitor Appreciation Hour (Evonik Raffle 3:30 pm)**

**4 – 4:30 pm**

Use of Additive Chemistry to Minimize Varnish Deposition in Gas Turbines

B. Butke, F. Cooney, D. Facchiano, R. Profill, The Lubrizol Corporation, Wickliffe, OH

The main focus in the development of turbine oils is often resistance to oxidation as measured by ASTM D2272 (Rotary Pressure Vessel Oxidation Test) and D943 (Turbine Oil Stability Test), with higher and higher numbers being reported. This increased level of performance is achieved with a careful balance of additive chemistry, and is facilitated by the concomitant use of API Group II and higher base oils. However, the power generation industry continues to have problems with varnish deposition in turbine systems, particularly with sticking inlet guide vane valves that can cause unplanned downtime. Additive technology has been developed to mitigate varnish related problems in turbine systems. This new fluid is being validated in a field trial that has been underway for more than three and a half years. The development process and field trial results will be presented.

**4:30 – 5 pm**

Coal Pulverizer Bearing Fluids: Laboratory Testing to Field Trial

J. Vinci, E. Akucewich, Lubrizol Corporation, Wickliffe, OH

Our 2012 STLE presentation described a predictive laboratory test designed to approximate conditions in coal pulverizer bearings. This test identified fluid chemistry potentially resistant to the abrasive effects of contaminating coal dust, and more recently we have arranged a field trial to further support our laboratory observations. Coal dust contamination is difficult to prevent in a crushing venue, and the problem is exacerbated by the necessarily high lubricant viscosities which may preclude easy filtration. Applying experimental design techniques in our laboratory testing, fluid formulations emerged which demonstrated unexpectedly high tolerance for contamination when compared to popular commercial lubricants used in this application. In order to further validate our testing & formulating approaches, we arranged a pulverizer field evaluation at a coal-fired power plant where frequent bearing failures have resulted in lost time & revenue.
5 – 5:30 pm
Effectiveness of Electrostatic Filtration System on the Removal of Submicron Particles from In-service Steam Turbine Phosphate Ester Control Fluids
G. Staniewski, Ontario Power Generation, Pickering, ON, Canada, S. Suryanarayan, Kinetics, Inc., Toronto, ON, Canada

Previous study indicated a significant concentration of sub-micron particles in the in-service steam turbine control fluids [1]. Since typical filtration systems are relatively ineffective in removal of these particles, electrostatic filtration has been employed. The paper will present characterization of the solid particles and their distribution in typical phosphate ester fluids from steam turbine control systems that currently experience dielectric. The intent is to understand the nature of the deposit including presence of amine/ammonium ions. In addition, the effect of solid particle removal on the fluid acidity and appearance will also be discussed. Reference: [1] W.D. Phillips, J.W.G. Staniewski, S. Suryanarayan, "Ion Exchange and Mechanical Purification of Fire-Resistant Phosphate Ester Fluids Used in Steam Turbine Control Systems" ASTM STP 1573 on Symposium on Fire Resistant Fluids, 2013.

5:30 – 6 pm
In situ Monitoring of Wear Particles and Water in Power Generation Lubricants
T. Canty, J.M. Canty Inc, Lockport, NY

Online monitoring or wear particles and water is now possible due to the advancements in dynamic microscopic imaging. The technology allows particles as small as .7 micron that are flowing to be analyzed by capturing a high speed image of the particles as they are flowing in a pipeline or process. Once the image is capture advanced imaging software is used to differentiate water and various types of wear particles in the oil to allow for a complete analysis of the fluid condition. The output is in both particle distribution and concentration. Having continuous data allows for better understanding of the long term condition of the system in addition it has helped detect fines build up in lubricating oil which can then be treated to eliminate their detrimental effects. The water detection is critical since a sudden increase can have major consequences.

Session 2H • Fantasia M/N

GREASE I

Session Chair: P. Sutor, Chevron Oronite Co., Richmond, CA
Session Vice Chair: M. Moon, Shamrock Technologies, Inc., Newark, NJ

1:30 – 2 pm
On the Film Thickness of Grease Lubricated Contacts at Low Speeds
P. Lugt, G. Morales-Espejel, Tribology & Lubrication, SKF Engineering and Research Centre, Nieuwegein, Netherlands, H. Cen, Faculty of Engineering Technology, University of Twente, Enschede, Netherlands

The contribution of the thickener to the thickness of the lubricating film in grease lubricated contacts is investigated. Four different types of greases have been tested in a ball/spherical roller-on-disc machine, where the film thickness was measured using the interferometry method, varying the temperature, load and slip. The test results show that there are two lubrication regimes. Below a "transition speed" the grease thickener plays an important role where the film thickness increases with decreasing speed. At higher speeds the film thickness is primarily governed by the base oil. This transition speed is a function of the temperature and not of the load and slip. At higher speeds the grease film thickness can be calculated using the base oil viscosity. The electrical capacitance method was applied to measure the film thickness at ultra-low speed in a real bearing, showing that the single contact results are indeed applicable to a full rolling bearing.

2 – 2:30 pm
Comparison of Laboratory Test Methods for predicting the Oxidation Induction Period of Grease Lubricants at Elevated Temperatures
D. Pallister, Materials Laboratories: Chemistry, SKF USA, Inc., Plymouth, MI, P. Lugt, M. van Zoelen, Group Technology Development, SKF Engineering & Research Centre, Nieuwegein, Netherlands

The oxidative stability of lubricating grease at elevated temperatures can be measured using laboratory methods such as ASTM D 942 (Oxidation Stability of Lubricating Greases by the Oxygen Bomb Method) and ASTM D 5483 (Oxidation Induction Time of Lubricating Greases by Pressure Differential Scanning Calorimetry). These two procedures use high pressures to accelerate the testing time involved. However, the overall oxidation reaction of greases will be disturbed by using elevated pressures. In this paper the results of testing the oxidation stability of grease lubricants using ASTM D 942, ASTM D 5483 and thermogravimetric analysis (TGA) at atmospheric pressure will be compared. TGA of lubricating greases is used to show that the oxidation process consists of two phases and that the volatile oxidation byproducts at elevated temperatures are primarily carbon dioxide and water vapor.

2:30 – 3 pm
Screen Tests – Identifying the “Good Actors” in Your Grease Component Line Up
J. Kaperick, Afton Chemical Corporation, Richmond, VA

The use of statistical tools and test modeling is invaluable in developing an understanding of additive effects on grease performance. The savings in time and capital investment in expensive rig or field testing are likely enough incentive on their own. However, the real return is the insight gained into the criticality of various tribological properties needed in a grease to perform well in a given application. A screening model used to evaluate high temperature performance of greases is demonstrated in this study along with data generated using various additive component combinations.

3 – 4 pm – Exhibitor Appreciation Hour
(Evonik Raffle 3:30 pm)

4 – 4:30 pm
An Investigation into Frictional Behaviour of Selected Custom-Made Greases in a Ball-on-Disc Rolling-Sliding Contact
Y. Kanazawa, R. Sayles, A. Kadiric, Tribology Group, Imperial College London, London, United Kingdom

This study investigates the influence of grease formulation on friction and film thickness in non-conformal rolling-sliding contacts. Selected custom greases were tested in a ball-on-disc tribometer with imposed fully-flooded conditions. Friction coefficient and film thickness were measured over a range of entrainment speeds, loads and temperatures. Specimens with two surface roughnesses were used in order to cover a wide range of lambda ratios. Custom prepared greases were all additive-free and included urea and lithium complex based greases. All respective base oils were also tested for comparison. Significant differences in friction were observed between different greases. Furthermore, greases generally had lower friction than respective base oils, particularly at low speeds and high temperatures where thin oil
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films may be expected. These observed differences in frictional behaviour are then related to the measured film thicknesses for all lubricants at given contact conditions.

4:30 – 5 pm  
Comparative Analysis of OSP, Mineral, PAO and POE- based Lithium Complex Greases: A Rheological Approach  
E. Blancas-Sanchez, C. Galeano-Guerra, M. Oyervides Muñiz, J. Chavez-Contreras, Research and Development, Lubricantes de America SA de CV, Santa Catarina, Mexico  
Recently, the OSP-based Lithium complex grease properties have been studied, important differential characteristics was observed. The dynamical analysis has become important since viscoelastic grease properties determines the behavior on the field, defining the performance that will be reflected in benefit or prejudice of final user. The rheological study could give us a major knowledge about the grease working under operational conditions close to reality, and thereby could recommend the grease that suits the equipment’s needs. The objective of this work focuses to analyze the rheology properties of OSP-based lithium complex grease in order to have more knowledge about the interactions among these polyalkylene glycols within the tridimensional network of lithium complex soap, and compare the data obtained with the rheological properties of lithium complex greases formulated with different base oils, mineral and synthetic.

5 – 5:30 pm  
Influence of Grease Formulation on Friction in Rolling-sliding Non-conformal Contacts  
N. De Laurentis, P. Cann, A. Kadiric, SKF UTC, Tribology Group, Imperial College London, London, United Kingdom, P. Lugt, SKF Engineering and Research Centre, Nieuwegein, Netherlands  
Improved understanding and optimisation of grease performance in concentrated rolling-sliding contacts can offer an important way of reducing frictional losses in rolling bearings. In this study a ball-on-disc tribometer is used to examine frictional behaviour of a selection of commercial and custom greases over a range of entrainment speeds, temperatures and surface roughnesses, in fully flooded and starved conditions. The test greases were selected to cover a wide spectrum of chemical compositions and rheological properties including different base oils (mineral, ester, PAO, mixed), base oil viscosities and grease thickeners (lithium, lithium complex, complex calcium sulphonate, polyurea). Results reveal large differences in frictional behaviour of tested greases. The trends in measured friction coefficients are analysed in relation to grease composition in an attempt to establish the relative influence of individual grease components on friction in different lubrication regimes.

5:30 – 6 pm – Grease Business Meeting

You’re invited to the free Welcoming Party!  
Monday, May 19, 6:30 – 8 pm (America’s A)  
Join your colleagues for light fare, entertainment and networking with hundreds of your industry peers. A great place to meet before embarking on your dinner plans, the Welcoming Party is a “can’t miss” annual meeting tradition.

Session 2I  •  Fantasia P/Q  
ROLLING ELEMENT BEARINGS II

Session Chair: N. Arakere, University of Florida, Gainesville, FL  
Session Vice Chair: B. Jalalahmadi, Sentient Corp., Buffalo, NY

1:30 – 2 pm  
Analytical Modeling of White Etching Phenomenon and Consequential Bearing Damage  
B. Jalalahmadi, Sentient Corporation, Buffalo, NY, N. Bolander, Sentient Corporation, Idaho Falls, ID

White Etching Area (WEA) formation is one of the microstructural alterations occurring in rolling bearings under normal design loads (only after many cycles) or subject to unknown, excessive, transient loading, in certain applications like wind turbine gear boxes (WTG) where these alterations form early in the expected life span of bearing. The consequence of white etching areas is either bearing race spalling or axial cracking of bearing rings. Different in-service observations and experimental tests have recognized different factors which are involved in WEA phenomenon. We have developed a model to simulate WEA formation including miscellaneous mechanisms and root causes involved. This model utilizes different theories including grain-level damage accumulation models, mixed-EHL models, crystal plasticity, metallurgical phase transformation, and chemical corrosive. Using the developed model, the WEA formation phenomena in the WTG bearings and their service lives are predicted.

2 – 2:30 pm  
The Electromagnetic Impact on Early White Etching Cracks in a Inhomogeneous Structures of Bearing Steel  
W. Holweger, AG Schaeffler & Co. KG, Herzogenaurach, Germany, M. Scepanakis, A. Jakovics, I. Kalder, Laboratory for Mathematical Modelling of Environmental and Technological Processes, University of Latvia, Riga, Latvia, B. Nacke, Leibnitz University of Hanover, Hanover, Germany

Several electromagnetic phenomena can be observed during the operation of bearings: the static electricity leads to periodic discharges in bearings, magnetisation of bearing elements results in magnetic field and induced current in moving elements. The testing showed that early WEC appears in bearing elements in the presence of electrical discharges. The hypothesis links the electromagnetic forces, resistivity heating in inhomogeneous structure of bearing steel and mechanical stresses, which can additionally impact the formation of white etching areas (WEA). Different electrical, magnetic and thermal properties of the grains of cementite, retained austenite and non-metalic inclusions in martensitic structure of steel lead to stresses inside the material that result in nano-structurization of grains, which is visualized as WEA. The influence of the properties and structures of bearing steel on the distribution of stresses in the material was analysed by means of mathematical modelling.

2:30 – 3 pm  
Development of a Granular Cohesive Model for Rolling Contact Fatigue Analysis: Investigations on Material Modeling  
J. Noël, P. Jacquet, ECAM Lyon, Université de Lyon, Lyon, France, F. Ville, LaMCoS-INSA Lyon, Université de Lyon, Villeurbanne Cedex, France

Many models have been developed in the past to predict life of components subjected to rolling contact fatigue (RCF). However, despite extensive research on this subject, proposing a complete predictive model is to this day an important challenge. The study presented in this paper focuses on the understanding of failure initiation mechanisms.
A numerical approach based on the finite element method is used. A model is developed using a microstructure representation and cohesive elements between each grain. First investigations enabled a better understanding of numerical behavior of cohesive elements and highlighted singularities at cross point (junction between three grains). Then, material modeling is studied as the effect of anisotropy of grain: the influence of mechanical model (isotropic elasticity or cubic elasticity) on the stress level is presented.

3 – 4 pm – Exhibitor Appreciation Hour
(Evonic Raffle 3:30 pm)

4 – 4:30 pm
Rolling Contact Fatigue Crack Initiation and Propagation in Bearing Steel

P. Rycerz, A. Kadiric, A. Olver, SKF UTC, Tribology Group, Imperial College London, London, United Kingdom, G. Morales-Espejel, SKF Engineering and Research Centre, Nieuwegein, Netherlands

This work investigates the initiation and growth of rolling contact fatigue cracks in bearing steel. A three-disc fatigue tester is used to perform experiments on hardened AISI 52100 rollers. The test rig incorporates a novel method of detection of surface fatigue cracks at an early stage. This allows crack propagation rates to be measured over a wide range of crack lengths, starting from incipient micro-cracks until the formation of a pit. Tests are performed to study the influence of contact conditions on crack growth behaviour and the relative duration of initiation and propagation phases in total life. Propagation rates are measured under various loads and contact geometries in order to establish the effect of contact pressure and size on crack growth. The principles of linear elastic fracture mechanics are then applied to describe the observed crack behaviour and draw parallels between rolling contact and classical fatigue.

4:30 – 5 pm
A Monte Carlo Simulation of the Influences of Material Inhomogeneities in Contact Fatigue

F. Niu, F. Duan, Q. Zhou, Chongqing University, Chongqing, China, Q. Wang, Mechanical Engineering, Northwestern University, Evanston, IL, X. Jin, Chongqing University, Chongqing, China

The stress field resulted from the contact load usually shows severe gradient in a localized region, and the situation is further involved with micro defects or material inhomogeneities arising from materials and manufacturing processes. Because of these uncertainties and complex issues, typical experimental results from rolling contact fatigue (RCF) may exhibit apparent scattering. Particularly for high cycle RCF, it is very costly and time consuming to repeat the experimental measurement to obtain a statistically reliable justification. In this work, a computational scheme based on Eshelby’s equivalent inclusion method is presented to explore the interactions between the contact load and the material inhomogeneities. The distributions of the inhomogeneities are generated randomly, and their influences on the life of rolling contact fatigue are evaluated through a computer program implementing the Monte Carlo method.

5 – 5:30 pm – Rolling Element Bearings Business Meeting

Session 2J • Republic A

ENVIRONMENTALLY FRIENDLY FLUIDS II: DEVELOPMENT AND PERFORMANCE

Session Chair: M. Miller, RSC Bio Solutions, Charlotte, NC
Session Vice Chair: B. Sharma, UIUC/PRI/ISTC, Champaign, IL

1:30 – 2 pm
Performance Ranking of Environmentally Friendly Lubricants Under Different Tribological Test Modes

S. Shaffer, Tribology & Mechanical Testing, Bruker Nano Surfaces, Campbell, CA, H. Benecke, D. Garbark, Advanced Materials Applications, Battelle Memorial Institute, Columbus, OH

New environmentally friendly lubricants can be evaluated using a number of standard tests (e.g. ASTM, ISO). Such tests cover the areas of tribology, rheology, oxidation resistance, seal swelling, etc., and allow one to efficiently compare new formulations or modifications to existing lubricant formulations. However, due to economic and performance considerations, consumers are reticent to switch to a new lubricant solely on the basis of its environmental friendliness. For evaluating “green” lubricants, we can find the relative rankings using a variety of tribology tests, and rank them compared with targeted mineral oil-based lubricant replacements. This paper presents a series of lubricant tribology-assessment tests using several modified neat soybean-oil (SBO) based environmentally-friendly lubricants and an unformulated mineral oil. The molecular structure of the SBO-based fluids is presented and related to their Tribological performance in the different tests.

2 – 2:30 pm
High Performance Air Compressor Oil Formulated with Biobased Hydrocarbon Base Oil

H. Hahn, P. Vettel, J. Brown, J. Wells, Lubricant Formulation, Novvi LLC., Emeryville, CA

Reliable operation of compressor is essential to the uninterrupted and successful operation of manufacturing facility in modern days. Due to its direct interaction with hot air and moisture in the presence of hot metal, air compressor oil requires to have excellent oxidative stability, quick separation from air & water while providing good protection to the internal parts of compressor under high loading condition. Biobased hydrocarbon base oil manufactured from naturally engineered farnesene were used to formulate air compressor oil with advanced performance characteristic inside compressor and out in the environment. These unique combinations of synthetic lubricant performance and great environmental benefit will be presented and compared to other fluids widely used in current market.

2:30 – 3 pm
Biodegradable Elevator Hydraulic Fluids – Development and Performance

J. Perez, L. Holland, M. Gates, Chemical Engineering, Pennsylvania State University, University Park, PA

Research collaboration between the USDA Oil Products Group, Peoria II and Tribology Group at Penn State on vegetable oils led to the development of bio-fluids including a soy-based bio-hydraulic elevator lubricant. After successful tests in the Statue of Liberty elevators, the fluid was considered for use in the University elevators. Occasional leakage and reduced remediation costs when using biodegradable fluids was the incentive. Some additive modification was required to meet the Pennsylvania Department of Environmental Protection’s cleanup standards. Over 17,000 gallons of petroleum based fluids in over 100 elevators was replaced by soy-based hydraulic fluid. Performance of the fluid since 2009 has been excellent. Fluid development and properties are discussed.
4 – 4:15 pm
Pyrolysis Bio-oils as Additives for Vegetable Oil Based Lubricants
B. Sharma, D. Murali, Illinois Sustainable Technology Center, University of Illinois, Champaign, IL, K. Doll, Bio-Oils Research Unit, USDA/NCAUR/ARS, Peoria, IL, K. Marley, R. Larson, Department of Natural Resources and Environmental Sciences, University of Wisconsin, Urbana, IL

Softwood and hardwood lignins along with hardwood as such were pyrolyzed to afford bio-oil distillates in which phenols were major products. Extraction with alkali gave a range of lignin-related phenols having molecular weights (MWS) from 110 to 344. The unfractonated extract when tested with a vegetable oil based product was equal in antioxidant activity to the synthetic compound BHT. Vegetable oils based lubricants have drawbacks, such as poor oxidative stability, poor low temperature properties, and low hydrolytic stability. Vegetable oils and synthetic base oils additized with bio-oils were examined for lubricant properties, such as oxidative stability, low temperature flow properties, corrosion properties, and friction/ wear properties.

4:15 – 4:30 pm
Oxidative Stability of Estolide Esters Using PDSC
B. Sharma, University of Illinois, Illinois Sustainable Technology Center, Champaign, IL, G. Biresaw, S. Cermak, T. Isbell, Bio-Oils Research Unit, USDA/NCAUR/ARS, Peoria, IL

Estolides are obtained by the formation of a carbocation that can undergo nucleophilic addition. The carboxylic acid functionality of one fatty acid links to the site of unsaturation of another fatty acid to form oligomeric esters. The estolide carboxylic acid functionality can then be converted to the corresponding estolide ester under saponification conditions with an alcohol. It has been shown earlier that estolide esters have improved oxidative stability over vegetable oils and have also overcome shortfalls associated with vegetable oils, such as low hydrolytic stability and poor low temperature properties. In this study three different methods of measuring oxidative stability were compared for a series of estolide esters additized with three antioxidants (a hindered phenol and two alkylated diphenyl amines). These methods were oxidative stability index (OSI), rotating pressurized vessel oxidation test (RPVOT), and pressurized differential scanning calorimetry (PDSC).

4:30 – 5 pm
The Effect of Phosphonium- and Imidazolium-Based Ionic Liquids as Additives in Natural Oil: An Investigation of Tribological Performance
P. Menezes, M. Lovell, Industrial Engineering, University of Wisconsin-Milwaukee, Milwaukee, WI, C. Reeves, T. Jen, Mechanical Engineering, University of Wisconsin-Milwaukee, Milwaukee, WI

Natural oils have been known to be viable lubricants since the emergence of lubrication and have regained their prominence due to new eco-friendly initiatives. The properties of natural oils are due to their bio-based derivation that promotes sustainability; triacylglycerol composition that facilitates adsorbed monolayer development; and superior tribological performance that encourages energy conservation. Recently, environmentally benign ionic liquids (IL) have been proposed as a new class of green lubricants. In this study, the effects of phosphonium- and imidazolium-based ILs as additives in natural oils on tribological performance are investigated using a pin-on-disk apparatus. The results indicate that the effects of both ILs as additives in natural oils enhance the tribological properties of the lubricant mixtures. More still as the amount of the IL additive increases within the natural oil, the tribological properties continue to improve.
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Defoamer Theory and Selection for Aqueous Metalworking Fluids

Foam can be problematic in aqueous metalworking fluids. Typically stabilized through surface active components, emulsifying surfactants, or from product degradation over time, foam often must be mitigated through the use of defoaming additives. Whether formulated or tank-side, defoamers themselves can introduce additional headspace, making proper selection critical. This paper will review the mechanisms of foam stabilization and disruption as well as the theories behind defoamer compatibility, stability, and efficacy in aqueous systems. Typical defoamer chemistries will be reviewed and selection guides presented to help formulators find the right products more quickly and avoid lengthy testing and troubleshooting.

Film Growth from Phosphorus Additives in Metalworking
S. Morrison, Metalworking Lab, Quaker Chemical, Conshohocken, PA

It has been suggested that phosphorus EP additives lubricate by reacting with metals to form thick, viscous surface films. This is different from traditional thin-film theory that suggests lubrication and enhanced load-bearing ability results from a thin mono-layer film that serves to protect the underlying metal. In metalworking formulas the growth of these thick films at high temperature has been observed using the Ultra-Thin Film Optical Interferometer. The purpose of this study is to examine the film growth properties of phosphates in metalworking fluids, and to relate this property to performance in bench-top lubrication tests, as well as to performance in aluminum machining. The end result is the correlation of film growth to advanced performance in machining as measured by reamed-hole surface finish in the machining of cast aluminum 356-T6.

A Comparison of Oil and Solvent Soluble Additives for Metalworking Fluids and Ferrous Rust Preventive Formulations
E. Schnellbacher, Research & Development, Additives International – Lockhart Chemical, Allen Park, MI

Metalworking fluids and rust preventives are commonly used for cutting and protecting ferrous materials like iron and steel. In some cases, the only difference between rust preventives and metalworking fluids (MWF) may be the addition of lubricity additives. Rust preventives & MWF may be used as in-process & removable rust preventive coatings for metals. Although these fluids fit into one of three categories: water soluble, emulsions, or oil/solvent soluble; the scope of this paper focuses on oil & solvent based ferrous formulations. Rust preventive additives for this study include: petrolatums, waxes, esters, sulfonates, and several oxidized materials. Some ingredients may be used in combinations. A matrix will be set up comparing different ingredients and characterizing additives to optimize performance. Performance will be determined by testing cold rolled steel (CRS) panels in a Salt Fog cabinet. A summary of the results and formulation recommendations will be presented.

Effect of Edible Sunflower Oil Applied Using MQF in the Feed Force in Drilling Operation of Steel AISI 1045
M. Da Silva, T. Neves, J. Rodrigues, Mechanical Engineering, Federal University of Uberlandia, Uberlandia, Brazil

In machining operations, the cutting fluids, when chosen and applied properly, may reflect benefits in the manufacturing processes. The method of application and the fluid properties are critical for good performance concerning lubrication and cooling effect. However the cutting fluid can be a major problem for the environment and also for the health of the operator. An alternative would be to use a less aggressive fluid to the operator and to the environment as the edible oils. This work studies the effect of edible sunflower oil in the feed forces in drilling operations of AISI 1045. The fluid is applied using minimal quantity of lubricant technique. The cutting conditions cutting speed, feed rate and the length of the role is variable. The results suggest that the performance of sunflower oil is significant when compared to dry condition but not when compared to conventional cutting fluid.

Effect of Application of Edible Vegetable Oils in Drilling Operation of Grey Iron
M. Da Silva, M. Finzi, Mechanical Engineering, Federal University of Uberlandia, Uberlandia, Brazil

The heat generated during the cutting is dissipated by the four systems processing the material: cutting tool, workpiece, chip and cutting fluid. The cutting fluid plays therefore an important role and many operations cannot be carried out efficiently without a fluid. Among their function, cutting fluids are used to cool the cutting tool and workpiece decreasing the temperature and lubricate the chip tool interface. The main objective of this work is the evaluation the performance of edible vegetable oils concerning the lubricant capacity in drilling operations. Some properties of the oils are evaluated throughout laboratory tests. The temperature in drilling operation is measured using an experimental technique proposed to evaluate the lubricant capacity. The cutting fluids used are the edible vegetable oils canola, soya, corn, sunflower and babassu and a commercial soluble oil. According to the results, the vegetable corn oil presented the best results in terms of temperatures.
COMMERICAL MARKETING FORUM II

1:30 – 2 pm
ExxonMobil Chemical Company
Synthetic Solutions for Tomorrow’s Lubricants
M. P. Sheehan, ExxonMobil Chemical Company, Houston, TX
Are you struggling to come up with the next generation lubricant that differentiates you from the competition? Lubricant Formulators today are faced with higher energy efficiency goals without compromising durability. In addition it is estimated that one third of the world’s total energy is consumed due to friction(1). Synthetic lubricants play a significant role in addressing these challenges. How is your organization responding to changing global lubricant requirements? Equipment with higher energy density and smaller sumps will subject lubricants to higher operating temperatures resulting in higher oxidation and thermal degradation. Future lubricants require improved oxidative, thermal, shear stability and lower volatility. Formulators will require base stocks that offer energy efficiency thus reduction in frictional losses and improved low temperature fluidity while maintaining stable performance. Please join us to learn how Group IV and V base stocks help Formulators develop innovative solutions to meet future demands including semi-synthetic products. (1) Introduction to Tribology, B. Bhusan, New York; Wiley and Sons Inc. 2002

2 – 2:30 pm
The Lubrizol Corporation
Lubrizol Ashless Multifunctional Additive Technology for Extended Life in Rolling Element Bearing Greases
G. Fish, PhD, The Lubrizol Corporation, Wickliffe, OH
Lubricating grease is essential to the operation of rolling element bearings for a wide range of both industrial and automotive applications. Formulating greases to extend their useful service life across a variety of applications is a challenge. It requires a careful balance of using proper additive technology, meeting application requirements, and addressing practical concerns of plant operations and regulatory demands. Lubrizol® 5240, a new premium ashless additive, is now available for manufacturers to produce grease in multiple thickener types that extends service life required for longer and more robust regreasing intervals across different applications. This new ashless technology is suitable in the formulation of lithium complex grease and next generation ashless urea grease for enhanced performance over a wide diverse range of speed and temperature conditions. The specific additive composition was chosen and optimized through rigorous laboratory tests. Fitness for bearing applications was proven through a wide range of bearing tests showing utility over various applications. This new additive was developed with the end in mind by choosing componentry in compliance with global chemical regulations that avoids EU risk phrase labeling of the finished grease to be marketed. Suitable base greases formulated with the new ashless additive meets or exceeds the NLGI GC-LB automotive service grease classification with both lithium complex and polyurea thickeners. Lubrizol® 5240 gives outstanding performance to the next generation of ashless greases including robust performance at high temperatures meeting ISO / DIN requirements and high temperature, high speed performance needed for electric motors. Grease made with the new ashless additive allows savings through extended grease service life, reduced downtime and lower overall maintenance cost. Not only does the new ashless additive utilize chemistry less harmful to the environment, but it reduces waste grease disposal while offering the grease manufacturer an opportunity to reduce overhead through logistics and complexity gains by stocking only one product for multiple thickeners and applications.

2:30 – 3 pm
Croda, Inc.
New Solutions for Growing Applications
J. Beyer, Croda, Inc., New Castle, DE
Within the past year, Croda has launched four new commercial products into the Lubricants industry. We introduced three new esters registered as HX-1 ingredients for incidental food contact by NSF, Priolube™ 2568, Priolube 2510 and Priolube 2520. These products are ideal for applications where food approval is needed; they have an operating temperature up to 230°C, and have both low volatility and low deposit formation. We also recently launched Perfad™ 3006, a new friction modifier with excellent frictional performance over a range of temperatures and is easy to handle (pourable at room temperature). Perfad 3006 will also help formulators address the upcoming GF-6 regulations. Croda also offers a range of esters which are considered environmentally acceptable lubricants (EAL’s), and can be used by formulators for applications pertaining to the vessel general permit (VGP) that took effect on December 19th, 2013.

3 – 4 pm – Exhibitor Appreciation Hour (Evonik Raffle: 3:30 pm)

4 – 4:30 pm
FEI
Automated Wear Debris Identification for the Non-Microscopist
S. Benes, FEI, Delmont, PA
As current economic conditions continue to force companies to drive down costs, it becomes increasingly important to monitor operational conditions and predict failures. Limited insight into what may be taking place inside an engine, turbine, or gearbox is often the case with traditional oil testing such as particle counting. A new automated particle analysis technique vastly improves the sheer number of particles one can analyze (upwards of 10,000/hr.), while at the same time offering reproducibility, coupling the particle size and shape, chemistry, imaging, and reporting into a single package. The author will discuss how a current customer used automated wear debris testing in order to further their oil testing program. Demonstrated will be the distinct differences in particle trending, as well as sensitivity to elemental detection or individual particle chemistries. With this new approach available for wear debris monitoring powerful knowledge can be obtained leading to proactive instead of reactive maintenance.

4:30 – 5 pm
The Lubrizol Corporation
Lubrizol’s Primary Emulsifier Technologies
L. S. Prickett, The Lubrizol Corporation, Wickliffe, OH
Lubrizol supplies a wide range of emulsifier technologies that provide formulators with the building blocks needed to produce and market water-based metalworking fluids that meet the challenges of today’s ever-changing manufacturing processes and environmental demands. Lubrizol is committed to the research, development and testing of advanced additive chemistry to address emerging market demands, including stringent regulatory requirements, security of supply and the increased performance requirements of an evolving metalworking industry.

Lubrizol’s latest advancement in metalworking technology, Lubrizol® MC91T, is a breakthrough non-ionic chemistry that delivers high emulsification efficiency, lower foaming tendency, hard water emulsion stability and low surface tension to enhance corrosion protection and lubricity performance. This presentation will highlight Lubrizol’s latest metalworking emulsifier solution developed to help make our customers more successful.
5 – 5:30 pm
Solazyme, Inc.
Commercializing New Environmentally Friendly Algal Base Oils with Enhanced Performance in Lubricants & Metalworking Fluids
J. Fink, Solazyme, Inc., South San Francisco, CA
Solazyme, Inc. has developed a breakthrough Renewable™ Tailored™ Oils technology that addresses and overcomes the traditional shortcomings associated with other vegetable and mineral-based lubricants and metalworking base oils, providing both high performance and sustainability benefits to its users. Through a revolutionary biotechnology platform that harnesses the power of microalgae, Solazyme is able to convert plant-based sugars into high-value oils in a scalable, reliable, and cost-effective manner. By using standard industrial fermentation equipment, Solazyme is able to efficiently scale and accelerate microalgae's natural oil production time to just a few days and at commercial levels using a completely closed fermentation system. Solazyme's core capability to “tailor oils” refers to the ability to produce oil with specific desired chain lengths, saturation and functional branching, providing benefits and functionality beyond those typically available with traditional oils. Additionally, the production technology is essentially immune to factors associated with climate, soil or geography, resulting in the production of oils with remarkably consistent profiles in geographic regions not previously possible.

This presentation will feature Solazyme's latest applications of Renewable™ Tailored™ oil products in the Lubricants and Metalworking Fluids Industries.

5:30 – 6 pm
MRG Group
Grease Sampling and Analysis with the Grease Thief®
R. Wurzbach, MRG Labs, York, PA
Getting meaningful grease samples from inservice equipment has always been a challenge. Being able to analyze small quantities of grease has prevented grease analysis from being a regularly used tool in the Condition Monitoring toolbox. With the development of the Grease Thief, both issues are being addressed by practitioners in the Wind Power, Pharmaceutical, Nuclear Power, Automotive and other manufacturing industries. This demonstration will show how Grease Thief sample kits can be used to follow ASTM D7718 for grease sampling, and obtain a full test slate analysis with just one gram of grease.

STLE Member Services Booth
Interested in volunteering on a technical committee or starting up a local section? How about obtaining your STLE certification? Come stop by and meet with STLE staff members and get your questions answered on anything you wanted to know about the society’s membership programs, publications and other resources. The STLE Member Services Booth is located on the main level (Fantasia Foyer) of the Disney Contemporary Resort.

Exhibition Appreciation Hour & Evonik Raffle
STLE is hosting an Exhibition Appreciation Hour Monday from 3-4 pm in the Fantasia Ballroom, site of this year’s trade show. All other annual meeting activities will be closed during this time. At 3:30 pm Evonik is hosting a raffle at Booth 405. The ticket for the drawing is included in your registration bag. Just drop it in the bin by Booth 405. You must be present in the hall at 3:30 pm Monday to win.

Exhibit Hours
Monday: 12:30 – 5 pm – Exhibitor Appreciation Hour 3-4 pm (Evonik Raffle 3:30 pm)
Tuesday: 9:30 am – Noon & 2-5:30 pm (Closed for Presidents Luncheon, Noon-2 pm)
Wednesday: 9:30 am – Noon
The exhibition is in the Fantasia Ballroom